

**A chemical catechism: in which the elements of chemistry, with the recent discoveries ... are fully explained. Containing an appendix of select experiments / By Thomas John Graham.**

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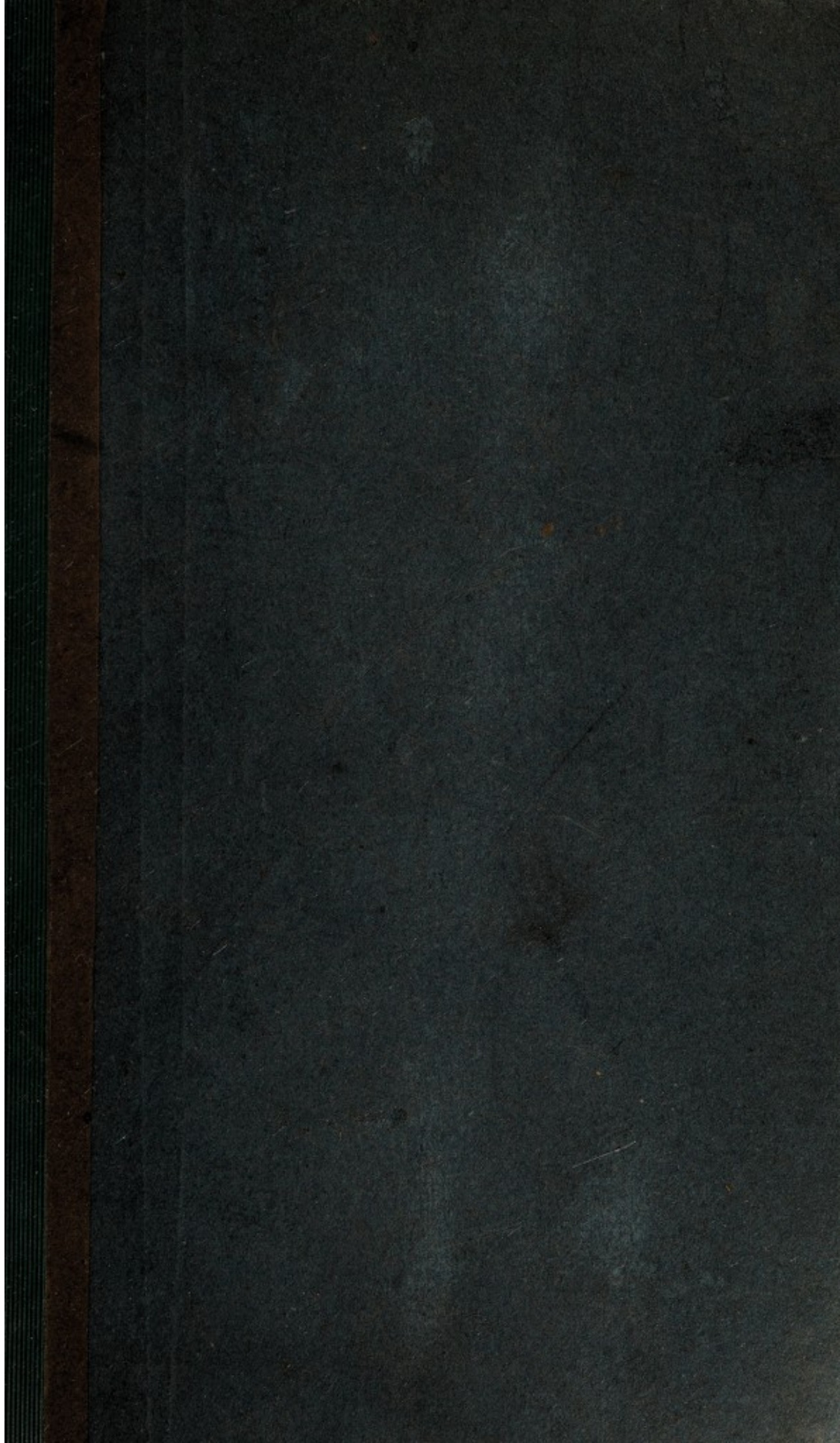
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C. J. Talbot  
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CHEMICAL CALCULATIONS

THE ELEMENTS OF CHEMISTRY

THE RECENT DISCOVERIES IN THE SCIENCE

THE CHEMICAL AND PHYSICAL PROPERTIES

THE CHEMICAL AND PHYSICAL PROPERTIES

OF MATTER

IN A SYSTEM OF CHEMICAL CALCULATIONS

BY WILLIAM JOHN TAYLOR

OF THE UNIVERSITY OF CAMBRIDGE

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# CHEMICAL CATECHISM:

IN WHICH

THE ELEMENTS OF CHEMISTRY,

WITH

THE RECENT DISCOVERIES IN THE SCIENCE,

ARE CLEARLY AND FULLY EXPLAINED.

---

ILLUSTRATED BY NOTES, ENGRAVINGS, AND TABLES;

AND CONTAINING

AN APPENDIX OF SELECT EXPERIMENTS, &c.

---

By THOMAS JOHN GRAHAM, M. D.

MEMBER OF THE ROYAL COLLEGE OF SURGEONS IN LONDON,  
&c. &c.

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1829.



“ — Search, undismayed, the dark profound  
Where Nature works in secret ; trace the forms  
Of atoms, moving with incessant change,  
Their elemental round ; behold the seeds  
Of being, and the energy of life,  
Kindling the mass with ever-active flame ;—  
Then say if nought in these external scenes  
Can move thy wonder ? — ”

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*London Medical Journal, Sept. 1824.*

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## PREFACE.

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THIS volume is manifestly designed as an elementary treatise on Chemistry, for the use of professional students and general readers; but as there is a *Chemical Catechism*, written by the late Mr. Parkes, already before the public, it will be expected that I should here explain why I have undertaken to write a second. There are few things so ignoble and base as for one man to endeavour to raise himself at the expense of another, and therefore I shall studiously avoid saying more of the demerits of Mr. Parkes's book, than is absolutely necessary to explain my reasons for undertaking the present publication. Although that book contains a great deal of useful information, the matter appears to me to be very badly arranged, and generally not to be of that scientific and elementary character which is universally expected in such a work. The author treats of compound substances before he refers to the simple elements of which they are constituted; the very important subject of attraction or affinity, which may be looked upon as the foundation of the science of Chemistry, and which all the best chemical writers therefore properly place first, he places *last*; he has no chapter or section whatever upon either vegetable or animal chemistry, those interesting and important subjects being alluded to merely incidentally, and with extreme brevity; he refers in the same manner only to the *atomic theory*; and his volume is without plates or cuts. It will be universally conceded, that these are



capital faults, which it appears to me ought to be avoided, and which it has consequently been my endeavour altogether to avoid, as the reader will immediately perceive. Those who are well acquainted with the subject are aware, that the book now alluded to contains also many errors, which it has been my aim to reject. How far I have been successful in this must be left to competent judges to determine. I ought to add, that it is now some time since Mr. Parkes was called to that land "from whose bourne no traveller returns," and as he can therefore no longer revise his work, this circumstance has appeared to me an additional reason why a new book of the same kind should be brought forward; for although that work may be revised by another, the result generally proves very different from that of a revision by the author. The book, indeed, may thereby be much improved, but is more likely to be injured.

With respect to the form of *Catechism*, which has been adopted for this volume, it appears to me to have several advantages in reference to the study of chemistry by youthful and other uninitiated students, and therefore I have preferred it. The more important facts of the science are here exhibited in the text, in the most striking and agreeable manner I was capable of, while the less useful matter, together with all details, are inserted in the form of notes, at the bottom of each page.

I would add, that the last chapter in this volume, viz. *on Combustion*, ought to have been introduced before the chapter on metals, but was omitted by mistake.

Croydon, Surrey,  
February, 1829.



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*William Shakespeare*

BORN APRIL 23<sup>RD</sup> 1564.

DIED APRIL 23<sup>RD</sup> 1616.





DIED APRIL 23<sup>RD</sup> 1616.  
BORN APRIL 23<sup>RD</sup> 1564.

William Shakespeare

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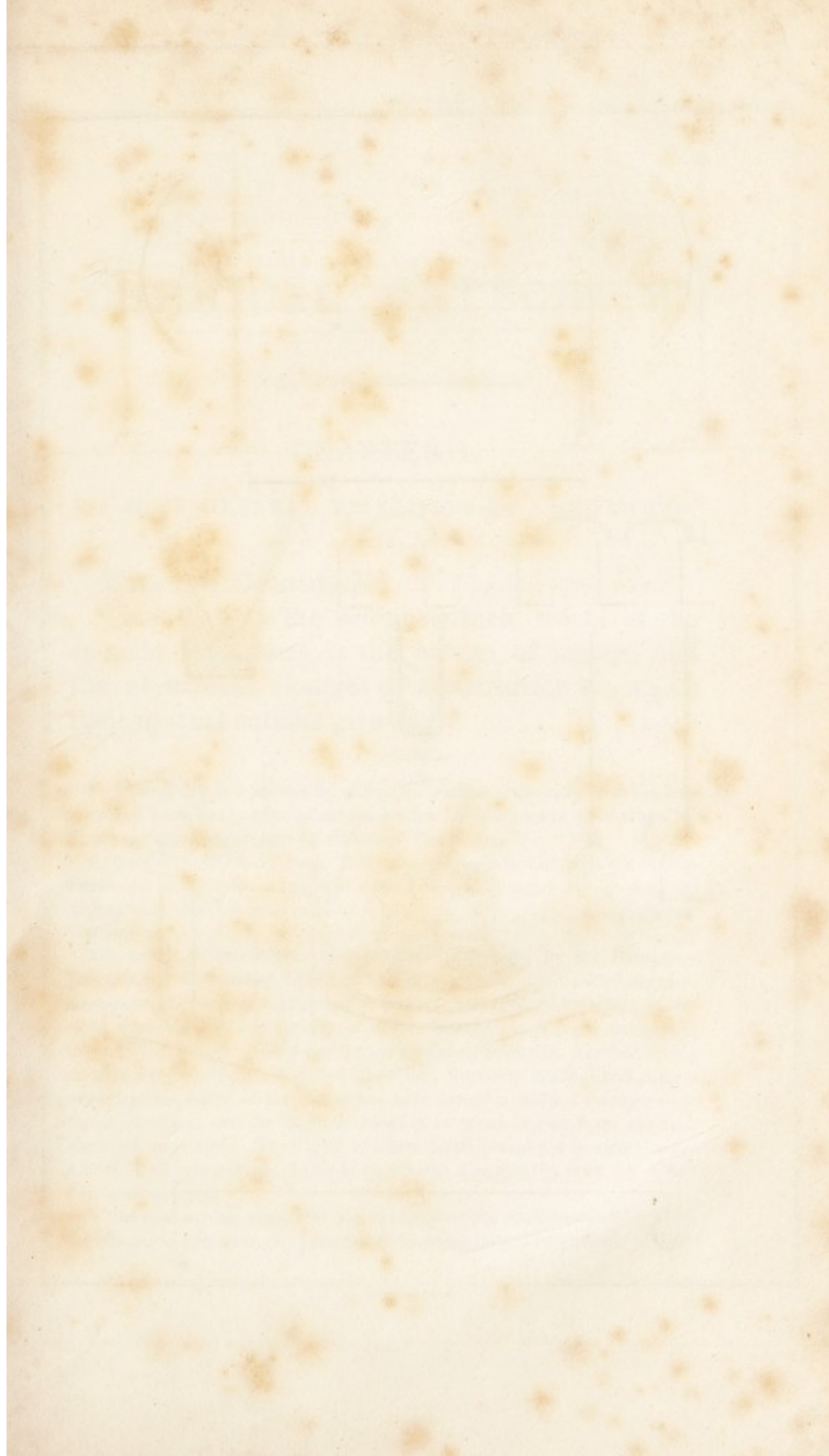
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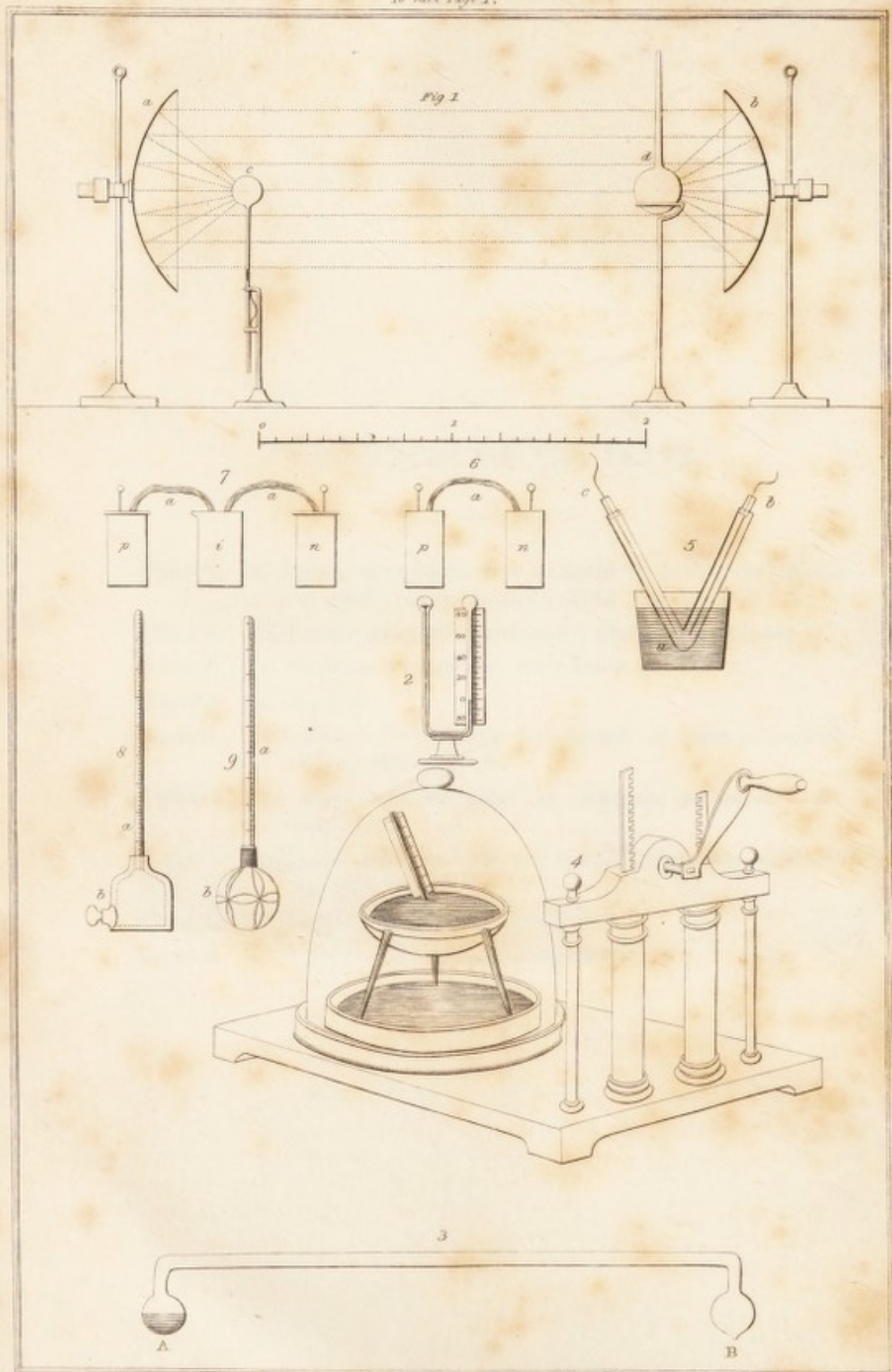
## DESCRIPTION OF THE PLATE.

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- Figure 1.* M. Pictet's arrangement of an apparatus for showing the radiation of caloric, unaccompanied by light.—See page 56.
- Figure 2.* Mr. Leslie's *differential* thermometer, described at page 51.
- Figure 3.* Dr. Wollaston's *cryophorus*, described at page 93.
- Figure 4.* An air pump.
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- Figure 7.* Agate cups, similarly connected, with an intermediate vessel *i*.— See page 124.
- Figure 8.* Dr. Hope's eudiometer.—See page 187.
- Figure 9.* Dr. Henry's eudiometer.—See page 187.









A

# CHEMICAL CATECHISM.

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## CHAPTER I.

### OF SOME GENERAL PRINCIPLES OF CHEMISTRY.

---

#### WHAT IS CHEMISTRY?

Chemistry is the science which treats of the specific differences in the nature of bodies, and the permanent changes of constitution to which their mutual actions give rise.\*

\* "Chemistry is a science by which we become acquainted with the intimate and reciprocal action of all the bodies in nature upon each other."—*Fourcroy's General System of Chemical Knowledge.*

"Chemistry may be defined, that science the object of which is to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies."—*Dr. Henry's Elements of Chemistry.*

The nature of this science is very clearly explained by Sir Humphrey Davy, in his *Elements of Chemical Philosophy*, p. 1. "Most of the substances belonging to our globe are constantly undergoing alterations in sensible qualities, and one variety of matter becomes as it were transmuted into another. Such changes, whether natural or artificial, whether slowly or rapidly performed, are called chemical; thus, the gradual and almost imperceptible decay of the leaves and branches of a fallen tree exposed to the atmosphere, and the rapid combustion of wood in our fires, are both chemical operations. The object of chemical philosophy is to ascertain the causes of all phenomena of this kind, and to discover the laws by which they are governed.

"The ends of this branch of knowledge, are the applications of natural substances to new uses, for increasing the comforts and enjoyments of man.

B



*How are the different substances or bodies which form the subjects of chemical investigation usually divided?*

Every substance, whether it be regarded generally as forming a part of the mass of this globe, or particularly as an object of science, may be arranged in one or other of the three following classes, viz.—*solids, liquids, and gaseous bodies.*

*What is the definition of a SOLID BODY?*

*Solid* bodies are masses of homogeneous particles, combined and held together by the attraction of aggregation or cohesion, so as strongly to resist impression.

*What are LIQUIDS?*

*Liquids* or fluids\* are compounds of caloric, or

and the demonstration of the order, harmony, and intelligent design of the system of the earth."

The difference existing between chemistry and natural philosophy will be readily understood by reading the following explanation, given by Dr. Paris in his *Elements of Medical Chemistry*, p. 1. "As the minute particles of matter are alone actuated by such forces as attraction, heat, and electricity, *chemical* changes are not accompanied by *sensible* motions; a fact which enables us, very conveniently, to consider *chemistry* as distinct from *natural philosophy*, for the phenomena which are constantly referred to this latter province, are characterized by *apparent* motion."

\* Their parts move easily upon each other, and yield to the smallest impression; but they are not sensibly elastic. The greater or smaller degree of liquidity of different substances, depends upon a difference of the force of cohesion exerted between their particles, which may be regarded as placed in the limit between attraction and repulsion: thus the cohesion of mercury is greater than that of water. Liquids differ very much in specific gravity; and the degree of this bears a relation to their density. The distances of the atoms are so regulated, that the attraction and repulsion by which they are at once actuated, just balance one another; while their form, which is supposed to be spherical, is such, that they can move freely among each other without altering these distances. It is this which seems to constitute the real cause of liquidity.



the matter of heat, with a solid base. In other words, the elementary state of all bodies is solidity; when they assume the form of a fluid, it is the result of the repulsive operation of caloric.

*What are GASES?*

*Gases* are æriform or elastic fluids, possessed of very different properties, but all agreeing in that peculiar kind of elasticity which constitutes ærial bodies.\*

*Will you explain more clearly the difference between gases and liquids?*

The particles of *gases*, like those of liquids, are moveable upon each other; but gases differ from liquids in possessing elasticity, or that power which allows them to be compressed into a smaller bulk, and by which, however large a portion of

\* The three forms of matter, the solid, liquid, and gaseous, seem immediately referable to the power of heat, modifying, balancing, or subduing cohesive attraction. Every solid may be liquefied, and many of them, as well as all liquids, may be vaporized at a certain elevation of temperature. And conversely, almost every known liquid may be solidified by the reduction of its temperature. Sulphuric ether, always a liquid in our climate, if exposed to the rigor of a Siberian winter, would become a solid, and transported to the torrid zone, would form a permanent gas. The same transitions are familiar to us with regard to water, only its vaporizing point being much higher, leads us at first to suppose steam an unnatural condition. But by generalizing our ideas, we learn that there is really no state of bodies which can be called more natural than another. Solidity, liquidity, the state of vapours and gases, are only accidents connected with a particular level of temperature. If we pass the easily condensed vapour of nitric acid through a red-hot glass tube, we shall convert it into gases which are incondensable by any degree of cold which we can command. The particles which formed the liquid can no longer join together to reproduce it, because their distances are changed, and with these have also changed the reciprocal attractions which united them.—See *Dr. Ure's Dictionary of Chemistry*, 3d edition, page 273.



any gas contained in a vessel be taken away, the small portion which is left behind is enabled to expand so as to fill the vessel.

*What is the difference between a gas and a vapour?*

A gas is usually denominated a permanently elastic fluid, and vapours, elastic fluids which have no permanence. A moderate reduction of temperature causes a vapour to assume the liquid or solid form, while a gas is uncondensable by such means. We therefore say, the *vapour* of ether, of water, &c.; and oxygen gas, carburetted hydrogen gas, &c.\*

*Are all the bodies of which you have now spoken, capable of being subjected to measurement and weight?*

Yes.

*And what is the total number of such bodies?*

Fifty-two.†

\* Although the distinction between vapours and gases is still retained in common chemical language, yet it should be observed, that recent discoveries of Mr. Faraday, of the Royal Institution, appear to have rendered them in some degree nugatory, for he has succeeded in condensing into liquids the greater number of those aerial or elastic fluids which were considered as permanently elastic.

† These fifty-two ponderable principles may be advantageously divided thus:—

Five bodies remarkable for the pre-eminent activity of combination which they display when brought into contact with the other substances:—

<i>Oxygen.</i>	<i>Fluorine.</i>
<i>Chlorine.</i>	<i>Bromine.</i>
<i>Iodine.</i>	

Six non-metallic bodies, viz.:—

<i>Hydrogen.</i>	} Gaseous bodies.
<i>Azote, or Nitrogen.</i>	
<i>Carbon.</i>	} Fixed and infusible solids.
<i>Boron.</i>	
<i>Sulphur.</i>	} Fusible and volatile solids.
<i>Phosphorus.</i>	



*But are there not some substances which cannot be subjected either to measurement or weight?*

Yes, there are four such elements, commonly called *imponderable elements*, viz. light, heat, electricity, and magnetism.\* There are consequently fifty-six elementary substances† in the whole.

*What is understood by the term SPECIFIC GRAVITY?*

Forty-one metallic bodies, viz. :—

Potassium.	Chromium.	Copper.
Sodium.	Tungsten.	Tellurium.
Lithium.	Columbium.	Lead.
Calcium.	Antimony.	Mercury.
Barium.	Manganese.	Silver.
Strontium.	Zinc.	Gold.
Magnesium.	Iron.	Platinum.
Glucinum.	Tin.	Palladium.
Yttrium.	Cadmium.	Rhodium.
Aluminum.	Uranium.	Iridium.
Zirconium.	Cerium.	Osmium.
Silicium.	Cobalt.	Nickel.
Arsenic.	Titanium.	
Molybdenum.	Bismuth.	

The first three metals above enumerated, by their union with oxygen are convertible into alkalies, the nine following into earths, the six following these, namely, arsenic, molybdenum, chromium, tungsten, columbium, and antimony, into acids, and the remainder into ordinary metallic oxides.

\* The separate identity of these imponderable elements is, however, not clearly ascertained.

† “In the language of modern Chemistry, the term *Elementary*, or *Simple*, has a signification very different from that attached to it by the ancient philosophers, who considered it as expressing substances possessing absolute simplicity, which, by modifications of form, or combination with each other, form the numerous substances which compose the material world; whereas the *Elements* of the moderns, are considered simple merely in relation to the present state of the art of analysis, for it is assumed as a general principle, that every substance is to be regarded as simple which has not been resolved into two or more constituent parts.” *Dr. Paris's Medical Chemistry*, p. 245.

The student will immediately perceive from this explanation of the meaning of the term *elementary*, that the number and nature of our elements will be constantly liable to vary during the progress of science,



The comparative weight of a body, that is, the weight of a body compared with that of another, whose magnitude is the same. Since the density of a body is as the quantity of matter contained in a given space, its *specific gravity* may be regarded as only another term for its density.

*For the accurate expression of such a relative quantity, it is necessary to fix upon some substance as a standard: What is the standard generally agreed upon?*

Distilled water, at the temperature of sixty degrees of Fahrenheit's thermometer. This is the unit of comparison, or the datum from which all calculations of specific gravity should proceed, and is always called 1 or 1.000.\*

*How do you calculate the specific gravity of a solid?*

We weigh it, first in air, and then in water: in the latter case it loses of its weight, a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with its total weight, we find its specific gravity. The rule, therefore, is, divide the total weight by

\* Thus, if a cubic inch of any solid body were found to be double the weight of a cubic inch of water, such a body would be specifically heavier than water, in the proportion of two to one, and its specific gravity would accordingly be set down thus, 2, or 2.000. If, again, its weight were equal to that of two and a half cubic inches of water, it would be specifically heavier than water in the proportion of two and a half to one, and its specific gravity would in that case be set down as 2.5, or 2.500, the fractional parts being always expressed by decimals. For example, the strongest sulphuric acid of commerce is very nearly nine-tenths specifically heavier than water, and is stated to be 1.850.



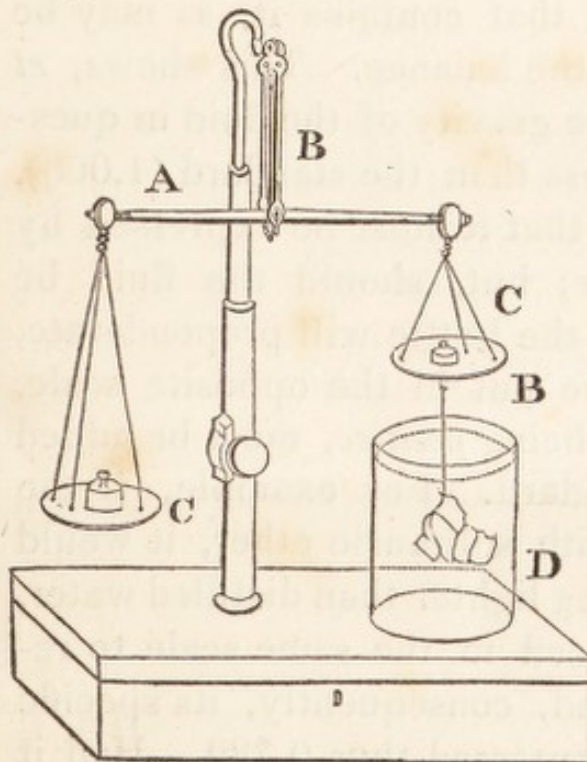
the *loss*\* of weight in water, the quotient is the specific gravity.†

*How do you ascertain the specific gravity of fluids?*

There are several methods by which it may be ascertained; but the best is performed by what is called a *gravity bottle*, which is a glass bottle with a slender neck, furnished with a ground conical stopper.‡ A gravity bottle, called “a

\* In saying that a body loses part of its weight in a fluid, it is not meant that its absolute weight is less than it was before, but that it is partly sustained by the re-action of the fluid under it, so that it requires a less power to support it.

† The specific gravity of solid bodies is most conveniently determined by the *Hydrostatic Balance*.



A B C is a balance, D a glass jar about six inches in height, which contains pure distilled water. The mode of using this instrument is as follows: let the solid, say for example a piece of gold, whose specific gravity is to be ascertained, be suspended by a fine hair, silk, or thread, from the scale B, and weighed in air; suppose it to weigh 48 grains: let it next, still suspended to the balance, be immersed in the distilled water of the temperature of 60° Fahr. as represented in the annexed figure; the scale containing the weight will now preponderate; add, therefore, to the scale B, as

many grain weights as may be necessary to restore the equilibrium; suppose that 6 grains are required for this purpose, then this will indicate the amount of the weight lost in the water. We now divide the real weight of the body in air, viz. 48 grains, by this loss, 6 grains, which gives us 8 as the specific gravity of the body under examination.

‡ In the side of the stopper there is a notch, or indentation, by which the



*Thousand Grain Bottle,*" from its containing just a thousand grains of distilled water, is considered the best instrument for determining this point with great facility. The thousand grain bottle is sold together with a weight, which is an exact counterpoise for it when filled with distilled water at 60° Fahrenheit. This instrument consequently does not require the aid of any computation, but is simply filled with the fluid to be examined, and placed in one scale of the balance, while its counterpoise is placed in the other. If the contained fluid be lighter than water, it will appear deficient in weight, and as many grains must be added, to the scale that contains it, as may be sufficient to restore the balance. This shews, *at once*, that the specific gravity of the fluid in question is *negative*, or less than the standard (1.000), and, consequently, that it must be expressed by a fractional number; but, should the fluid be heavier than water, the bottle will preponderate, and weights must be put in the opposite scale, when their amount being *positive*, must be added to that of the standard. For example, if the bottle were filled with sulphuric ether, it would require, from its being lighter than distilled water, 739 grains to be placed in the same scale to restore the balance, and, consequently, its specific gravity would be expressed thus 0.739. Had it

operator is enabled to put in the stopper after the vessel has been completely filled, the redundant fluid escaping through this groove. Unless such a contrivance were adopted, it would be difficult to fill a bottle with liquid, without inclosing some bubbles of air,

been filled with sea water, which is rather more dense than that which is distilled, twenty-six hundredths, or rather better than a quarter of a grain must have been added in the opposite scale, and which, as already explained, must be added to the standard 1.000 to express the specific gravity of such water, which would be stated thus, 1.026.\*

\* Sulphuric acid, again, being still heavier, would, in like manner, require 875 grains, and must accordingly be expressed as 1.875.



## CHAPTER II.

## OF ATTRACTION.

*The subject of attraction is considered of great importance among chemical philosophers: What do they mean by it?*

Attraction is the term employed to denote that power which causes bodies to approach towards each other, and which preserves them in a state of union after they come into contact.

*Is there more than one kind of attraction?*

Yes, there are two kinds, namely, that exerted on masses of matter at *sensible* distances, and that which is confined to the minute atoms of bodies at *insensible*\* distances. The former is

\* That chemical affinity is effective only at *insensible* distances, may be demonstrated by the following experiment:—Into a deep ale-glass, or glass jar, pour two fluid drachms of a solution of the sub-carbonate of potass, (*liquor potassæ*) diluted with about fourteen drachms of distilled water. Under this introduce, very cautiously, half a fluid ounce of water holding a drachm of common salt in solution; and again, under both these, two fluid ounces of sulphuric acid, which has been previously diluted with an equal quantity of water. The delivery of these different fluids may be effected by the *dropping tube*, or by means of a common glass tube, open at each extremity, which, having been plunged in the liquid, must be withdrawn with the thumb closely applied to the upper orifice; when, by immersing it to the bottom of the jar, and then removing the thumb, the fluid will be deposited in the manner required. If this arrangement be carefully accomplished, we shall perceive, notwithstanding the powerful attraction which subsists between the alkali and acid, that no action will take place; because their particles are separated from each other by a thin stratum of brine; as soon, however, as this arrangement is disturbed by agitation, a brisk effervescence will commence, and a chemical combination take place.



denominated the *attraction of gravitation*,\* the latter, *contiguous attraction*.†

*How is contiguous attraction farther divided?*

Into the attraction of cohesion or aggregation, and chemical attraction or affinity.

*What is the attraction of cohesion?*

It is that force, or power, by which particles or atoms of matter, of the *same* kind, attract each other, and produce an aggregate or mass. Hence, it is also sometimes called the ATTRACTION OF AGGREGATION.‡

\* When a stone is thrown into the atmosphere, it rapidly descends towards the surface of the earth. This is owing to *gravitation*. All the great bodies in the universe are urged towards each other by a similar force.

† It frequently happens, that bodies which have no tendency to unite, are made to combine together by means of a third, which is then called *the medium*. Thus water and fat oils are made to unite by the medium of an alkali, in the combination called soap. Some writers, who are evidently desirous of multiplying terms unnecessarily, call this tendency to unite *the affinity of intermedium*. Others call this case *disposing affinity*. We might explain more fully the nature of disposing affinity, by the following example:—Iron has an attraction for oxygen; but so little superior to that of hydrogen for the same body, that it is unable to decompose water at a low temperature, or at least, with any energy; but, if a small quantity of sulphuric acid be added, the decomposition instantly proceeds with very considerable rapidity. Here the sulphuric acid is said to exert a *disposing affinity*.

Berthollet likewise distinguishes affinity into *elementary*, when it is between the elementary parts of bodies; and *resulting*, when it is a compound only, and would not take place with the elements of that compound.

‡ Dr. Ure, in his Chemical Dictionary, page 175, correctly remarks, “That the parts of bodies do attract each other, is evident from that adhesion which produces solidity, and requires a certain force to overcome it. For the sake of perspicuity, the various effects of attraction have been considered as different kinds of affinity or powers. That power which physical writers call the attraction of cohesion, is generally called the attraction of aggregation by chemists. Aggregation is considered as the adhesion of parts of the same kind. Thus a number of pieces of brimstone united by fusion, form an aggregate, the parts of which may be



*Is this cohesive attraction the same in all bodies?*

No; it is manifestly different in different bodies. It is most strongly exerted in solids; and in these it is proportionate to the mechanical force required for their disunion. In liquids, it acts with considerably less energy, as is evident from their particles being moveable with regard to each other by a very small force. In gases, we have no evidence that it exists at all, for their particles are mutually repulsive, and, if not held together by pressure, separate to great distances.

*What is meant by chemical attraction?*

Chemical attraction, or affinity, is exerted between the particles or atoms of bodies of *different* kinds, producing not a mere aggregate or homogeneous mass, but bodies possessed of *new*\*

separated again by mechanical means. These parts have been called *integrant* parts, that is to say, the minutest parts into which a body can be divided, either really or by the imagination, so as not to change its nature, are called *integrant* parts. Thus, if sulphur and an alkali be combined together, and form liver of sulphur, we may conceive the mass to be divided and sub-divided to an extreme degree, until at length the mass consists of merely a particle of brimstone and a particle of alkali. This, then, is an *integrant* part, and if it be divided farther, the effect which chemists call decomposition will take place; and the particles, consisting no longer of liver sulphur, but of sulphur alone, and of alkali alone, will be what chemists call component parts or principles."

The force of the cohesive attraction is not only different in different bodies, but in various states of the same body. Thus, in the cohesion of certain metals, (steel for instance,) important changes are produced by the rate of cooling, by hammering, and by other mechanical operations.

\* The older chemists were wont to say, that the properties of compounds are *intermediate* between those of their component parts, but this is erroneous, and the following experiments afford striking illustrations of the fact, that the result of chemical combination is the formation of a *new* body, in which the properties of the components have either wholly, or in part, disappeared.

1. Water impregnated with *strong solution of ammonia*, and concen-



properties, different from those of their components.

*Is not the doctrine of chemical attraction considered of great importance among chemists? \**

Certainly; for it is by the force of chemical attraction, that all compositions and decompositions are effected. Indeed, all chemical phenomena are owing to affinity or chemical attraction. It is, therefore, the basis on which the science of chemistry is founded.

*What example can you give of chemical affinity?*

The affinity of carbonic acid for lime, for instance, is readily shewn by adding a little water impregnated with carbonic acid, to a wine glass of clear lime water; a white precipitate of carbonate of lime will immediately appear. Again, when grease or oil spots are to be removed from clothes, the part is sometimes rubbed over with a solution of soda, potass, or ammonia, in a little water; either of these alka-

trated *muriatic acid*, are fluids of a very pungent odour; mix them together in proper proportions, and a fluid will result entirely devoid of smell.

2. Into a saturated solution of *muriate of lime*, let fall, gradually, concentrated *sulphuric acid*, (oil of vitriol); a quantity of pungent vapour, (*muriatic acid gas and water*,) will immediately arise, and an almost solid compound, (*sulphate of lime*,) be produced. Here two fluids produce a solid.

3. Into a wine-glass, containing water, add a few drops of prussiate of potass; and into another, a little of the dilute solution of sulphate of iron; on mixing these two *colourless* liquids together, a bright deep blue colour will be instantly produced, which is the true "*Prussian Blue*."

\* Sir Humphrey Davy has suggested an ingenious hypothesis respecting chemical affinity, which is, that the chemical combination of substances is owing to the different states of electricity in which they may be when they come in contact with each other; those bodies being disposed to combine which possess opposite electricities.



lies, from their affinity for oily matter, will combine with it, and form a soap, which will speedily disappear by the application of a little water.

*And are the forces with which chemical affinity is exerted always the same?*

No. They are different in different bodies. In other words, the attractions or affinities exerted by any body towards others, are different in their force with respect to each other.\*

*How do you illustrate this?*

It may be shewn thus: mix together equal weights of magnesia and of quick lime, in fine powder, and add diluted nitric acid. After some hours, it will be found that a considerable part of the lime has been dissolved, but that the whole of the magnesia has remained untouched. Hence, it is clear, that nitric acid has a stronger attraction for lime than for magnesia.

*Chemists often speak of ELECTIVE affinity. What is meant by it?*

In such a case of attraction as that just noticed, the nitric acid is metaphorically represented as making an election, whence this species of affinity, is denominated *elective* affinity.†

\* "This is all," says Dr. Henry, "that the present state of our knowledge authorizes us to affirm; for we are ignorant *how much* the affinity of one body for another is superior to that of a third. The determination of the precise forces of affinity would be an important step in chemical philosophy; for its phenomena would be then reduced to calculation; and we should be enabled to anticipate the results of experiment. That the force of chemical affinity must be prodigiously great, is evident from its effect in preserving the combination of water with some bodies, (the alkalies for instance,) when exposed to a violent heat, notwithstanding its great expansive force, and though water is not essential to the constitution of those bodies." *Elements of Chemistry*, vol. i. p. 63.

† This may be further explained by supposing we have three bodies, A,



*What do you understand by SINGLE elective affinity and DOUBLE elective affinity?*

The first, is that in which a body acts upon a compound of two ingredients, and unites with one of its constituents, leaving the other at liberty; \* while *double* elective affinity takes

B, and C. A will often combine with B in preference to C, even when these two bodies are presented to it under equally favourable circumstances; or when A is united with C, the application of B will detach A from C, and we shall have a new compound consisting of A and B, C being set at liberty. Such cases are examples of what is termed in chemistry, *simple decomposition*.

\* Thus, if to the muriate of lime, consisting of lime and muriatic acid, we add potassa, the muriatic acid exerts a stronger elective affinity for the potassa than for the lime; and the lime falls down in the state of a powder, or is *precipitated*. Of facts of this kind, a great variety have been comprehended in the form of tables, the first idea of which seems to have occurred many years ago to Geoffroy, a French chemist. The substance, whose affinities are to be expressed, is placed at the head of a column, and is separated from the rest by a horizontal line. Beneath this line are arranged the bodies, with which it is capable of combining, in the order of their respective forces of affinity; the substance which it attracts most strongly being placed nearest to it, and that, for which it has the least affinity, at the bottom of the column. The affinities of the muriatic, sulphuric, and nitric acids, for example, are exhibited by the following series:—

<i>Muriatic Acid.</i>	<i>Sulphuric Acid.</i>	<i>Nitric Acid.</i>
Baryta.	Baryta.	Lime.
Potassa.	Strontia.	Ammonia.
Soda.	Potassa.	Zinc.
Lime.	Soda.	Iron.
Ammonia.	Lime.	Copper.
Magnesia.	Magnesia.	Lead.
&c.	Ammonia.	Mercury.
	&c.	Silver.
		&c.

Simple decompositions may be expressed also by another form, contrived by Bergman. Thus the following scheme illustrates the decomposition of muriate of magnesia by potassa:—

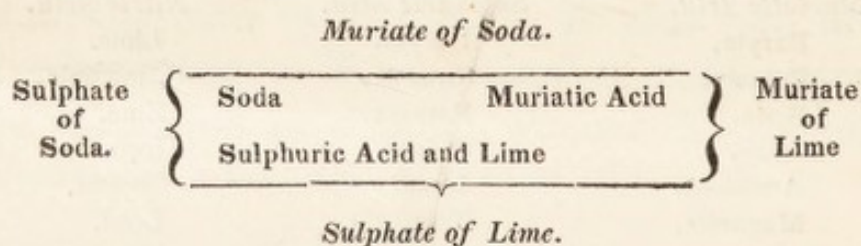
	Muriate of Potassa.		
Muriate of Magnesia.	{	Muriatic Acid.	Potassa.
		Magnesia.	Water at 60°
		Magnesia.	



place when two bodies, each consisting of two principles, are presented to each other, and mutually exchange a principle of each; by which means two new bodies, or compounds, are produced, of a different nature from the original compounds.\*

The original compound (muriate of magnesia) is placed on the outside and to the left of the vertical bracket. The included space contains the original principles of the compound, and also the body which is added to produce decomposition. Above and below the horizontal lines are placed the new results of their action. The point of the lower horizontal line being turned downwards, denotes that the magnesia falls down, or is precipitated; and the upper line, being perfectly straight shows, that the muriate of potassa remains in solution. If both the bodies had remained in solution, they would both have been placed above the upper line; or, if both had been precipitated, beneath the lower one. If either one or both had escaped in a volatile form, this would have been expressed, by placing the volatilized substance above the diagram, and turning upwards the middle of the upper horizontal line. And since decompositions vary under different circumstances, it is necessary to denote, by the proper addition to the scheme, that the bodies are dissolved in water of the temperature of 60°.

\* Such cases are examples of what are called *double decomposition*. They are sometimes also termed *complex affinity*. These decompositions are rendered more intelligible by the following diagram:—



On the outside of the vertical brackets are placed the original compounds, (sulphate of soda and muriate of lime,) above and below the horizontal lines, the new compounds produced, (*muriate of soda* and *sulphate of lime*,) the upper line being straight, indicates that the *muriate of soda* remains in solution; the dip of the lower line, that the *sulphate of lime* is precipitated.

It is curious that in this case it frequently happens, that the compound of two principles cannot be destroyed, either by a third or fourth *separately* applied; whereas, if the third and fourth be combined, and placed in con-



*In all such cases of decomposition, it is evident that two distinct series of attractions must be in conflicting operation: viz. those tending to preserve the original compounds, and those which tend to disunite them, and to raise up new compounds by a fresh combination of their ingredients. By what names are these different series of attractions distinguished?*

The former are termed *quiescent* affinities, and the latter, *divellent* affinities.

*And what obvious fact presents itself in regard to the exercise of these opposing affinities?*

That a double decomposition can only be effected where the sum of the *divellent* is superior to that of the *quiescent* attractions.\*

tact with the former compound, a decomposition, or a change of principle, will ensue. For instance, if to a solution of sulphate of soda, we add lime water, no decomposition takes place, because the attraction of the sulphuric acid is stronger for the soda than for the lime; so again, if muriatic acid be added to the same salt no change is induced, since the sulphuric acid attracts soda more powerfully than the muriatic acid. But if the lime and muriatic acid previously combined (muriate of lime) be mixed with the sulphate of soda, a double decomposition is effected. The lime, quitting the muriatic acid, unites with the sulphuric; and the soda being separated from the sulphuric acid, combines with the muriatic.

\* Dr. Henry has placed this subject in a clear point of view, thus:—

Suppose—The attraction of lime to muriatic acid	=	104
soda to sulphuric acid	=	78
		<hr/>
<i>Quiescent affinities</i>	=	182
Suppose—The attraction of soda to muriatic acid	=	115
lime to sulphuric acid	=	71
		<hr/>
<i>Divellent affinities</i>	=	186

The original compounds, therefore, are preserved by a force equivalent to 182, and the tendencies to produce new compounds are represented by the number 186. The *divellent* affinities are consequently predominant.



*What are the phenomena which usually accompany chemical action, that is, the exertion of chemical affinity?*

The principal phenomena observed to attend it are :—

1st. An alteration of *properties*.\*

2dly. An alteration of *density*, or *specific gravity*.†

3dly. A change of *temperature*.‡

4thly. A change in the *forms of bodies*.§

\* Numerous examples of this kind are afforded by the action of acids and alkalies on one another. Sulphuric acid and potass, for example, are highly caustic. The former is intensely sour, reddens the blue colour of vegetables, and has a strong affinity for alkaline substances; the latter has a pungent taste, converts the blue colour of vegetables to green, and combines readily with acids. On adding these principles cautiously to one another, a compound results, called a neutral salt, which does not in any way affect the colouring matter of plants, and in which the other distinguishing features of the acid and alkali can no longer be perceived. They appear to have destroyed the properties of each other, and are, therefore, said to neutralize one another.

† In cases of chemical union, the *specific gravity*, (that is, the comparative weight of a body,) of the compound is very generally greater than the mean of its components. Thus a mixture of 100 equal measures of water, and an equal quantity of sulphuric acid, do not occupy the space of 200 measures, but considerably less. The law extends also to solids, and gases. But though general, it is not universal; for in a very few instances, chiefly of æriform fluids, condensation does not attend chemical union.

‡ For example, equal weights of sulphuric acid and water, both at the temperature of 50 degrees of Fahrenheit, are heated, when suddenly mixed together, to considerably above 212 degrees.

§ The changes of form that attend chemical action are exceedingly various. The combination of gases may give rise to a liquid or a solid; solids sometimes become liquids, or liquids solids. Several familiar chemical phenomena, such as explosions, effervescence, and precipitations, are owing to these changes. The sudden evolution of a large quantity of gaseous matter occasions an explosion, as when gunpowder detonates. The slower disengagement of a gas causes effervescence, as occurs when marble is put into muriatic acid. A precipitate is owing to the formation of a new body which happens to be insoluble in the liquid in which its elements were dissolved.



5thly. A change of colour.\*

*But are there not some circumstances which modify the operation of chemical affinity?*

Yes, affinity is influenced by several circumstances, the chief of which are,

1. Temperature.†
2. Insolubility.‡

\* In some cases, brilliant colours are destroyed, as when chlorine is made to act on solution of indigo. In other instances, two substances, which are nearly colourless, form, by their union, a compound distinguished by beauty of colour, as when liquid potassa is added to very dilute syrup of violets. Dr. Turner, in his *Elements of Chemistry*, has correctly remarked, that there does not appear to be any uniform relation between the colour of a body and that of its elements, so that it is not possible to anticipate the colour of any particular compound by knowing the principles which enter into its composition. Iodine, whose vapour is of a violet hue, forms a beautiful red compound with mercury, and a yellow one with lead. The brown oxide of copper generally gives rise to green and blue coloured salts; while the salts of the oxide of lead, which is itself yellow, are, for the most part, colourless. The colour of precipitates is a very important study, as it often enables the chemist to distinguish bodies from one another when in solution.

† The influence of *temperature* over chemical affinity is extremely extensive and important. In some cases, an increased temperature acts in promoting, and in others in impeding, chemical combination. If alcohol, for example, be added to a solution of nitrate of potash, it unites with the water, and precipitates the salt at a common temperature; but if the temperature be raised, the alcohol rises on account of its volatility, and the salt is again dissolved. An increased temperature promotes chemical union by diminishing or overcoming cohesion. Thus metals unite by fusion, and several salts are more soluble in hot than in cold water. Whenever heat is an obstacle to combination, it produces its effect by increasing elasticity. Hence, water absorbs a less proportion of ammonia at a high than a low temperature.

‡ This has great effect in modifying the exertion of affinity. When a soluble substance and an insoluble one are presented, at the same time, to a third, for which they have nearly an equal affinity, the soluble body is brought into the sphere of action with great advantages over its antagonist. Its cohesion at the outset is but little, and by solution is reduced almost to nothing; while that of the insoluble substance remains the same. The whole of the soluble body also exerts its affinity at once, while a part only of the insoluble one can oppose its force. Hence the soluble substance may



3. Quantity of matter.\*
4. Cohesion.†
5. Great specific gravity.
6. Elasticity.‡
7. Electrical states of bodies.§

*What do we learn from the existence of these circumstances modifying affinity?*

prevail, and may attach to itself the greatest proportion of the third body, even though it has a weaker affinity than the insoluble one to the subject of combination.

\* If one body A unites with another body B in several proportions, that compound will be most difficult of decomposition which contains the smallest quantity of B. Of the three oxides of lead, for instance, the peroxide parts most easily with its oxygen by the action of caloric; a higher temperature is required to decompose the deutoxide, and the protoxide will bear the strongest heat of our furnaces without losing a particle of oxygen. M. Berthollet, an able French chemist, published some time since a new opinion on this subject, and from a great number of experiments deduced the following law:—That in elective attractions the power exerted is not in the ratio of the affinity simply, but in a ratio compounded of the force of the affinity and the quantity of the agent; so that quantity may compensate for weaker affinity. Thus, an acid which has a weaker affinity than another for a given base, if it be employed in a certain quantity, is capable of taking part of that base from the acid which has a stronger affinity for it; so that the base will be divided between them in the compound ratio of their affinity and quantity. To this law of Berthollet's, however, many facts of an irreconcilable nature occur, and it is considered by no means established. For a detailed account of it, the reader may refer to *Berthollet's Statique Chimique*; *Dr. Ure's Dictionary*, article *Attraction*; and *Henry's Chemistry*, vol. i. p. 55.

† Bodies seldom act chemically in their solid state; their molecules do not come within the sphere of attraction, and, therefore, combination cannot take place, although their affinity may in fact be considerable. Liquidity, on the contrary, favours chemical action; it permits the closest possible approximation, while the cohesive power is comparatively so trifling as to oppose no appreciable barrier to affinity.

‡ Bodies evince little disposition to unite when presented to each other in the elastic form. The cause of this is obviously the distance between the particles preventing that close approximation which is so necessary to the successful exercise of affinity. Hence, oxygen and hydrogen gases, though their mutual affinity is very powerful, may be preserved together for any length of time without combining.

§ This will be noticed under the chapter on *Electricity*.



That in every case of combination and decomposition, we are not to consider the force of affinity abstractedly, but are to take into account the agency of other powers, as just noticed.

*Will you now recapitulate the laws of chemical attraction?*

The first law is, that IT TAKES PLACE ONLY BETWEEN BODIES OF A DIFFERENT NATURE ;

The second, that IT TAKES PLACE ONLY BETWEEN THE MOST MINUTE PARTICLES OF BODIES ;

The third, that IT CAN TAKE PLACE BETWEEN TWO, THREE, FOUR, OR EVEN A GREATER NUMBER OF BODIES ;

The fourth, that A CHANGE OF TEMPERATURE ALWAYS TAKES PLACE AT THE MOMENT OF COMBINATION ;

The fifth, that THE PROPERTIES WHICH CHARACTERIZE BODIES, WHEN SEPARATE, ARE ALTERED OR DESTROYED BY THEIR COMBINATION ;

The sixth, that THE FORCE OF CHEMICAL AFFINITY BETWEEN THE CONSTITUENTS OF A BODY IS ESTIMATED BY THAT WHICH IS REQUIRED FOR THEIR SEPARATION.

The seventh, that BODIES HAVE AMONGST THEMSELVES DIFFERENT DEGREES OF ATTRACTION.

*We have now been speaking somewhat at length of chemical affinity, and I would ask you, what is said to be the result of the operation of this affinity between two or more substances?*

A combination of the constituent particles of the substances, so intimate that the components can-



not be recognised nor separated by any mechanical force.\*

*And how is a compound body resolved into its component or constituent parts?*

By exposure to a high temperature, which weakens the force of attraction existing between its principles; or, by mixture, under favourable circumstances, with some other chemical agent, which has a more powerful affinity for one of the components than these have for each other. This is called *decomposition*, or chemical analysis.†

*What is the difference between MIXTURE and COMBINATION?*

The union of bodies in a gross way is called mixture. Thus sand and an alkali may be mixed together. But when the very minute parts of a body unite with those of another so intimately as to form a body which has properties different from those of either of them, the union is called combination, or composition. Thus, if sand and an alkali be exposed to a strong heat, the minute parts of the mixture combine, and form glass.

\* Thus, lime acts as a powerful caustic when applied to animal matter, and is partially soluble in water; phosphoric acid has an acid taste, and is very soluble in water; but phosphate of lime, the compound produced by the chemical combination of these substances, is inert when applied to animal matter, insipid, and insoluble in water; and cannot be again resolved into lime and phosphoric acid by any mechanical power.

† The word *analysis* is applied by chemists to denote that series of operations by which the component parts of bodies are determined, whether they be merely separated, or exhibited apart from each other, or whether these distinctive properties be exhibited by causing them to enter into new combinations. The forming of new combinations is called *synthesis*. Thus, whenever the component parts of any body are reunited in order to form a similar substance, and a similar substance is actually produced, the nature of that body is said to be proved by synthesis.



*And do bodies chemically combine in all proportions?*

No. Some bodies unite in all proportions, as water with sulphuric acid, or alcohol with water, &c.; other bodies combine in all proportions, as far as a certain point, beyond which combination no longer takes place.\* Again, there are many examples in which bodies unite in one proportion only.† Other bodies unite in several proportions, but these proportions are definite, and, in the intermediate ones, no combination ensues.

*Give an example of bodies combining in all proportions, as far as a certain point.*

We have an example of it in mixing together common salt and water. The water will take up successive portions of the salt, until at length it becomes incapable of dissolving any more.

*And what is this point called, at which the water ceases to dissolve the salt?*

The point of *saturation*; and the fluid obtained is termed a *saturated solution*.‡

\* In cases of this sort, as well as in those described in the preceding sentence, combination is weak and easily destroyed, and the qualities which belonged to the components in their separate state, continue to be apparent in the compound.

† Here combination is generally energetic; and the characteristic qualities of the components are no longer observable in the compound.

‡ But saturation with one substance does not deprive the fluid of its power of acting on and dissolving some other bodies; in many cases it increases this power. For example, water saturated with salt will dissolve sugar, and water saturated with carbonic acid will dissolve iron, though without this addition its action on this metal is scarcely perceptible. The explanation of this apparent paradox is to be found in the simple fact, that new compounds acquire new powers as solvents.



*Give an example of bodies uniting in one proportion only.*

In all such cases, the proportion of the elements of a compound must be uniform for the species. Thus, hydrogen and chlorine unite in no other proportions than those constituting muriatic acid, which, by volume, is one of the former to one of the latter, and, by weight, 1 to 36.

*Give an example of bodies uniting in several, but definite,\* proportions.*

Six parts, by weight, of charcoal, combine with 8 of oxygen, or with 16, but with no intermediate quantity. Again, 64 parts of copper combine with 8 of oxygen, or with 16, and with those proportions only.

*In the combination of substances that unite in a few proportions only, there are two laws worthy of particular regard. What are they?*

The first law is, that the composition of such bodies is fixed and invariable; that is, such a compound substance, so long as it retains its characteristic properties, must always consist of the same elements united together in the same proportion. Thus, sulphuric acid is always composed of sulphur and oxygen in the ratio of 16 parts of the former to 24 of the latter.† The second law is, that in the several different

\* This law of combination in definite proportions is of the first importance in chemistry, as the student will fully understand as he proceeds in the study of the science.

† Therefore, no other elements can form sulphuric acid, nor can its own elements form it in any other proportion. Water, in like manner, is formed



proportions in which one body enters into combination with another, the numbers indicating the greater proportions are exactly *simple multiples* of that denoting the smallest proportion. For example, if the smallest proportion in which B combines with A be denoted by 10, A may combine with twice 10 of B, or with three times 10, and so on; but with no intermediate quantities.\*

*You will not be able fully to understand all the uses of this doctrine of definite proportions until you are farther advanced in the study of chemistry, but*

of one part of hydrogen and eight of oxygen; and were these two elements to unite in any other proportion, some new compound, different from water, would be the product. The same observation applies to all other substances, however complicated, and at whatever period they were produced. Thus, sulphate of barytes, whether formed ages ago by the hand of nature, or quite recently by the operations of the chemist, is always composed of 40 parts of sulphuric acid and 78 of barytes. This law, in fact, is universal and permanent, and its importance is equally manifest.

\* This is often called the law of multiples, or of combination in multiple proportion. Some bodies unite in three, four, five, or even six definite proportions, which is the greatest number of compounds that any two substances are known to produce. For example, nitrogen and oxygen combine together in five proportions, viz.:

1 proportion of nitrogen and 1 of oxygen,	forming <i>nitrous oxide</i> ;
1 ditto                      ditto    and 2 of ditto	forming <i>nitric oxide</i> ;
1 ditto                      ditto    and 3 of ditto	forming <i>hypo-nitrous acid</i> ;
1 ditto                      ditto    and 4 of ditto	forming <i>nitrous acid</i> ;
1 ditto                      ditto    and 5 of ditto	forming <i>nitric acid</i> .

An interesting fact, connected with the law of definite proportions, is, that two neutral salts, in reciprocally decomposing each other, give birth to two new saline compounds, always perfectly neutral, no excess of acid or of base ever occurring in the interchange of principles; thus, if 100 parts of nitrate of barytes, which contain 41 nitric acid, and 59 barytes, be mixed with 67 of sulphate of potass, which consist of 30 of sulphuric acid, and 37 of potass, there will be found 89 of sulphate of barytes, and 78 of nitrate of potass; so that 41 of nitric acid will combine with the 37 of potass, and 30 of sulphuric acid with the 59 of barytes.



*you are acquainted with one very considerable use of it, and I shall be glad if you will state it.*

It enables the chemist to form tables, by which they can see at one glance the composition of all the bodies which have been accurately analysed, and ascertain directly what quantity of one body will be necessary to decompose a certain quantity of another. For example, when we have ascertained the proportion in which any two or more bodies, A, B, C, &c., of one class, neutralize another body X of a different class, it will be found that the same relative proportions of A, B, C, &c., will be required to neutralize any other body of the same class as X. Thus, since 40 parts of real sulphuric acid, and 54 of real nitric acid, neutralize 48 of potassa, and since 40 of sulphuric acid neutralize 28 of lime, we may infer that 54 of nitric acid will neutralize the same quantity (28) of lime.\*

*Then you would say, that forty parts of real sulphuric acid, and fifty-four of real nitric acid are EQUIVALENTS to each other?*

Certainly.

\* "From such data, calculations, which would otherwise be difficult or tedious, may be made rapidly and with ease, without reference to books, and frequently by a simple mental process. The exact quantities of substances required to produce a given effect can be determined with certainty, thus affording information which is often necessary to the success of chemical processes, and of vast consequence, both in the practice of the chemical arts, and in the operations of pharmacy."—*Dr. Turner's Elements of Chemistry*, p. 126.



## CHAPTER III.

## OF THE ATOMIC THEORY.

*The atomic theory, as it is called, is much thought of at this time by chemists: \*—Pray what do they mean by it?*

A theory promulgated by Mr. Dalton, of Manchester, which is founded on the supposition, that all bodies are composed of *ultimate atoms*,† the weight of which is different in different kinds of matter. According to this view, every compound is formed by a combination of the atoms of its constituents.‡

\* “The developement of this theory must be considered,” says Dr. Thomson, “as the greatest step which chemistry has yet made, as a science.” See Dr. Thomson’s paper on the Daltonian Theory of Definite Proportions, in the *second vol. of the Annals of Philosophy*.

† By the term *atoms*, we are to understand the smallest parts of which bodies are composed. An atom, according to this theory, must be mechanically indivisible.

‡ Dr. Paris, in his *Medical Chemistry*, page 151, has clearly explained the nature of this theory in the following terms:—“In order to understand the atomic, or Daltonian theory, it must be remembered that every particle of a true chemical compound, however minutely divided, will contain a portion of each ingredient. It is true, that mechanical division cannot be carried practically beyond certain limits, but since the most minute particle or atom which it is capable of presenting to us, shews no difference in composition from that of the entire mass, the inference is plain, that could we proceed to the ultimate term of material divisibility, we should still have the same result; thus, chalk is a compound of lime and carbonic acid; now, however minute a portion of chalk we take, we shall find it to contain both of these ingredients. It is evident that this could not occur unless the atoms of the combining bodies united with each other; and, as all

*Then Mr. Dalton's theory is in some measure founded on the law of simple multiples, noticed in the last chapter?*

Yes. We say an atom of A may combine with 1, 2, 3, or more atoms of B, an arrangement on which depends the law of multiples. If water, for example, is composed of an atom of hydrogen and an atom of oxygen, it follows that every compound of hydrogen with an additional quantity of oxygen must contain 2, 3, or more atoms of oxygen, that is, some multiple by a whole number of the quantity of oxygen contained in water.

*Then how would you define the term, atomic weight of a body?*

The atomic weights of bodies are the proportions in which bodies combine, reduced to their lowest terms.\*

*And how are the atomic weights of bodies ascertained?*

The commencement was made by carefully analyzing a definite compound of two simple substances which possess an extensive range of affinity. For example, no two bodies are better adapted for this purpose than oxygen and hydrogen, and that compound is selected which contains the smallest quantity of oxygen. Water

chemical compounds contain the same constant proportion of their constituents, it is equally evident that an union must take place of a certain determinate number of the atoms of one constituent with a certain number of the atoms of the other."

\* In other words, the proportional or atomic numbers merely express the relative quantities of different substances which combine together.

The different terms, *atomic weight*, *proportion*, *combining proportion*, *equivalent*, have the same signification.



is such a substance, and it is, therefore, regarded as a compound of one proportion of oxygen to one proportion of hydrogen. But *analysis* proves that it is composed of 8 parts of the former to 1 of the latter, by which the relative weights of their proportions are determined, that of oxygen being eight times heavier than that of hydrogen.

Some compounds are next examined, which contain the smallest proportion of oxygen or hydrogen in combination with some other substance, the quantities of each being the smallest that can unite together. Carbonic oxide with respect to carbon, and sulphuretted hydrogen with respect to sulphur, answer this description perfectly. The former consists of 8 oxygen and 6 carbon; the latter of 1 hydrogen and 16 sulphur. The proportional number, or atomic weight, of carbon is consequently 6, and of sulphur 16, and so they are marked in the table. The proportion of all other bodies may be determined in the same manner.\*

\* In order that the student may fully comprehend this subject, he should study the articles written respecting it in *Mr. Dalton's New System of Chemical Philosophy*, *Sir Humphrey Davy's Elements*, *Dr. Ure's Dictionary*, article *Equivalents*, and *Thomson's System of Chemistry*, &c.

"As an illustration of the mode in which the weight of the atoms of bodies is determined, let us suppose that any two elementary substances, A and B, form a binary compound; and that they have been proved experimentally to unite in the proportion, by weight, of 5 of the former to 4 of the latter; then, since, according to the hypothesis, they unite particle to particle, those numbers will express the relative weights of their atoms. But besides combining atom to atom singly, 1 atom of A may combine with 2 of B, or with 3, 4, &c. Or 1 atom of B may unite with 2 of A, or with 3, 4, &c. When such a series of compounds exists, the relative proportion



*What is the use of this theory of Mr. Dalton?*

It is of very great use. Till this theory was proposed, we had no adequate explanation of the uniformity of the proportions of chemical compounds; or of the nature of the cause which renders combination, in other proportions, impossible. Indeed, it may be applied to the explanation of a variety of phenomena.

of their elements ought necessarily, on analysis, to be proved to be 5 of A to 4 of B; or 5 to  $(4 + 4 =) 8$ ; or 5 to  $(4 + 4 + 4 =) 12$ , &c.; or contrariwise, 4 of B to 5 of A; or 4 to  $(5 + 5 =) 10$ ; or 4 to  $(5 + 5 + 5 =) 15$ . Between these there ought to be no intermediate compounds."

"To verify these numbers, it may be proper to examine the combinations of A and B with some third substance, for example, with C. Let us suppose that A and C form a binary compound, in which analysis discovers 5 parts of A and 3 of C. Then, if C and B are, also, capable of forming a binary compound, the relative proportion of its elements ought to be 4 of B to 3 of C; for these numbers denote the relative weights of their atoms. Now this is precisely the method, by which Mr. Dalton has deduced the relative weights of oxygen, hydrogen, and nitrogen; the two first from the known composition of water, and the two last from the proportion of the elements of ammonia. Extending the comparison to a variety of other bodies, he has obtained a scale of the relative weights of their atoms."

"In several instances additional evidence is acquired of the accuracy of the weight assigned to an element, by our obtaining the same number from the investigation of several of the compounds. For example:—

1. In *water*, the hydrogen is to the oxygen, as 1 to 8.
2. In *olefiant gas*, the hydrogen is to the carbon, as 1 to 6.
3. In *carbonic oxide*, the oxygen is to the carbon, as 8 to 6.

Whether, therefore, we determine the weight of the atom of carbon, from the proportion in which it combines with hydrogen, or with oxygen, we arrive at the same number 6: an agreement which, as it occurs in various other instances, can scarcely be an accidental coincidence. In a similar manner, 8 is deducible, as representing the atom of oxygen, both from the combination of that base with hydrogen and with carbon; and 1 is inferred to be the relative weight of the atom of hydrogen from the two principal compounds into which it enters." See *Dr. Henry's Elements of Chemistry*, vol. i. p. 45.



*What is Dr. Wollaston's scale of chemical equivalents?*

It is a logometric scale capable of solving, with the utmost facility, a number of problems, interesting both to the scientific and practical chemist. Some consider it an instrument which has contributed more to facilitate the general study and practice of chemistry than any other invention of man, and a description of it will tend, in some measure, further to illustrate the uses of the atomic theory. In this scale, the list of substances which Dr. Wollaston has estimated, are arranged on one or other side of a scale of numbers, in the order of their relative weights, and at such distances from each other, according to their weights, that the series of numbers placed on a sliding scale can at pleasure be moved, so that any number expressing the weight of a compound, may be brought to correspond with the place of that compound in the adjacent column. The arrangement is then such, that the weight of any ingredient in its composition, of any reagent\* to be employed, or precipitate that might be obtained in its analysis, will be found opposite the point at

\* The application of certain bodies to different solutions will, by producing changes which are striking to the senses, detect the presence of very minute proportions of particular ingredients. Such bodies are termed *tests*, or *reagents*: thus, the infusion of galls is a reagent, which detects iron by a dark purple precipitate; the prussiate of potass exhibits a blue with the same metal, &c. Some reagents are extremely delicate in their operations, such, for instance, is the delicacy of nitrate of silver, used as a test for any muriatic salt, that if two glasses be filled with distilled water, and the finger is merely dipped into one of them, the silver test will actually indicate the impurity thus introduced, by occasioning a white precipitate.



which its respective name is placed.\* Dr Wollaston's paper on this subject is in the Philosophical Transactions, for 1814.

*Since Mr. Dalton has deduced, from the relative weights in which bodies unite, the relative weights of their ultimate particles, or atoms, has he not formed a series or table of such representative numbers?*

He has, and it is accordingly called a table of atomic weights, or chemical equivalents.†

*But before any table, expressive of the relative weights of the atoms of different bodies, can be constructed, it is evident that we must fix upon some one substance, whose atom shall be considered as the unit*

\* If the slider be drawn upwards, says Dr. Ure, *Dictionary of Chemistry*, p. 428, till 100 corresponds to muriate of soda (common salt), the scale will then show how much of each substance contained in the table is equivalent to 100 of common salt. It shows, for example, with regard to the different views of this salt, that it contains 46.6 dry muriatic acid, and 53.4 of soda, or 39.8 sodium, and 13.6 oxygen; or if viewed as chloride of sodium, that it contains 60.2 chlorine, and 39.8 sodium. With respect to reagents, or tests, it may be seen, that 283 nitrate of lead, containing 191 of litharge, employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead, and that there would then remain in solution nearly 146 nitrate of soda. It may at the same time be seen, that the acid in this quantity of salt would serve to make 232 corrosive sublimate, containing 185.5 red oxide of mercury; or make 91.5 muriate of ammonia, composed of 62 muriatic gas (or hydromuriatic acid), and 29.5 ammonia. The scale shows also, that for the purpose of obtaining the whole of the acid in distillation, the quantity of oil of vitriol required is nearly 84, and that the residuum of this distillation would be 122 dry sulphate of soda, from which might be obtained, by crystallization, 277 of Glauber's salt, containing 155 water of crystallization. These, and many more such answers, appear at once, by bare inspection, as soon as the weight of any substance intended for examination is made, by motion of the slider, correctly to correspond with its place in the adjacent column. Now, surely, the accurate and immediate solution of so many important practical problems, is an incalculable benefit conferred on the chemist.

This instrument may be bought, at a trifling expense, of Mr. Cary, Optician, London.

† The table is given at page 36.



*of comparison. Have philosophers agreed to adopt the same general standard?*

It is much to be regretted that they have not, because it is perfectly immaterial whether, for instance, *oxygen* or *hydrogen* be taken as the unit or radix. Mr. Dalton selected *hydrogen* as the radix, because it is the lightest of all known bodies, and unites with others in the smallest proportion. According to his scale, therefore, hydrogen is one and oxygen eight. Dr. Thomson, on the other hand, has taken *oxygen* as the radix, from its almost universal relations to chemical matter. With him, consequently, oxygen is 1, and hydrogen .125.\*

*And is this theory considered to be fully established in all its details?*

No. In a variety of cases, we stand in need of analyses sufficiently exact to enable us to assign, with perfect confidence, the relative weights in which bodies combine; and it is probable too, that many of these, now considered as well determined, will hereafter be essentially changed. The instances in which the theory

\* Hydrogen, according to Dr. Thomson's scale, is stated at .125, because the eighth part of 1 is so expressed in decimals. Sir Humphry Davy, Dr. Ure, and others, prefer Mr. Dalton's numbers, having assumed *hydrogen* as unity; while Wollaston and Berzelius have taken *oxygen*, the former making it 10, and the latter 100,—Dr. Thomson making it 1. It will, however, be perceived that these numbers are readily reduced to Mr. Dalton's. But the student need not in the beginning trouble himself at all about any other numbers than Dalton's and Thomson's, and that he may see them both at one glance, the table at page 36, contains them in separate columns. Dr. Thomson's numbers are converted into Mr. Dalton's by multiplying by 8, and those of the latter into the former by dividing by 8.



agrees with the results of analysis are, however, too numerous to allow them to be considered as accidental coincidences; and no phenomena have hitherto been shown to be irreconcilable with the hypothesis.\*

*Do not chemists say there are three oxides of lead, and that the oxygen in these oxides exists in the ratio of  $1 : 1\frac{1}{2} : 2$ : that is, that the first oxide † (the lowest degree of oxidation) consists of 1 atom of oxygen united with 1 atom of the metal; the second, or deutoxide, of 1 atom and a half of oxygen with 1 of metal, and the third, or peroxide, of 2 atoms of oxygen and 1 of base. How can this be explained consistently with the atomic theory, since half an atom cannot exist, and is a contradiction in terms?*

It is certainly a palpable contradiction, but the statement respecting the three oxides of lead does not appear to me hostile to the supposed atomic constitution of matter, because it is probable that our analyses of these oxides, and also of others, are imperfect. Several methods of accounting for this seeming anomaly, have, however, been devised. One method is, by re-

\* Its value and importance, if not contradicted by new facts, will be scarcely less felt as a guide to further investigations into the constitution of bodies, than as a test of the accuracy of our present knowledge; and the universality of its application to chemical phenomena will be scarcely inferior to that of the law of gravitation in explaining the facts of natural philosophy.—See Mr. Ewart on the Atomic Theory, in the 6th volume of Thompson's Annals, and Dr. Henry's Chemistry, vol. 1, p. 50.

† By turning to the chapter on Chemical Nomenclature, the student will see what is meant by protoxide, deutoxide, &c. In the commencement of a book of this kind, it is impossible to avoid introducing terms and remarks which suppose the reader in possession of information which the student can, in reality, rarely have.



garding the present deutoxide as a compound of the protoxide and peroxide combined with one another.\*

*Who first made use of the atomic hypothesis in chemical reasonings?*

A Mr. Higgins, of Dublin; who in a work † of his published in the year 1789, observes, that “in volatile vitriolic acid, a single ultimate particle of sulphur is intimately united only to a single particle of dephlogisticated air, being the quantity necessary to saturation;” and he reasoned in the same way concerning the constitution of water, and the compounds of nitrogen and oxygen.‡

\* Another method is by doubling both elements of the anomalous compounds, by which the exact ratio is preserved, and the idea of the fraction of an atom avoided. Thus, the protoxide and peroxide of iron are composed, the first of one proportion, or 28 metal, to 8 of oxygen, and the second of 28 metal to an atom and a half or 12 of oxygen; or what amounts to the same, of 56, or 2 atoms of iron, to 24, or 3 atoms of oxygen. Even the student will immediately perceive that this is merely avoiding the idea of the fraction by multiplying the representative numbers, without in any degree altering the real state of the case. In my opinion, it is far more consistent to suppose our analyses of the oxides of lead to be not sufficiently exact.

† *A Comparative View of the Phlogistic and Antiphlogistic Theories.*

‡ These remarks of Mr. Higgins appear to have been quite unknown to Mr. Dalton at the time he published his *New System of Chemical Philosophy*.

## A TABLE

OF THE

ATOMIC WEIGHTS, OR CHEMICAL EQUIVALENTS, OF BODIES,

ACCORDING TO THE SCALES OF

MR. DALTON AND DR. THOMSON.\*

	ATOMIC WEIGHT.			ATOMIC WEIGHT.	
	Oxygen Scale.	Hydr. Scale.		Oxygen Scale.	Hydr. Scale.
Hydrogen . . . .	0.125	1	Naphthaline . . .	1.25	10
Carbon . . . . .	0.75	6	Phosphorus . . .	1.5	12
Boron . . . . .	1	8	Magnesium . . . .	1.5	12
Silicon . . . . .	1	8	Phosphuretted hydrogen	1.625	13
Oxygen . . . . .	1	8	Azote . . . . .	1.75	14
Carburetted hydrogen .	1	8	Carbonic oxide . .	1.75	14
Water . . . . .	1.125	9	Olefiant gas . . .	1.75	14
Aluminum . . . .	1.25	10	Bihydroguret of phosphorus	1.75	14
Lithium . . . . .	1.25	10	Sulphur . . . . .	2	16
Fluoric acid . . . .	1.25	10	Silica . . . . .	2	16
Subphosphuretted hydrogen	1.25	10	Ammonia . . . . .	2.125	17

N.B. The atomic weights of those substances marked \* are doubtful.

\* The present Author prefers Mr. Dalton's numbers, on account of their being remembered more easily, and the calculations made with greater facility than is possible by Dr. Thomson's scale; but it is immaterial which the student adopts. To comprehend the nature and uses of this table, he has only to consider that the figures represent the relative weights of the atoms of the different substances marked, thus *hydrogen* being 1, and *oxygen* being 8, water, from being a compound of 1 atom of hydrogen and 1 of oxygen, will, consequently, be  $(1+8)$  9:—again, *carbon* being 6, and *oxygen* 8, carbonic oxide is  $(8+6)$  14, which shews that this is the lowest degree of oxidation of carbon, since we cannot have less than 1 atom of oxygen to 1 of base: so, the next degree of oxidation of carbon is 2 atoms of oxygen to 1 of carbon, forming carbonic acid, the representative number of which is accordingly  $(8+8+6)$  22. In this way, the numbers lead to a knowledge of the composition of substances: thus, for instance, *alcohol*, or spirit of wine, is marked 23, shewing it is composed of 3 atoms of hydrogen = 3, 2 atoms of carbon = 12, and 1 of oxygen = 8,— $3+12+8=23$ .

To reduce Dalton's scale to Thomson's, it is only necessary to divide by 8, thus 23, the atomic weight of alcohol, according to Dalton, divided by 8, produces 2.875, which is Dr. Thomson's number.



	ATOMIC WEIGHT.			ATOMIC WEIGHT.	
	Oxygen Scale.	Hydr. Scale.		Oxygen Scale.	Hydr. Scale.
Sulphuretted hydrogen	2.125	17	Formic acid . . .	4.625	37
Deutoxide of hydrogen	2.125	17	Sulphuric ether . .	4.625	37
Alumina . . . . .	2.25	18	Peroxide of nickel .	4.75	38
Lithia . . . . .	2.25	18	Peroxide of cobalt .	4.75	38
Glucinum . . . . .	2.25	18	Arsenic . . . . .	4.75	38
Phosphuret of carbon	2.25	18	Protoxide of iridium .	4.75*	38*
Magnesia . . . . .	2.5	20	Hyponitrous acid . .	4.75	38
Phosphorous acid . .	2.5	20	Bisulphuret of carbon	4.75	38
Calcium . . . . .	2.5	20	Arsenietted hydrogen .	4.875	39
Oil gas . . . . .	2.625	21	Potassium . . . . .	5	40
Carbonic acid . . . .	2.75	22	Deutoxide of manganese	5	40
Protoxide of azote . .	2.75	22	Peroxide of iron . . .	5	40
Alcohol . . . . .	2.875	23	Zirconium . . . . .	5	40
Boracic acid . . . . .	3	24	Sulphuret of sodium .	5	40
Sodium . . . . .	3	24	Sulphuric acid . . .	5	40
Hyposulphurous acid .	3	24	Oxide of copper . . .	5	40
Hydrate of silica . .	3.125	25	Oxide of tellurium . .	5	40
Sulphuret of lithium .	3.25	26	Protoxide of titanium .	5	40
Glucina . . . . .	3.25	26	Selenium . . . . .	5	40
Cyanogen . . . . .	3.25	26	Dihydrate of silica . .	5.125	41
Nickel . . . . .	3.25	26	Selenietted hydrogen .	5.125	41
Cobalt . . . . .	3.25	26	Yttria . . . . .	5.25	42
Fluosilicic acid . . .	3.25	26	Oxide of zinc . . . .	5.25	42
Hydrate of alumina . .	3.375	27	Sulphuret of nickel . .	5.25	42
Hydrocyanic acid . . .	3.375	27	Sulphuret of cobalt . .	5.25	42
Sulphuret of magnesium	3.5	28	Naphtha . . . . .	5.25	42
Iron . . . . .	3.5	28	Strontium . . . . .	5.5	44
Manganese . . . . .	3.5	28	Rhodium . . . . .	5.5	44
Chromium . . . . .	3.5	28	Tritoxide of manganese	5.5	44
Phosphoric acid . . .	3.5	28	Protoxide of chlorine .	5.5	44
Phosphuret of sulphur	3.5	28	Protosulphuret of iron	5.5	44
Lime . . . . .	3.5	28	Deutoxide of chromium	5.5	44
Iridium . . . . .	3.75	30	Sulphuret of chromium	5.5	44
Deutoxide of azote . .	3.75	30	Antimony . . . . .	5.5	44
Nephrin . . . . .	3.75	30	Nitrous acid . . . .	5.75	46
Sulphurous acid . . .	4	32	Lactic acid . . . . .	5.75	46
Copper . . . . .	4	32	Peroxide of iridium . .	5.75*	46*
Tellurium . . . . .	4	32	Chloride of lithium . .	5.75	46
Titanium . . . . .	4	32	Zirconia . . . . .	6	48
Suboxide of manganese	4	32	Molybdenum . . . . .	6	48
Tellaretted hydrogen	4.125	33	Potash . . . . .	6	48
Zinc . . . . .	4.25	34	Titanic acid . . . . .	6	48
Fluoboric acid . . . .	4.25	34	Sulphuret of titanium .	6	48
Protoxide of nickel . .	4.25	34	Sulphuret of copper . .	6	48
Protoxide of cobalt . .	4.25	34	Protochloride of phosphorus	6	48
Yttrium . . . . .	4.25	34	Chloride of magnesium	6	48
Chlorine . . . . .	4.5	36	Oxide of selenium . .	6	48
Sulphuret of calcium .	4.5	36	Protohyd. of sulphuric acid	6.125	49
Protoxide of iron . . .	4.5	36	Perhydrate of iron . .	6.125	49
Protoxide of manganese	4.5	36	Cerium . . . . .	6.25	50
Protoxide of chromium	4.5	36	Sulphuret of zinc . . .	6.25	50
Bihydrate of alumina .	4.5	36	Acetic acid . . . . .	6.25	50
Oxalic acid . . . . .	4.5	36	Succinic acid . . . . .	6.25	50
Muriatic acid . . . .	4.625	37	Chlorocarbonic acid .	6.25	50



	ATOMIC WEIGHT.			ATOMIC WEIGHT.	
	Oxygen Scale.	Hydr. Scale.		Oxygen Scale.	Hydr. Scale.
Strontian . . . .	6.5	52	Barium . . . .	8.75	70
Sesquisulphuret of iron . . . .	6.5	52	Tannin . . . .	8.75*	70*
Chromic acid . . . .	6.5	52	Bismuth . . . .	9	72
Protoxide of antimony . . . .	6.5	52	Molybdic acid . . . .	9	72
Protoxide of rhodium . . . .	6.5	52	Uric acid . . . .	9	72
Chloride of sulphur . . . .	6.5	52	Suboxide of copper . . . .	9	72
Nitric acid . . . .	6.75	54	Deutosulphuret of potass. . . .	9	72
Sulphuret of arsenic . . . .	6.75	54	Peroxide of sodium . . . .	9	72
Arsenious acid . . . .	6.75	54	Sulphuret of cadmium . . . .	9	72
Cadmium . . . .	7	56	Sulphuret of palladium . . . .	9	72
Palladium . . . .	7	56	Hyposulphuric acid . . . .	9	72
Protoxide of molybdenum . . . .	7	56	Oxalic acid crystals . . . .	9	72
Deutosulphuret of potassium . . . .	7	56	Oil of turpentine . . . .	9.125*	73*
Deutoxide of antimony . . . .	7	56	Peroxide of tin . . . .	9.25	74
Chloride of calcium . . . .	7	56	Protosulphuret of tin . . . .	9.25	74
Selenic acid . . . .	7	56	Tartaric acid crystals . . . .	9.375	75
Trishydrate of silica . . . .	7.125	57	Bichloride of calcium . . . .	9.5	76
Hydrate of zirconia . . . .	7.125	57	Citric acid crystals . . . .	9.5	76
Tin . . . .	7.25	58	Chloric acid . . . .	9.5	76
Protoxide of cerium . . . .	7.25	58	Chloride of potassium . . . .	9.5	76
Citric acid . . . .	7.25	58	Barytes . . . .	9.75	78
Acetic acid crystals . . . .	7.375	59	Seleniet of arsenic . . . .	9.75	78
Peroxide of rhodium . . . .	7.5	60	Oxide of bismuth . . . .	10	80
Peroxide of antimony . . . .	7.5	60	Bisulphuret of molybdenum . . . .	10	80
Manganic acid . . . .	7.5*	60	Bisulphuret of copper . . . .	10	80
Chloride of sodium . . . .	7.5	60	Chloride of antimony . . . .	10	80
Sulphuret of rhodium . . . .	7.5	60	Chloride of strontium . . . .	10	80
Persulphuret of iron . . . .	7.5	60	Sesquisulphuret of tin . . . .	10.25	82
Sulphuret of strontium . . . .	7.5	60	Perchloride of phosphorus . . . .	10.5	84
Tritoxide of chlorine . . . .	7.5	60	Sulphuret of barium . . . .	10.75	86
Antimonic acid . . . .	7.5	60	Peroxide of barium . . . .	10.75*	86*
Sulphuret of antimony . . . .	7.5	60	Sulphuret of bismuth . . . .	11	88
Kermes mineral . . . .	7.625	61	Tritosulphuret of potassium . . . .	11	88
Chloride of nickel . . . .	7.75	62	Chloride of strontium . . . .	11	88
Arsenic acid . . . .	7.75	62	Fuming sulphuric acid . . . .	11.125	89
Chloride of cobalt . . . .	7.75	62	Persulphuret of tin . . . .	11.25	90
Sesquisulphuret of arsenic . . . .	7.75	62	Gum . . . .	11.25	90
Peroxide of cerium . . . .	7.75	62	Uric acid crystals . . . .	11.25	90
Chlorocyanic acid . . . .	7.75	62	Perchloric acid . . . .	11.5	92
Gallic acid . . . .	7.75*	62*	Chloride of cadmium . . . .	11.5	92
Oxide of cadmium . . . .	8	64	Protochloride of tin . . . .	11.75	94
Oxide of palladium . . . .	8	64	Platinum . . . .	12	96
Peroxide of potassium . . . .	8	64	Perchloride of iron . . . .	12.5*	100
Chloride of iron . . . .	8	64	Bichloride of copper . . . .	12.5	100
Chloride of manganese . . . .	8	64	Persulphuret of bismuth . . . .	13	104
Bisulphuret of copper . . . .	8	64	Protoxide of platinum . . . .	13	104
Molybdous acid . . . .	8	64	Lead . . . .	13	104
Sesquisulphuret of selenium . . . .	8	64	Saccharic acid . . . .	13	104
Tartaric acid . . . .	8.25	66	Chloride of barium . . . .	13.25	106
Protoxide of tin . . . .	8.25	66	Chloride of bismuth . . . .	13.5	108
Quadroxide of chlorine . . . .	8.5	68	Silver . . . .	13.75	110
Chloride of copper . . . .	8.5	68	Protoxide of lead . . . .	14	112
Chloride of zinc . . . .	8.75	70	Sulphuret of platinum . . . .	14	112



	ATOMIC WEIGHT.			ATOMIC WEIGHT.	
	Oxygen Scale.	Hydr. Scale.		Oxygen Scale.	Hydr. Scale.
Peroxide of platinum	14	112	Bichloride of platinum	21	168
Bichloride of selenium	14	112	Iodide of strontium .	21	168
Dentoxide of lead	14.5	116	Suboxide of silver .	21.625	173
Oxide of silver .	14.75	118	Iodide of cadmium .	22.5	180
Peroxide of lead .	15	120	Iodide of barium .	24.25	194
Protosulphuret of lead	15	120	Iodide of bismuth .	24.5	196
Quintosulphuret of potass.	15	120	Chloriodic acid .	24.5	196
Benzoic acid .	15	120	Gold . . .	25	200
Octohydrate of zirconia	15	120	Mercury . . .	25	200
Iodine . . .	15.5	124	Protoxide of gold .	26	208
Bichloride of antimony	15.5	124	Uranium . . .	26	208
Hydriodic acid .	15.625	125	Protoxide of mercury	26	208
Decahydrate of chlorine	15.75	126	Protoxide of uranium	27	216
Sulphuret of silver .	15.75	126	Peroxide of mercury	27	216
Tungsten . . .	15.75	126	Protosulphuret of mercury	27	216
Bisulphuret of platinum	16	128	Peroxide of gold .	28	224
Perchloride of tin .	16.25	130	Peroxide of uranium	28	224
Chloride of platinum	16.5	132	Sulphuret of uranium	28	224
Tridecahydrate of silica	16.625	133	Disulphuret of lead	28	224
Persulphuret of lead	17	136	Iodide of lead .	28.5	228
Iodide of phosphorus	17	136	Persulphuret of mercury	29	232
Chloride of lead .	17.5	140	Iodide of silver .	29.25	234
Iodide of sulphur .	17.5	140	Chloride of mercury	29.5	236
Starch . . .	17.75	142	Chloride of gold .	29.5	236
Oxide of tungsten .	17.75	142	Tritosulphuret of gold	31	248
Columbium . . .	18	144	Periodide of phosphorus	32.5	260
Iodide of calcium .	18	144	Margaric acid .	33	264
Chloride of silver .	18.25	146	26 hydrate of chromium	33.75	270
Iodide of sodium .	18.5	148	Bichloride of mercury	34	272
Tungstic acid .	18.75	150	Bichloride of gold .	34	272
Columbic acid .	19	152	Oleic acid . . .	36	288
Iodide of iron .	19	152	Tritiodide of azote .	37.25*	298
Iodide of copper .	19.5	156	Morphia . . .	40.25	322
Iodide of zinc .	19.75	158	Protiodide of mercury	40.5	324
Quadrochloride of azote	19.75	158	Picrotoxia . . .	45	360
Bisulphuret of tungsten	19.75	158	Strychnia . . .	47.5*	380
Sulphuret of columbium	20	160	Brucia . . .	51.5	412
Iodic acid . . .	20.5	164	Periodide of mercury	56	448
Iodide of potassium	20.5	164			

The student is recommended to fix the atomic weights of the principal substances in his memory.

N.B. The atomic weights of the principal salts will be found under the chapter on *Salts*.

## CHAPTER IV.

## OF CALORIC.

*What is caloric?*

It is the matter of heat. In other words, it is the agent to which the phenomena of heat are ascribed.\*

*What is the nature of caloric?*

There are different opinions entertained among philosophers on this subject. Some regard it as a fluid, of inappreciable tenuity, whose particles are endowed with indefinite ideo-repulsive powers. Others doubt the separate identity of a calorific matter, and have adduced evidence to shew that the phenomena might be rather referred to a vibratory or intestine motion of the particles of common matter.† Of the real nature of caloric, we have, however, no satisfactory evidence.

\* The term *heat* usually signifies the sensation we experience on touching a hot body, while *caloric* expresses the cause of that sensation.

Caloric is imponderable; that is, it is so exceedingly light, that a body undergoes no appreciable change of weight, either by the addition or abstraction of caloric. It is present in all bodies, and cannot be wholly separated from them. For if we take any substance whatever, at any temperature, however low, and transfer it into an atmosphere, whose temperature is still lower, a thermometer will indicate that caloric is escaping from it. That its particles repel one another, is proved by observing that it flies off from a heated body.

† The opinion more generally adopted is, that caloric is a material substance. That illustrious philosopher Lord Bacon, originated the idea of its being a vibration of the particles of matter, and, in the present day, Sir Humphry Davy is the most distinguished advocate of this view of the subject.



*And can caloric be transferred from one body to another?*

Yes. For example, if a cup of water at 60 degrees be plunged into hot water, caloric passes rapidly from one into the other, until the temperature in both is the same.

*From this fact we would suppose it has a tendency to an equilibrium: is that the case?*

It is, all bodies on the earth are constantly tending to an equality, or, as it is technically called, an equilibrium of temperature.

*What proof can you give of this?*

If, for instance, a number of substances, different in temperature, be enclosed in an apartment, in which there is no actual source of caloric, they will very soon acquire an equilibrium, so that a thermometer will stand at the same point in all of them. The varying sensations of heat and cold, which we constantly experience, are owing to a similar cause. On touching a hot body, caloric passes from it into the hand, and excites the feeling of warmth; when we touch a cold body, caloric is communicated to it from the hand, and thus produces the sensation of cold.

*What are the sources of caloric?*

Its chief sources are, 1, the sun; 2, combustion; 3, electricity; 4, chemical action; 5, mechanical action, as friction, percussion, &c.\*

\* Combustion and electricity, as sources of caloric, we shall consider in the distinct chapters allotted to those subjects.



*What instances can you produce of chemical action being a source of caloric?*

Many examples might be readily given. In the mixture, or chemical union of two substances, caloric, is, in many cases, evolved. This always takes place when the density or specific gravity of the mixture is greater than the mean of the substances mixed, as in the mixture of alcohol and water, or of sulphuric acid and water: and every one knows that much caloric is, also, evolved when water is thrown upon quicklime, which is owing to the solidification of the water when it unites with the lime.\*

*What examples can you give of mechanical action being a source of heat?*

A familiar instance we have in the mode which the smith often has recourse to in order to kindle his fire: he takes an iron-rod, which is smartly and quickly hammered until it become red hot. Here percussion proves a source of heat. That friction is a source equally productive of caloric is universally known. The axle-tree of carriages, when not sufficiently greased, sometimes take fire from the constant friction to which they are exposed; and the sides of ships have been known to take fire by the rapid descent of the cable.†

\* The caloric which is evolved in these and other instances of chemical combination, is called *latent* caloric, and is the cause of the fluidity of the components; for, as the compound is less fluid, and consequently requires the presence of a smaller quantity of combined caloric, the superabundance which the more fluid components contained must be necessarily set free. This point the student will understand better after he has read the observations on latent heat, further on.

† It is said by some, that percussion gives rise to an evolution of heat,



*In establishing an equilibrium of temperature, how is caloric distributed?*

In two ways; that is, either by direct communication, through the means of intermediate bodies, or by radiation. If, for example, a cold bar of iron be thrust into a glowing fire, the excess of caloric in the hot body passes rapidly to the particles on the surface of the other; from them it is transferred to those situated more internally, and so forth, till the bar arrives at the same temperature as the fire. In this case, the caloric is said to be communicated or conducted from one body to another. To illustrate the distribution by radiation, it might be observed, that if a glass globe, full of hot water, be suspended in the vacuum of an air-pump, the excess of its caloric will still pass away, and in a very short time it will have acquired the temperature of the surrounding objects: now, here the heated substance is placed under such circumstances as preclude the possibility of its caloric being communicated or conducted from one body to another, yet the caloric does pass off, and it is, therefore, said to be projected or radiated.\*

from its causing condensation, or forcing the integrant particles of the bodies closer together, so as to dislodge the latent caloric they contain, and give it out in the form of sensible caloric. But by continued friction in a moderate degree, as would appear by Count Rumford's experiments, a piece of metal may be kept hot for any length of time, so that if the heat be pressed out, the quantity must be inexhaustible. This fact led Rumford to infer, that caloric could not be a material substance.

\* It should, however, be observed, that in order that the passage of caloric should take place in this manner, that is, by radiation, it is not necessary for the heated body to be *in vacuo*; it radiates with equal facility through the air, as through a vacuum.



*And do all bodies conduct caloric with equal rapidity?*

No; there is a great difference in this respect. Some substances oppose very little impediment to its passage, while it is transmitted slowly by others. If we coat two rods, of equal length and thickness, the one of glass, the other of iron, with wax, at one end of each only, and then apply heat to the uncoated ends, the wax will be melted much sooner from the end of the iron rod, than from the glass one; which shews, that iron conducts heat more quickly than glass.

*Is the conducting power of solid bodies related to any of the other properties of matter, as its hardness, density, &c.?*

It does not appear to have any intimate relation to any such properties, but it approaches nearer to the ratio of their densities than to that of any other property; so that the metals conduct caloric best.\*

*But do not the different metals possess very different powers of conducting caloric?*

Yes; silver is the best conductor, then gold, copper, tin, platinum, iron, steel, and lead. Dense stones follow metals in conducting power,

\* Count Rumford found a considerable difference in the conducting power even of the same material, according to the state in which it was employed. From his observations, we may conclude, that in the same substance the conducting power increases with the compactness of structure.



then bricks, pottery, and, at a long interval, glass.\*

*Why is it that glass, pottery, and stone ware so readily crack on the sudden application of heat?*

Because of their inferior conducting powers. The part acted on by the caloric expands, while the adjacent parts, retaining their pristine form and volume, do not accommodate themselves to the change; whence a fissure necessarily ensues.

*Is it not chiefly owing to the different conducting powers of bodies that they affect us, when we touch them, with different sensations of cold?*

It is: thus, if we apply the hand in succession to a number of bodies, (as wood, marble, &c.), they appear cold in very different degrees; and as this sensation is occasioned by the passage of caloric out of the hand into the body which it touches, that body will feel the coldest which carries away the heat most quickly; or which, in other words, is the best conductor.†

*Would it not appear then that the theory of clothing depends on the principle of low conducting power?*

\* Glass may be held in the fingers for a long time, at the distance of an inch from where it is ignited and fused by the blow pipe. Charcoal and saw-dust rank very low in conducting power. Hence the former is admirably fitted for arresting the dispersion of heat in metal furnaces. If the sides of them be formed of double plates, with an interval between them of an inch filled with pounded charcoal, an intense heat may exist within, while the outside is scarcely affected.

† For the same reason, of two bodies which are heated to the same degree, and both considerably above the temperature of the hand, the best conductor is the hottest to the touch. Thus, the money in our pockets often feels hotter than the clothes which contain it.



Certainly. Spongy organic substances, as silk, wool, cotton, &c., are still worse conductors than any of the substances above mentioned,\* and the heat generated by the animal powers, is, therefore, accumulated round the body, that is, prevented from flying off by the imperfect conductors of which clothing is composed.

*Solid bodies convey heat in all directions, upwards, downwards, and laterally:† do liquids convey it in the same manner?*

No; they communicate heat by an actual change in the situation of their particles. That portion of the fluid which is nearest to the source of heat is expanded, and becoming specifically lighter, ascends, and is replaced by a colder portion from above. This, in its turn, becomes heated

\* The finer the fibres the less conducting power they possess. Count Rumford devised an ingenious plan for ascertaining the relative conducting powers of the different materials employed for clothing. He enveloped a thermometer in a glass cylinder blown into a ball at its extremity, and filled the interstices with the substance to be examined. Having heated the apparatus to the same temperature in every instance, by immersing it in boiling water, he transferred it into melting ice, and observed carefully the number of seconds which elapsed during the passage of the thermometer through 135 degrees. When there was only air between the thermometer and cylinder, the cooling took place in 576"; when the interstice was filled with fine lint, it took place in 1032"; with cotton wool in 1046"; with sheep's wool in 1118"; with raw silk in 1284"; with beaver's fur in 1296"; with eider down in 1305"; and with hare's fur in 1315". Experiment seems, therefore, fully to justify the general practice of mankind, in having recourse to silk and woollen stuffs in the winter, in order to retain the animal heat as much as possible, and in using cotton and linen articles in the summer, with an opposite intention.

† This is shown by heating the middle of an iron rod, and holding it in different directions.



and dilated, and gives way to a second colder portion; and thus the process goes on, as long as the fluid is capable of imbibing heat.\*

*Can you illustrate this fact by an experiment?*

If a portion of water be frozen in the bottom of a tube one inch wide, and about two inches in depth, and the tube be then filled with water of the common temperature, and held inclined over an Argand's lamp, so that the upper portion only of the tube may be heated, the water may be made to boil violently at the surface, while the ice will remain unmelted. But if the experiment be reversed, and (the ice floating on the surface) heat be applied to the bottom of the tube, the ice will be liquefied in a few seconds.†

\* It follows that if heat be applied to the bottom of a vessel containing any liquid, a double set of currents must be immediately established, the one of hot particles rising towards the surface, and the other of colder particles descending to the bottom. And since the diffusion of heat through a fluid mass is thus accomplished almost solely by the intestine currents, whatever obstructs these must obstruct the change of temperature. Hence, fluids intermingled with porous matter, such as silk, wool, cotton, down, fur, hair, &c., are more slowly cooled than in their pure and limped state.

† This may be further illustrated by the following experiment; Take a glasstube, 8 or 10 inches long, and about an inch in diameter. Pour into the bottom part, for about the depth of an inch, a little water tinged with litmus, (a rich purple colour,) and then fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. If the upper part of the tube be first heated, the coloured liquor will remain at the bottom; but if the tube be afterwards heated at the bottom, the infusion will ascend, and will tinge the whole mass of fluid.

From some facts similar to the above, Count Rumford concluded that water is a perfect non-conductor of caloric, but this is not correct. The opinion now generally entertained is, that it is a conductor of caloric, although an imperfect one.



*How do gases convey caloric?*

In a manner similar to liquids, but it is still more difficult to estimate the conducting power of gaseous bodies.\*

*You have now spoken of the distribution of caloric by direct communication. There is still another mode by which changes of temperature amongst bodies are propagated, and which you have said is called RADIATION: How is heat radiated?*

In parallel lines, with extreme velocity.

*How is it proved to move with extreme velocity?*

By experiment. For instance, no perceptible interval takes place between the time at which caloric quits a heated body, and its reception by a thermometer at the distance of 69 feet. M. Pictet, of Geneva, has shown this; and it appears also, from the experiments of the same philosopher, that radiant caloric moves with equal ease in all directions, and is not at all impeded by a strong current of air meeting it transversely. Hence it follows, that the propagation of caloric, in this state of rapid movement,

\* With respect to gaseous bodies, it is well known that bodies cool much more slowly in them than in liquids. But as the cooling of hot bodies in gases is produced by a variety of causes besides the conducting power of these fluids, it is difficult to form an estimate of their relative intensities as conductors from the time that elapses during the cooling of bodies in them. Count Rumford found that a thermometer cooled nearly four times as fast in water as in air of the same temperature; but no fair inference can be drawn from that experiment, as it is known that the rate of cooling varies with the temperature much more in water than in air.

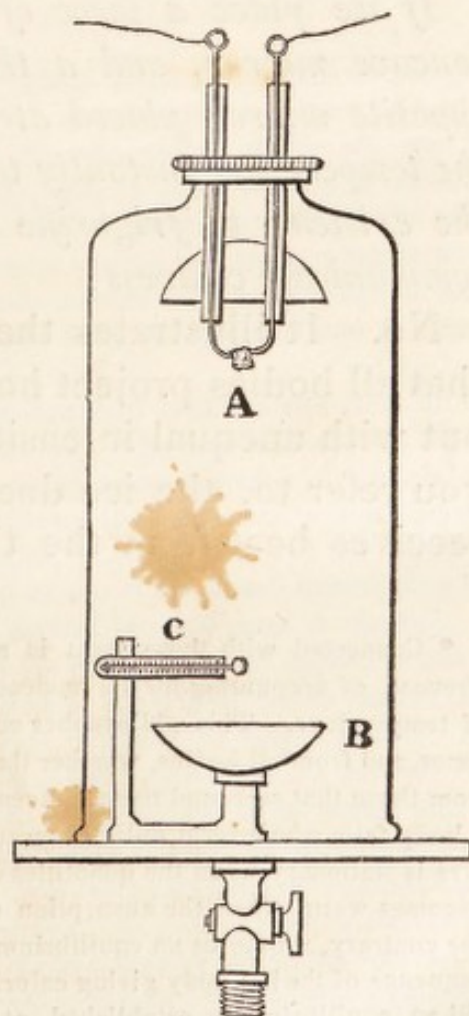


does not depend on any agency of the medium through which it passes.\*

*Supposing a heated body is suspended in the air, is it known how much caloric passes off by radiation, and how much by the conducting power of the air?*

It is generally supposed, that about one half of the caloric lost by a heated body escapes by radiation, and that the rest is carried off by the ambient atmosphere.

\* This was satisfactorily proved likewise by Sir H. Davy, who contrived, by means of an apparatus, (represented in the annexed sketch), to effect the radiation of heat in a vacuum. Between the points of two wires, inclosed in glass tubes which passed through a brass plate, was placed a piece of charcoal, which was intensely ignited by voltaic electricity, and the effect of radiation in the focus of the lower concave mirror was ascertained by a delicate thermometer, first when the receiver was full of air, and next when it was exhausted to  $\frac{1}{120}$ . In the latter case, the effect of radiation was found to be three times greater than in an atmosphere of common density. This greater rise of the thermometer *in vacuo* than in air is to be ascribed to the conducting power of the latter; for this, by reducing the temperature of the heated body, has a constant tendency to diminish the activity of radiation, which is proportional to the excess of temperature of the heated body above that of the surrounding medium.



A. a piece of charcoal, B. lower concave mirror, C. thermometer.



*And is caloric radiated from bodies at all temperatures?*

Yes; but the quantity radiated bears some proportion to the excess of the temperature of the hot body above that of the surrounding medium. Hence, if we have any number of bodies at different temperatures in the vicinity of each other, they may all be considered both as radiating and receiving caloric; but the hot ones will radiate more than they receive, while the cold ones will receive more than they radiate.\*

*If we place a piece of ice in the focus of one concave mirror, and a thermometer in that of an opposite mirror placed at some distance, we perceive the temperature instantly to fall; Does not this prove the existence of frigorific rays, whose property is to communicate coldness?*

No. It illustrates the observation just made, that all bodies project heat at every temperature, but with unequal intensities. In the experiment you refer to, the ice does not give out cold, but receives heat from the thermometer, and as this

\* Connected with these facts is an ingenious mode, proposed by M. Prevost, of accounting for the tendency of bodies to acquire an equilibrium of temperature. This philosopher contends, that radiation goes on at all times, and from all bodies, whether their temperature is the same or different from those that surround them. According to this view, the temperature of a body falls whenever it radiates more caloric than it absorbs; its temperature is stationary when the quantities emitted and received are equal; and it becomes warm when the absorption exceeds the radiation. M. Pictet, on the contrary, supposes an equilibrium of temperature to take place in consequence of the hot body giving calorific rays to the surrounding colder ones till an equilibrium is established, at which moment the radiation ceases. Neither of these theories has been proved to be true, but that of M. Prevost is generally considered to be the more probable.



instrument gives more rays of caloric to the ice than it receives in return, it must necessarily become colder, which is indicated by its temperature instantly falling.\*

*Has the nature of the SURFACE of bodies any influence over their power of RADIATING caloric?*

It has an important influence, which was first accurately examined by Mr. Leslie. To measure the amount of this influence with precision, he contrived a peculiar instrument, called a *differential thermometer*,† and made many experiments.

\* So far from ice giving out cold, (which is but the absence of heat,) a lump of it at  $32^{\circ}$ , (the freezing point,) would become a focus of heat if transported into a chamber where the temperature of the air was at zero, ( $32^{\circ}$  below the freezing point), and, in this situation, a mass of melting ice placed before the mirror would affect the bulb of the thermometer, just as a cube of heated water does in the ordinary temperature of our atmosphere. Again, a frigorific mixture of snow and salt at zero, would, in like manner, become a warm body when carried into an atmosphere at  $40^{\circ}$  below zero.

† It consists of a glass tube, (see figure 2,) bent into the form of the letter U, terminated at each end by a bulb. The bore is about the size of that of large thermometers, and the bulbs have a diameter of  $\frac{1}{8}$  of an inch and upwards. Before hermetically closing the instrument, a small portion of sulphuric acid, tinged with carmine, is introduced, and the liquid so adjusted as to make it stand at the top of one of the stems, immediately below the bulb. To this stem a scale divided into 100 parts is attached. If the finger, or any body warmer than the ambient air, be applied to one of these bulbs, the air within will be heated, and will of course expand, and issuing in part from the bulb, depress before it the tinged liquor. The amount of this depression observed upon the scale will denote the *difference* of temperature of the two balls. But if the instrument be merely carried without touching either ball, from a warmer to a cooler, or from a cooler to a warmer air, it will not be affected; because the equality of contraction or expansion in the enclosed air of both bulbs, will maintain the equilibrium of the liquid in the stem. Being thus independent of the fluctuations of the surrounding medium, it is well adapted to measure the calorific emanations of different surfaces, successively converged, by a concave reflector, upon one of its bulbs.—See fig. 2, in plate at page 1.



He employed a hollow tin vessel, six inches cube, filled with hot water, as the radiating substance. The rays proceeding from it were brought, by means of a concave mirror,\* into a focus, (see figure 1), in which the bulb of the differential thermometer was placed; and he found that certain substances radiated heat much more rapidly than others, the nature of the surface having a singular influence upon its radiation. Thus, by adapting thin plates of different metals to the sides of the tin cube, and turning them successively towards the mirror, he found a very variable effect produced upon the thermometer. A bright, smooth, polished, metallic surface radiated caloric very imperfectly; but if the surface was in the least degree dull or rough, the radiating power was immediately augmented. By covering the tin surface with a thin layer of isinglass, paper, wax, or resin, its power of radiation increased surprisingly. Metallic substances were observed to be the worst possible radiators, particularly such as are susceptible of a high polish, as gold, silver, tin, and brass; but it is easy to make them radiate well by giving them the opposite properties, either by scratching their surface, or covering it with lamp black, writing paper, &c.

*Are not these varieties in the radiating power of different surfaces attended with corresponding variations in the RATE OF COOLING?*

\* Mr. Leslie's reflecting mirrors consisted of planished tin-plate, hammered into a parabolical form.



Yes. Water, for instance, enclosed in a clean and polished tin ball, cools about twice more slowly than water in the same ball covered with oiled paper. Blacking the surface with paint, or even a thin coat of varnish, on the same principle, accelerates greatly the rate of cooling.

*Can you draw any practical lessons from these results?*

They evidently teach us that since bright metals project heat most feebly, vessels which are intended to retain their heat, as tea and coffee-pots, should be made of bright and polished metals.\*

*Is not the deposition of dew and hoar-frost dependent on the radiation of caloric from the surface of the earth?†*

It is. The projection or radiation of heat from the terrestrial surface, into free space, makes it colder than the atmosphere, and a deposition of moisture is the consequence; so that the cold which was formerly considered as the *effect* of dew, is in reality its *cause*. Dr. Wells has proved, by numerous experiments, *that bodies become colder than the neighbouring air BEFORE they are dewed.‡*

\* For the same reason, steam pipes intended to convey heat to a distant apartment should be likewise bright in their course, but darkened when they reach their destination.

† The process of radiation appears to be constantly going on from the surface of the earth, and it is partly on this principle that we are to explain why the heat, which our planet is incessantly receiving from the sun, does not accumulate to such a degree as to render it a less fit habitation for man.

‡ The temperature always falls in clear nights, but the deposition of dew depending on the moisture of the air, may occur or not. Now, if cold were the *effect* of dew, the cold connected with dew ought to be always propor-



*Dew appears only on calm and clear nights. When clouds form in the sky on a clear night it is found that the deposition of dew is lessened, or wholly prevented: Can you explain the reason of this?*

It is concluded that clouds produce this effect almost entirely by radiating heat to the earth, in return for that which they intercept in its progress from the earth towards the heavens.\* For it is found, that whatever diminishes the view of of the sky, as seen from the exposed body, obstructs the depression of its temperature, and occasions the quantity of dew formed upon it to be less than what would have occurred, if the exposure to the sky had been complete.

*When the radiant calorific rays projected from a hot body fall upon the surface of a solid or liquid substance near it, what happens?*

They are either reflected from it, and thus receive a new direction, or they are absorbed.

*How do you prove the absorption of radiant caloric?*

tionate to the quantity of that fluid ; but this is contradicted by experience. The student will find *Dr. Wells's Essay*, and also *Dr. Ure's Dictionary*, article *Dew*, very instructive on this subject.

\* Dr. Henry observes, " A covering of clouds serves as a mantle to the earth, and prevents the free escape of radiant heat."—*Elements of Chemistry*, vol. i, p. 83.

Dr. Ure remarks, (*Dictionary of Chemistry*, p. 389), " Insulated bodies, or prominent points, are sooner covered with hoar-frost and dew than others ; because the equilibrium of their temperature is more difficult to be restored. As ærial stillness is necessary to the cooling effect of radiation, we can understand why the hurtful effects of cold, heavy fogs, and dews, occur chiefly in hollow and confined places, and less frequently on hills. In like manner, the leaves of trees often remain dry throughout the night, while the blades of grass are covered with dew."



Many experiments might be related in proof of it, but the following may suffice. Expose the bulb of a sensible thermometer to the direct rays of the sun. On a hot summer's day it will probably rise, in this climate, to 108 degrees. Cover it with indian ink, and again expose it in a similar manner. During the evaporation of the moisture in the ink it will fall; but as soon as the coating becomes dry, it will ascend to 118° or upwards, of Fahrenheit, or 10° higher than when uncovered with the pigment. This cannot be explained, by supposing that the black coating is gifted with the power of retaining caloric, and preventing its escape; because it appears from experiment, that a similar coating accelerates the cooling of a body to which it is applied. The rise of the thermometer is then owing to the greater absorbing power of the black surface than of the white one.\*

*Has colour any great influence over the absorption of caloric?*

It has considerable influence over it, which is shewn by the following experiment of Sir Humphry Davy. Take six pieces of sheet copper, each about an inch square, and colour the one white, another yellow, a third red, the fourth green, the fifth blue, and the sixth black: on the centre of one side of each piece, put a small

\* The effect we are sensible of in approaching a fire, chiefly results from radiation, and is little connected with the immediate conducting power of the air. Therefore, the absorption of radiant caloric may be proved by placing a thermometer before the fire, when the mercury will be seen to rise in the stem.



portion of a mixture of oil and wax, or cerate, which melts at about  $76^{\circ}$ . Then expose their coloured surfaces, under precisely equal circumstances, to the direct rays of the sun. The cerate on the black plate will begin to melt perceptibly before the red; the blue next; then the green and the red; and, lastly, the yellow. The white will scarcely be affected, when the black is in complete fusion.

*What practical lesson, with regard to clothing, does this law of the absorption of caloric teach us?*

Since black colours absorb most caloric, and light ones least, we are thereby taught the propriety of wearing dark coloured clothes during the winter season, and light coloured ones in summer.

*What relation has the power of different surfaces to absorb heat, to their radiating power?*

A direct relation; that is, those surfaces which absorb most caloric, also radiate most.

*And how do you prove the reflection of radiant caloric?*

The following experiment of M. Pictet proves not only the reflection of caloric, but also that it is reflected according to the same law that regulates the reflection of light. Procure two reflectors of planished tin, (*a* and *b*, fig. 1), which may be 12 inches diameter, and segments of a sphere of nine inches radius. Each of these must be furnished, on its convex side, with the means of supporting it in a perpendicular position on a proper stand. Place the mirrors oppo-



site to each other on a table, at the distance of from 6 to 12 feet. In the focus of one, let one of the balls of a differential thermometer, be situated; and in that of the other, suspend a ball of iron *d*, about four ounces in weight, and heated below ignition; having previously interposed a screen before the thermometer. Immediately on withdrawing the screen, the depression of the column of liquid in the thermometer, evinces an increase of temperature in the instrument. In this experiment, the caloric flows first from the heated ball to the nearest reflector; from this, it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument. This is precisely the course that is followed by radiant light; for if the flame of a taper be substituted for the iron ball, the image of the candle will appear precisely on that spot, (a sheet of paper being presented for its reception,) where the rays of caloric were before concentrated.\*

*Different substances reflect caloric with different degrees of force; but what relation has the power they possess of reflecting heat to their absorbing and radiating power?*

The faculty of reflection is *inversely* as that of absorption and radiation; that is, those surfaces

\* The reflecting power may be shown in a familiar manner, by standing at the side of a fire in such a position that its heat cannot reach the face directly, and then placing a large plate of tinned iron opposite the grate, and at such an inclination as permits the observer to see in it the reflection of the fire: as soon as it is brought to this inclination, a distinct impression of heat will be felt upon the face.



which absorb and radiate least, reflect most powerfully. Thus, as we have already seen, bright metals absorb and radiate least heat, but they reflect most.

*What are the usual effects of caloric on bodies?*

They are expansion, liquefaction, vaporisation, incandescence, and combustion.\*

*Does caloric expand all bodies?*

Yes; expansion is an almost universal effect of an increase of temperature. Its amount, however, is not the same in all bodies, but differs very essentially: by the same increase of temperature, liquids† expand more than solids, and gaseous bodies more than either.

*Is the same quantity of expansion effected in the SAME solid or fluid, at all temperatures, by adding similar quantities of heat?*

No. Generally speaking, bodies expand under an augmented heat, more in high than in low temperatures.‡

*What exception is there to this law?*

In the case of gases; for all gaseous or æriform bodies undergo the same expansion from equal increments of heat.

\* Combustion is so interesting a phenomenon that it will be considered in a distinct chapter.

† Neither do all liquids expand to the same degree, from an equal increase of temperature: alcohol expands much more than water, and water than mercury.

‡ Thus, if a fluid is heated from  $32^{\circ}$  to  $122^{\circ}$ , it will not expand so much as it would do in being heated from  $122^{\circ}$  to  $212^{\circ}$ , though an equal number of degrees is added in both cases. The explanation of this fact is, that the force opposing expansion, (viz. cohesion), is diminished by the interposition of caloric between the particles of bodies: and, therefore, when equal quantities of caloric are added in succession, the last portions meet with less resistance to their expansive force than the first.



*How do you clearly prove that caloric causes an expansion in solids, for example, in a rod of iron?*

It may be shown thus: take a rod of iron, of such a length as to be included, when cold, between two points, and the diameter of which is such, as barely to allow it to pass through an iron ring. When heated, it will have become sensibly longer; and it will be found incapable of passing through the ring.\* Indeed, the method in daily use among coach-makers for applying iron rings to the wheels of carriages, affords a familiar and convincing proof of this expansion; for it is by heat, that they enlarge their strong iron rims, so as to make them embrace

\* The following circumstance shows that the force with which solids expand or contract by heat and cold, is so prodigiously great as to overcome the strongest obstacles. Some years ago it was observed, at the *Conservatoire des Arts et Metiers* at Paris, that the two side walls of a gallery were receding from each other, being pressed outwards by the weight of the roof and floors. Several holes were made in each of the walls, opposite to one another, and at equal distances, through which strong iron bars, were introduced so as to traverse the chamber. Their ends outside of the wall were furnished with thick iron discs, firmly screwed on. These were sufficient to retain the walls in their actual position: but to bring them nearer together would have surpassed every effort of human strength. All the alternate bars of the series were now heated at once by lamps, in consequence of which they were elongated. The exterior discs being thus freed from contact of the walls, permitted them to be advanced farther, on the screwed ends of the bars. On removing the lamps, the bars cooled, contracted, and drew in the opposite walls. The other bars became, in consequence, loose at their extremities, and permitted their end plates to be farther screwed on. The first series of bars being again heated, the above process was repeated in each of its steps. By a succession of these experiments, they restored the walls to the perpendicular position; and could easily have reversed their curvature inwards, if they had chosen. The gallery still exists with its bars, to attest the ingenuity of its preserver, M. Molard. See *Dr. Ure's Dictionary of Chemistry*, article *Caloric*.



and firmly bind, by their retraction when cooled, the wooden frame work of their wheels.

*What is the most expansible metal?*

Zinc appears to be one of the most expansible of metals, then follows lead, tin, copper, bismuth, iron, steel, antimony, palladium, and platinum.

*Is not the circumstance of the expansion of metals likely to affect many mechanical instruments, especially the going of clocks and watches?*

Yes. The pendulum of a clock vibrating seconds will, by a change of temperature equal to 30 degrees of Fahrenheit's thermometer, alter its length about  $\frac{1}{5000}$  part, which is sufficient to change its rate of going eight seconds of time every day. The balance wheel of a watch likewise varies, in the time of its oscillations, by its expansions and contractions with variations of temperature.\*

*And how do you make the expansion of liquids and gases by heat apparent?*

\* To obviate these inconveniences, various contrivances have been resorted to. One of such contrivances is Arnold's comparative balance, which has incalculably improved the accuracy of marine chronometers. This invention consists of a wheel or interrupted ring, composed of concentric laminae of two metals, which obviate the above defects by their difference of dilatation.

Dr. Ure observes, (*Dictionary of Chemistry*, p. 269,) "The first, the most simple, and most perfect invention for obviating these variations in clocks is due to Graham. The bob of his compensation pendulum consisted of a glass cylinder, about six inches long, holding ten or twelve pounds of mercury. In proportion as the iron or steel rod to which this was suspended, dilated by heat, the mercury also expanded, and raised thereby the centre of oscillation, just as much as the lengthening of the rod had depressed it."



If we put a common thermometer, made with mercury or alcohol, into warm water, the dilatation of the liquid will be shown by its ascent in the stem. The expansion of gases is shown, by holding, near the fire, a bladder half-filled with air, the neck of which is closely tied, so as to prevent the enclosed air from escaping. The bladder will soon be fully distended, and may even be burst by continuing and increasing the heat.

*Are there no exceptions to the general law of the expansion of bodies by heat and their contraction by cold?*

There are a few exceptions to that law. For example, water by freezing is considerably increased in bulk; \* salts in the act of crystallizing, expand; and a few metals, as cast iron, bismuth and antimony, have their dimensions enlarged, at the instant of solidification.

*What is the cause of the expansion of water at the moment of freezing?*

It is attributed to a new and peculiar arrangement of its particles. Ice is in reality crystallized water, and during its formation, the particles arrange themselves in ranks and lines, which cross each other at angles of  $60^\circ$  and  $120^\circ$ , and, consequently, occupy more space than when they were in a liquid state.

\* It is well known that ice swims upon the surface of the water, and, therefore, it must be lighter than water, which is a convincing proof that it must expand, at the moment of freezing. The increase is estimated at about  $\frac{1}{10}$  of its volume.



*Is not the anomaly presented by water in its dilations by change of temperature, connected with the production of a natural phenomenon, attended with the most beneficial consequences to mankind?*

It is. The circumstance you refer to, is the formation of ice *only* on the surface of our rivers and lakes under the influence of a severe frost; for if this anomaly did not exist, the whole of the water of rivers and lakes would be gradually cooled down to the freezing point, at which point it would freeze throughout almost simultaneously, and each river and lake would become a single mass of ice.

*Can you explain the reason of this more clearly?*

It should be observed, that fresh water possesses a maximum density (its greatest gravity or weight) about  $40^{\circ}$  of Fahr.:\* when its temperature deviates from this point, *either upwards or downwards*, its density diminishes, or its volume enlarges. Hence, in winter an intensely cold air progressively abstracts the heat from the water

\*  $39^{\circ}.5$  is perhaps more correct, but to avoid fractions it is usually said to be  $40^{\circ}$ . In studying this subject, the student should recollect that the freezing point of fresh water is  $32^{\circ}$  Fahr. so that water in having its temperature cooled from  $40^{\circ}$  down to  $32^{\circ}$  expands through that  $8^{\circ}$ , and becomes specifically lighter. Since the surface of the water is, therefore, specifically lighter than the deeper seated parts, it must remain at the surface, and be alone frozen in intensely cold weather, thus affording a complete security for the water beneath.

Ice is a bad conductor of heat, and if it be broke in winter the water beneath it will be found at the temperature of  $40^{\circ}$ . This temperature is congenial to fish, and thus they live through the severest winters. In large quantities of water the ice breaks or rifts, and by this means fishes are supplied with air; but in small fish ponds it is necessary to break the ice, that they may receive the requisite supply.



of rivers and lakes, till the temperature of the whole aqueous mass sinks to  $40^{\circ}$ . At this term the refrigerating influence of the atmosphere incumbent on the water becomes nearly null. For, as the superficial stratum, by farther cooling, becomes specifically lighter, it remains on the surface, and soon becomes a cake of ice, which being an imperfect conductor of heat, screens the subjacent liquid water, from the cold air. Had water resembled other liquids, in continuing to contract in volume, by cooling, till its congelation commenced, then the incumbent cold air would have robbed the mass of water in a river or lake of its caloric, by unceasing precipitation of the cold particles to the bottom, till the whole sunk to  $32^{\circ}$ . Then the consequence would have been that the water at the bottom, as well as that above, would have begun to solidify, and in the course of a severe winter in this country, deep lakes and rivers would have become throughout bodies of ice, never again to be liquefied.\*

*When water is frozen, is not the expansion that ensues capable of exerting a prodigious force?*

Yes, and it is a remarkable circumstance. Mr. Boyle filled a brass tube, three inches in diameter, with water, and confined it by means of a

\* From this we can easily see, that such frozen masses would have acted as centres of baleful refrigeration to the surrounding country; and that under such a disposition of things, Great Britain would probably have been another Lapland. It has been correctly remarked, that nothing illustrates more strikingly the beneficent economy of the Almighty than this peculiarity in the constitution of water, and thus what seems void of law to unenlightened man, is often, as in the present case, found to be the finest symmetry, and truest order.



moveable plug; the expansion, when it froze, took place with such violence as to push out the plug, though preserved in its situation by a weight equal to 74 pounds.\* Indeed, the greatest obstacles cannot resist the exertion of this expansive force.†

*Are there not some important instruments in general use, the construction of which is founded on the principle of the expansion of bodies by the application of caloric?*

There are two instruments of that kind, namely, the thermometer and pyrometer. The thermometer‡ indicates the comparative temperature of bodies, at ordinary degrees of heat; while the pyrometer is used for measuring intense degrees of heat.§

\* The Florentine academicians burst a hollow brass globe, whose cavity was only an inch in diameter, by freezing the water with which it was filled; and it has been estimated that the expansive power necessary to produce such an effect was equal to a pressure of 27,000 pounds weight.

† Even mountain rocks are sometimes burst by the dilatation of the water in their cavities, when it is converted into ice. In the same way our pavements are raised in winter.

But although this expansive force is occasionally attended with some inconvenience, yet it has sometimes a very beneficial operation, as in the comminution or loosening the texture of dense clay soils, (during the winter's frost,) whereby the delicate fibres of plants can easily penetrate them.

‡ Those who wish to understand how accurate thermometers are constructed, will find ample information on the subject in *Dr. Henry's Elements of Chemistry*, vol. i. and *Dr. Ure's Dictionary*, page 765.

§ The first attempt to measure the intensity of heat on the principle of expansion, was made by Sanctorious, a very enlightened Italian philosopher, in the seventeenth century. He employed a glass tube blown into a ball at one extremity and open at the other. After expelling a small quantity of the air from the ball by heating it gently, the open end was dipped into a coloured liquid, a portion of which ascended in the tube as the air within the ball contracted. Any variation of temperature would cause the



*What kind of thermometer is commonly used in this country?*

Fahrenheit's thermometer; which consists of an hermetically sealed glass tube, terminating at one extremity with a bulb. The bulb and part of the tube are filled with quicksilver, and a graduated scale being attached to the stem, whenever the instrument is applied to bodies of a certain temperature, the quicksilver being expanded by elevated temperatures, and contracted by those which are low, accordingly indicates a degree of heat corresponding to that of the bodies to which it is applied. In dividing the scale, the two fixed points usually resorted to are the freezing and boiling of water, which always take place at the same temperature, under ordinary circumstances;\* the freezing point of water is  $32^{\circ}$ , the boiling point  $212^{\circ}$ , and the intermediate space is equally divided into  $180^{\circ}$ ; the  $0^{\circ}$ , or zero, is consequently placed at  $32^{\circ}$  below the freezing of water, that is, the  $0^{\circ}$ , or zero, is the beginning of the scale.†

surface of the liquid to rise or fall in the stem, according as the air within the ball was either contracted by cold or dilated by heat. This was, therefore, an *air thermometer*. Air is peculiarly well adapted for the purpose, if we refer only to the uniformity of its expansion from equal increments of caloric; but there are strong objections to its employment, from its dilations and contractions being so great as to make it inconvenient to measure them when the change of temperature is considerable, and also because its bulk is influenced by pressure, so that the instrument would be affected by variations of the barometer, though the temperature should be quite stationary.

\* That is, under the same atmospheric pressure.

† When we speak of a temperature below the beginning of the scale, we consequently say, that it is so many degrees *below 0*, or the *zero*, as it is



*Are there not other kinds of thermometers in frequent use?*

Yes, there are the centigrade thermometer, employed by the modern French chemists, and Reaumur's,\* which is generally used on the continent. There is also the *differential thermometer* of Leslie, already noticed.

called. Some think a more convenient way of expressing it, is to add the word *minus*, or its algebraic sign —. Thus, minus 40, or — 40, signifies 40 degrees below zero.

\* In the *Centigrade*, the scale is divided into 100 degrees, as its name imports; the freezing point of water being marked 0°, the boiling point 100°. In Reaumur's, (the thermometer commonly used on the Continent,) the freezing point is marked 0°, the boiling point 80°. As it is necessary the student should know the difference existing between these thermometers, a table is here given in which their numbers may be seen at one view. He will see that nine degrees of Fahrenheit are equal to five of the centigrade, and four of Reaumur's thermometer.

De Lisle's thermometer is used in Russia. Here the graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

M. Breguet, member of the Academy of Sciences of Paris, has invented an exquisitely sensible thermometer, on the principle of Arnold's compensation balance for chronometers. M. Breguet's instrument consists of a narrow metallic slip, about  $\frac{1}{100}$  of an inch thick, composed of silver and platina, soldered together; and it is coiled in a cylindrical form. The top of this spiral tube is suspended by a brass arm, and the bottom carries, in a horizontal position, a very delicate golden needle, which traverses as an index on a graduated circular plate. A steel stud rises in the centre of the tube, to prevent its oscillations from the central position. If the silver be on the outside of the spiral, then the influence of increased temperature will increase the curvature, and move the appended needle in the direction of the coil; while the action of cold will relax the coil, and move the needle in the opposite direction.



TABLE shewing the degrees of Reaumur's and Fahrenheit's thermometers corresponding with those of the centigrade thermometer.

Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.	Cent.	Reau.	Fahr.
100	80°	212°	58	46·4	136·4	16	12·8	60·8
99	79·2	210·2	57	45·6	134·6	15	12°	59°
98	78·4	208·4	56	44·8	132·8	14	11·2	57·2
97	77·6	206·6	55	44°	131°	13	10·4	55·4
96	76·8	204·8	54	43·2	129·2	12	9·6	53·6
95	76°	203°	53	42·4	127·4	11	8·8	51·8
94	75·2	201·2	52	41·6	125·6	10	8°	50°
93	74·4	199·4	51	40·8	123·8	9	7·2	48·2
92	73·6	197·6	50	40°	122°	8	6·4	46·4
91	72·8	195·8	49	39·2	120·2	7	5·6	44·6
90	72°	194°	48	38·4	118·4	6	4·8	42·8
89	71·2	192·2	47	37·6	116·6	5	4°	41°
88	70·4	190·4	46	36·8	114·8	4	3·2	39·2
87	69·6	188·6	45	36°	113°	3	2·4	37·4
86	68·8	186·8	44	35·2	111·2	2	1·6	35·6
85	68°	185°	43	34·4	109·4	1	0·8	33·8
84	67·2	183·2	42	33·6	107·6	0	0°	32°
83	66·4	181·4	41	32·8	105·8	1	0·8	30·2
82	65·6	179·6	40	32°	104°	2	1·6	28·4
81	64·8	177·8	39	31·2	102·2	3	2·4	26·6
80	64°	176°	38	30·4	100·4	4	3·2	24·8
79	63·2	174·2	37	29·6	98·6	5	4°	23°
78	62·4	172·4	36	28·8	96·8	6	4·8	21·2
77	61·6	170·6	35	28°	95°	7	5·6	19·4
76	60·8	168·8	34	27·2	93·2	8	6·4	17·6
75	60°	167°	33	26·4	91·4	9	7·2	15·8
74	59·2	165·2	32	25·6	89·6	10	8°	14°
73	58·4	163·4	31	24·8	87·8	11	8·8	12·2
72	57·6	161·6	30	24°	86°	12	9·6	10·4
71	56·8	159·8	29	23·2	84·2	13	10·4	8·6
70	56°	158°	28	22·4	82·4	14	11·2	6·8
69	55·2	156·2	27	21·6	80·6	15	12°	5°
68	54·4	154·4	26	20·8	78·8	16	12·8	3·2
67	53·6	152·6	25	20°	77°	17	13·6	1·4
66	52·8	150·8	24	19·2	75·2	18	14·4	0·4
65	52°	149°	23	18·4	73·4	19	15·2	2·2
64	51·2	147·2	22	17·6	71·6	20	16°	4°
63	50·4	145·4	21	16·8	69·8	21	16·8	5·8
62	49·6	143·6	20	16°	68°	22	17·6	7·6
61	48·8	141·8	19	15·2	66·2	23	18·4	9·4
60	48°	140°	18	14·4	64·4	24	19·2	11·2
59	47·2	138·2	17	13·6	62·6	25	20°	13°



*Why is quicksilver always employed in the construction of thermometers?*

Because its expansions under the application of caloric are more uniform than those of other liquids, and also from its boiling and freezing points being very remote from one another.\*

*How is the pyrometer constructed?*

The best pyrometer is that invented by the late Mr. Wedgewood, founded on the principle that clay progressively contracts in its dimensions, as it is progressively exposed to higher degrees of heat. The apparatus consists of a metallic groove, 24 inches long, the sides of which converge, being half an inch wide above, and three-tenths below. The clay, well-washed, is made up into little cubes that fit the commencement of the groove, after having been heated to redness; and their subsequent contraction by heat is determined by allowing them to slide from the top of the groove downwards, till they arrive at a part of it through which they cannot pass. Mr. Wedgewood divides the whole length of the groove into 240 degrees, each of which he sup-

\* Dr. Turner observes, (*Elements of Chemistry*, page 28,) "No fluid can support a greater degree of heat without boiling than mercury, and none, except alcohol and ether, can endure a more intense cold without freezing. It has, besides, the additional advantage of being more sensible to the action of caloric than other liquids, while its dilatation, between  $32^{\circ}$  and  $212^{\circ}$ , are almost perfectly uniform. Strictly speaking, the same quantity of caloric does occasion a greater dilatation (in it) at high than at low temperature, so that, like other fluids, it expands in an increasing ratio. But it is remarkable that this ratio, within the limits assigned, is exactly the same as that of glass; and, therefore, if contained in a glass tube, the increasing expansion of the vessel compensates for that of the mercury."



poses equal to 130° of Fahr. The zero of his scale corresponds to 1077° of Fahr.\*

\* The following table exhibits the effect of heat on different substances, according to Fahrenheit's thermometer, and Wedgewood's pyrometer.

	Wedgewood.	Fahrenheit.
Extremity of the scale of Wedgewood's pyrometer .....	240° equal to	32277°
Greatest heat of his small air furnace .....	160° —	21877°
Cast-iron melts .....	130° —	17977°
Greatest heat of a common smith's forge....	125° —	17327°
Welding heat of iron, greatest .....	95° —	13427°
Welding heat of iron, least .....	90° —	12777°
Fine gold melts .....	32° —	5237°
Fine silver melts .....	28° —	4717°
Swedish copper melts .....	27° —	4587°
Brass melts .....	21° —	3807°
Heat by which Mr. Wedgewood's enamel colours are burnt in.....	6° —	1857°
Red heat fully visible in day-light.....	0° —	1077°
Red heat fully visible in the dark .....	1° —	947°
Mercury boils .....	3 $\frac{675}{1000}$ —	600°
Water boils .....	6 $\frac{658}{1000}$ —	212°
Vital heat .....	7 $\frac{542}{1000}$ —	97°
Water freezes .....	8 $\frac{42}{1000}$ —	32°
Proof spirit freezes .....	8 $\frac{289}{1000}$ —	0°
The point at which mercury congeals, consequently the limit of mercurial thermometers, about .....	8 $\frac{596}{1000}$ —	40°

Dr. Ure, in his *Dictionary*, page 674, has the following interesting remarks, suggested by a view of this table. "In a scale of HEAT drawn up in this manner, the comparative extents of the different departments of this grand and universal agent are rendered conspicuous at a single glance of the eye. We see at once, for instance, how small a portion of it is concerned in animal and vegetable life, and in the ordinary operations of nature. From freezing to vital heat is barely a five hundredth part of the scale (Wedgewood's); a quantity so inconsiderable, relatively to the whole, that in the higher stages of ignition ten times as much might be added or taken away without the least difference being discernable in any of the appearances from which the intensity of fire has hitherto been judged of. Hence, at the same time, we may be convinced of the utility and importance of a physical measure for these higher degrees of heat, and the utter insufficiency of the common means of discriminating and estimating their force. Mr. Wedgewood adds, that he has often found differences, astonishing when considered as a part of this scale, in the heats of his own kilns and ovens, without being perceivable by the workmen at the time, or till the ware was taken out of the kiln."



*Does the thermometer indicate the actual or absolute quantity of caloric present in bodies?*

No; as before remarked, it shows only the *relative* quantity, that is, whether the temperature of one body is greater or less than that of another. Thus, a substance at  $50^{\circ}$  is not supposed to have only 50 degrees of heat. It means that it has 50 more than one at zero. Again, a body at 100 is not supposed to be twice as warm, or to contain actually twice as much heat, as another at 50, it has only twice as many degrees, reckoning from the commencement of the scale.\*

*From what you now say, we may presume that different kinds of substances, whose temperatures, as estimated by the thermometer, are the same, do not contain equal quantities of caloric: is it so? †*

It is: this may be proved in the following way. If equal quantities of water are mixed together, one portion being at  $100^{\circ}$  Fahr. and the other at  $50^{\circ}$ , the mixture will have a temperature of  $75^{\circ}$ , or intermediate between the two; that is, the 25 degrees which the warm water has lost, have just sufficed to raise the cold water by as many degrees. It is hence inferred, that equal weights of water of the same temperature contain equal quantities of caloric; and the same is found to be true of other bodies, (that is, the *same* substances). But

\* Of the *absolute* quantity of heat in bodies we know nothing.

† That is, for example, does a pound of iron under the ordinary state of the atmosphere, contain as much caloric as a pound of water, or of mercury? The answer is, No.



if equal weights, or equal bulks, of *different* substances are used in the experiment, the result will be different. Thus, if one pound of mercury at  $180^{\circ}$  Fahr. is mixed with a pound of water at  $40^{\circ}$  Fahr. the mixture will have a temperature of  $45^{\circ}$  Fahr. only. The hot mercury has lost 140 degrees, all of which must have gone into the water; yet its temperature is raised only five degrees. This experiment demonstrates, that 28 times \* more caloric is required to raise the temperature of water through one or more degrees, than is required for heating an equal weight of mercury to the same extent; from which it is rightly inferred that the former contains 28 times more caloric than the latter.†

*How is this remarkable difference expressed by chemists?*

By the term *capacity for caloric*, or that of *specific caloric*.‡

\* Because 28 multiplied by 5 make 140.

† This result may be rendered more striking by reversing the experiment, by mixing a pound of water at  $185^{\circ}$  Fahr. with a pound of mercury at  $40^{\circ}$ . The temperature of the mixture will be  $180^{\circ}$  Fahr. the water having lost only five degrees, while the mercury has gained 140. From experiments like these, it appears evident, that different bodies always require unequal quantities of caloric to heat them equally. Thus, the same quantity of caloric which heats a pound of water one degree, will heat an equal weight of spermaceti oil two degrees, and, therefore, water is supposed to contain twice as much caloric as oil.

‡ The following remarks of Dr. Turner, (*Elements of Chemistry*, p. 34,) will be found useful in the further illustration of the meaning of these terms, which are almost synonymous. "The word capacity was probably suggested by the idea that the capacity of a body for caloric depends upon its capaciousness, or the distance between its particles, in consequence of which, there is more room for caloric. And indeed at first view, there appear sufficient grounds for this opinion; for it is observed, that very compact bodies have the smallest capacity for caloric, and that the capacity



*Then if you were asked, what is meant by specific heat or caloric, what would you say?*

That it is the relative quantities of heat which different bodies require to raise them to the same temperature.

*Has any explanation been given of this singular and unexpected fact, that two substances of equal (thermometric) temperature should contain unequal quantities of caloric?*

Dr. Black, who was the first to notice the fact itself, has offered the following explanation:—He conceived that caloric exists under two opposite conditions; in one it is supposed to be in a state of chemical combination, lying hid as it were within a body,\* without evincing any signs of its presence; in the other, it is free and uncombined, passing readily from one substance to another, affecting our senses in its passage, determining the height of the thermometer, and, in a word, giving rise to all the phenomena which we attribute to this active principle.†

of the same substance increases as its density becomes less. But as Dr. Black himself pointed out, if this was the real cause of the difference, the capacity of bodies for caloric should be inversely as their density. Thus, since mercury is 13 times and a half denser than water, the capacity of the latter for caloric ought to be only 13 times and a half greater than the former, whereas it is 28 times as great. Oil occupies more space than an equal weight of water, and yet the capacity of the latter for caloric is double that of the former. The word capacity, therefore, is apt to excite a wrong notion, unless it is carefully borne in mind, that it is merely an expression of the fact without allusion to its cause; and to avoid the chance of error from this source, the term specific caloric has been substituted for it, and is now very generally employed."

\* Called, therefore, *latent* heat.

† It should be observed, that this ingenious conjecture is not without objections; yet it is considered to have the merit of explaining phenomena more satisfactorily than any view that has been proposed in its place.



*How is the specific heat of bodies determined?*

Three distinct modes have been employed for this purpose, but perhaps the best is the following:—A given weight or bulk of the body to be examined, being heated to a certain point, is suddenly mixed with a given weight or bulk of another body, at a different temperature; and the resulting temperature of the mixture shows the relation between their specific heats. Hence, if the second body be water, or any other substance whose relation to water is ascertained, the relative heat of the first to that of water will be known.\* Let us take oil for an example. If a pound of it at  $90^{\circ}$  Fahr. be mixed with a pound of water at  $60^{\circ}$ , the resulting temperature will not be the mean  $75^{\circ}$ , but only  $70^{\circ}$ . And conversely, if we mix a pound of water heated to  $90^{\circ}$ , with a pound of oil at  $60^{\circ}$ , the temperature of the mixture will be  $80^{\circ}$ . We see here, that the water in the first case acquired  $10^{\circ}$ , while the oil lost  $20^{\circ}$ , and in the second case, that the water lost  $10^{\circ}$ , while the oil gained  $20^{\circ}$ .† Hence we say, that the specific heat of water is double to that of oil, or that the same quantity or intensity of heat which will change the temperature of oil  $20^{\circ}$ , will change that of water only  $10^{\circ}$ ; and, therefore, if the specific heat, or capacity for heat, of water be called 1.000, that of oil will be 0.500 (one-half.)

\* It is an essential precaution in using this mode, to avoid all such chemical action as happens in mixing water with alcohol or acids.

† The other methods of determining the specific heat of bodies may be seen in *Dr. Ure's Dictionary*, page 262.



*What are the principal facts hitherto determined respecting the specific heat of bodies?*

1st, That every substance has a specific heat peculiar to itself; whence it follows that a change of composition will be attended by a change of capacity for caloric.

2ndly, That whenever a body changes its form, the composition remaining the same, there is likewise a change of capacity.\*

3dly, That the atoms of all simple bodies have exactly the same capacity for heat.†

4thly, That a change of capacity for caloric always occasions a change of temperature.‡

5thly, That those bodies which are most slowly heated and cooled have generally the greatest capacity for heat.

*You have remarked (page 58) that LIQUEFACTION is another effect of caloric; when solid bodies are*

\* It is increased when a solid liquefies, and diminished when a liquid passes into a solid. Thus the capacity of water in the solid state is 900, and in the liquid 1000.

† "Hence," says Dr. Ure, "the specific heat of a simple substance, multiplied into the weight of its atom or prime equivalent, ought to give always the same product."

‡ An increase of capacity for caloric is attended by a diminution of the temperature; and a decrease in the former, by an increase of the latter. Thus, when air, confined within a flaccid bladder, is suddenly dilated by means of the air-pump, a thermometer placed in it will indicate the production of cold. On the contrary, when air is compressed, the corresponding diminution of its specific caloric gives rise to an increase of temperature; nay, so much heat is evolved when the compression is sudden and forcible, that tinder may be kindled by it. The explanation of these facts is, that in the first case, a quantity of caloric becomes insensible or latent, which was previously in a sensible state; in the second, that caloric is evolved, which was previously latent.



*liquefied, or become fluid, do they always pass gradually from the solid to the liquid state?*

No: in some cases the transition is sudden; in others, solids pass through various stages of liquidity, before they become completely fluid. The metals are examples of the first, and wax or tallow of the second kind of liquefaction. To express the former of these operations the term *fusion* has been employed; to denote the latter, that of *liquefaction*.

*May all solids be liquefied?*

It is an opinion generally entertained among chemists, that by a sufficiently intense heat every solid may be converted into a fluid, and every fluid into a gaseous state.\*

*Are the particular temperatures at which bodies undergo these changes always the same?*

No; they are exceedingly various, but always constant for the same bodies. Thus, ice always melts at 32 degrees,† sulphur at 218: every

\* I have already observed, (see page 3,) that the three forms of matter, the solid, liquid, and gaseous, seem immediately referable to the power of heat, modifying, balancing, or subduing cohesive attraction.

† It is a remarkable circumstance, that although the freezing point of water be 32°. yet it may be cooled down in favourable circumstances considerably below that temperature without becoming solid, but if anything occurs to cause it to freeze, the temperature instantly rises to 32°. Thus if fresh water is exposed in an open vessel, to a cold but calm atmosphere, so that it be kept without agitation, the temperature may be reduced to 10° or even 5°. without freezing: if, however, the vessel be struck so as to agitate the water, the whole of it is converted into ice, and the temperature is augmented to 32°.

These observations refer to fresh water. When any salt is dissolved in water, its freezing point is in most cases lowered; and this is the reason why sea-water does not freeze so readily as pure water. The following



other substance has its point of liquefaction fixed.\*

*It has been thought that solids were converted into liquids by a small addition of heat after they have been once raised to the melting point, and that they returned again to the solid state on a very small diminution of the quantity of heat necessary to keep them at that temperature: Is that opinion now considered correct?*

It is at the present time considered quite incorrect, for many circumstances concur to prove,

table shows the result of some experiments on this subject. The first column contains the names of the salts; the second the quantity of salt, by weight dissolved in 100 parts of water; and the third, the freezing point of water holding such salt in solution:—

Name of Salts.	Proportion.	Freezing Point.
Common salt.....	25	4°.
Sal ammoniac .....	20	8
Rochelle salt.....	50	21
Epsom salt .....	41.6	25.5
Nitre .....	12.5	26
Sulphate of iron .....	41.6	28
Sulphate of zinc .....	53.3	28.6

From this table it appears that common kitchen salt is by far the most efficacious in lowering the freezing point of water. A solution of 25 parts of salt in 100 of water does not freeze till reduced to 4° of Fahrenheit.

\* The following table contains a list of the melting points of several solid bodies:—

Substance.	Melting Point.	Substance.	Melting Point.
Lead .....	612°.	Ice .....	32
Bismuth .....	476	Milk .....	30
Tin .....	442	Vinegar .....	28
Sulphur .....	218	Blood .....	25
Wax .....	142	Oil of Bergamot	23
Spermaceti ....	112	Wines .....	20
Phosphorus ....	108	Oil of Turpentine	14
Tallow .....	92	Mercury .....	40
Oil of Aniseed ..	50	Liquid Ammonia	46
Olive Oil .....	36	Ether .....	46



that in order to make a solid body liquid, it is not merely necessary to bring it to its melting point, but that there must be *an absorption of caloric*, otherwise there is no liquefaction. Still, this absorption of caloric does not occasion any elevation of temperature.

*How do you prove these opinions to be founded in fact?*

It is to Dr. Black\* we are indebted for the discovery of these facts, and he proved it by some simple but decisive experiments. The following experiment places the subject in a clear light. Put some ice into a jar, and call it A, and into another some ice-cold water, and call it B, and in each jar let there be a thermometer.† By adding to these equal quantities of caloric, the result will be very different. Now to get similar quantities of caloric, we have only to take equal measures of a substance at the same temperature, as, for instance, boiling water, which is always under ordinary circumstances, at the same heat ( $212^{\circ}$ .) If, then, a measure of boiling water be added to the water in the jar B, the temperature is affected, as is shewn by the rise of the fluid in the thermometer, say to  $40^{\circ}$ . On adding the same measure to the ice A, part of the latter is melted, but there is not the slightest

\* Dr. Black was a distinguished Scotch philosopher. He was at first professor of chemistry in the University of Glasgow, and afterwards in Edinburgh.

† The student should observe that the thermometer stands at  $32^{\circ}$  in both jars, because ice and ice-cold water are commonly of the same temperature.



rise of temperature; the thermometer still continuing at  $32^{\circ}$ . The addition of another measure to the water, causes a greater elevation, say to  $50^{\circ}$ , but on adding it to the ice, more of it is melted, but the thermometer in that jar still stands at  $32^{\circ}$ . Here it is evident, that the heat has been absorbed by the ice, but the temperature is not elevated.\*

*And what is said to have become with the caloric which has entered into the ice, but is not to be found in it by the thermometer?*

It is said to have become *latent*. As it may be considered the cause of the liquefaction of the ice, it is sometimes called *caloric of fluidity*.

*Can you give any other very striking proof of the absorption of heat in the liquefaction of bodies?*

Yes. Powdered snow and salt mixed at  $32^{\circ}$ ,

\* Indeed, it is necessary to continue the addition, till the whole of the ice is melted, before the thermometer indicates any rise of temperature.

Other examples of the absorption of caloric, during the liquefaction of bodies, are furnished by the mixture of snow and nitric acid, or of snow and common salt, both of which, in common language, produce intense cold. Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption and intimate fixation of the free caloric of the mixture, by the melting snow. We are thus, enabled to account for the production of cold, by what are called freezing mixtures. On this principle of the absorption of caloric and consequent production of cold, during the liquefaction of bodies, we can generate a cold equal to that of Siberia, and sufficient to freeze mercury, (which does not freeze till reduced to 40 degrees below zero of Fahrenheit's scale,) by mixing together strong nitrous acid, sulphate of soda, and nitrate of ammonia. This mixture was first made known by Mr. Walker, apothecary in Oxford, and it will be perceived, that it does not contain a particle of ice or snow. Two tables of freezing mixtures will be found in the appendix.



will produce a depression of the thermometer plunged into them of about  $38^{\circ}$ . Hence, if a pan containing the above freezing mixture be set on a fire, with a small vessel of water plunged into it, in a few seconds the water will actually be found to be frozen!

*Is it known how much latent heat water contains; in other words, how much heat becomes latent when ice is converted into water?\**

This is another point connected with the present subject which has been determined by Dr. Black:  $140^{\circ}$  of heat must be absorbed by ice (at  $32^{\circ}$ ) before it can melt, which is proved by the following experiment:—To a pound of water at  $172^{\circ}$ , add a pound of ice at  $32^{\circ}$ . The temperature will not be the arithmetical mean ( $102^{\circ}$ ), but much below it, viz.  $32^{\circ}$ . All the excess of caloric in the hot water has therefore disappeared. From  $172^{\circ}$  take  $32^{\circ}$ ; the remainder,  $140^{\circ}$ , shows the quantity of caloric that enters into a pound of ice during liquefaction.†

*Is the quantity of latent heat‡ the same in other fluid bodies, for instance, in melted lead or bees-wax?*

No; the heat rendered latent by the fusion of various bodies is not a constant quantity, but various for each individual body. Thus, lead

\* Ice, in its conversion into water, uniformly absorbs the same quantity of caloric, and it is on this fact that Lavoisier constructed his *Calorimeter*, an instrument used to measure the heat given out by a body in cooling, from the quantity of ice it melts.

† That is, as much caloric is absorbed by a pound of ice, during its conversion into water, as would raise a pound of water from  $32^{\circ}$  to  $172^{\circ}$ .

‡ Or caloric of fluidity, which is the same thing.



when fused contains  $162^{\circ}$  of latent caloric, and bees-wax  $175^{\circ}$ .\*

*If solids in passing to a state of fluidity absorb heat, and thus produce cold, is not the reverse also true, that fluids in becoming solid, evolve or give out heat, in common language, produce heat?*

Certainly. For example,† if two vessels, one with ice-cold spirit of wine, (call it S,) another with ice-cold water, (call it W,) and each having a thermometer in it, be placed in a freezing mixture of salt and snow, caloric will be taken from both; by which the latter will be frozen, but the former will continue fluid. The thermometer in the spirit will sink extremely below, say to 0 (zero); but that in the water will still remain at  $32^{\circ}$ . Here, then, heat has been withdrawn from the spirit, so as to bring it down to zero; it must also have been taken from the water, yet its temperature is not diminished. And why? because the water being brought down to its freezing point, begins to congeal or solidify, and, during its congelation, must give forth heat. Thus, then, it is proved, that a substance, in passing

\* The caloric of fluidity in some other substances is here shown:—

Sulphur contains .....	144°
Spermaceti .....	145°
Zinc .....	493°
Tin .....	500°
Bismuth .....	550°

† Many experiments might be detailed, the result of which prove this fact, and we will here add one to that described above. To a saturated solution of sulphate of potassa in water, or of any salt that is insoluble in alcohol, add an equal measure of alcohol. The alcohol, attracting the water more strongly than the salt, retains it, precipitates the salt, and considerable heat is produced.



from a fluid to a solid, gives out a large quantity of caloric, but the loss of which does not in the least diminish its temperature; in other words, its *latent* heat is disengaged.

*Do you know any important natural phenomena which may be accounted for by this absorption and evolution of caloric when bodies change their state?*

It explains several such phenomena, for instance, we understand by it how the thaw which supervenes after an intense frost, should so slowly melt the wreaths of snow and beds of ice. As before remarked, it is not merely necessary, that the state of the weather be such as to raise their temperature to the melting point; a great deal of caloric must be thrown in, otherwise they will not become fluid. Were it not for this, frightful deluges would follow a sudden liquefaction; but as the heat is slowly absorbed, they are gradually melted, and the water formed is thus distributed over the surface of the globe.

*What opinions are entertained with respect to the cause of the absorption and evolution of caloric?*

Different sentiments are maintained on this subject. Dr. Black imagined, that when a body arrived at its melting point, it absorbed caloric, by which it was made to assume the fluid form; the absorption thus being supposed to be the *cause* of the fluidity. Others suppose, that a solid, during its conversion to a fluid state, gains an increase of capacity; it must, therefore, require more heat than before to keep it at the same temperature, consequently, it absorbs it,



and as the heat taken in goes to satisfy this increased capacity, it cannot of course have any effect on the thermometer. In this view, the absorption is the *effect* of the liquefaction.\*

*You have said that VAPORIZATION is another effect of caloric: How are fluids converted into vapour?*

In the same way that solids are converted into fluids, viz. by the application and absorption of heat.

*And does caloric become latent in vapours as well as in fluids?†*

Yes; but there is a great deal more caloric that becomes latent in vapours than in fluids, for instance, 900° are latent in steam.

*How do you prove this?*

The first point, viz. the existence of *latent* heat in vapours, may be satisfactorily proved thus:—when a vessel of water is put upon the fire, the water gradually becomes hotter till it reaches 212°, afterwards its temperature is not increased. Now caloric must be constantly entering from the fire and combining with the water. But as the

\* The student who wishes to study this point fully may have recourse with much advantage to *Dr. Thomson's System of Chemistry*, vol. i.; *Dr. Ure's Dictionary*, article *Caloric*; or *Dr. Turner's Elements*, page 43.

† The fixation of caloric in water, by its conversion into vapour or steam, is satisfactorily shown by the following fact:—When a quantity of water is heated several degrees above the boiling point in a close vessel, and a cock is then suddenly opened, the steam rushes out with prodigious noise and violence, and the heat of the water is reduced in three or four seconds to the boiling temperature. The water, however, constituting the steam which has escaped, amounts to only a very trifling quantity, and yet it has been sufficient to absorb and carry off the whole excess of heat from the water in the digester.



water does not become hotter, the caloric must combine with that part of it which flies off in the form of steam: but the temperature of the steam is only  $212^{\circ}$ , therefore the caloric combined with it does not increase its temperature. We must conclude, then, that the change of water to steam is owing to the combination of this caloric; for it produces no other change.\*

\* The uses of steam are very numerous and valuable. The elasticity of this vapour is employed as a moving power in "that splendid trophy erected to the science of caloric," the steam engine of Watt. The construction of this machine depends on two properties of steam, namely, the expansive force communicated to it by caloric, and its ready conversion into water by cold. The effects of both these properties is well shown by a little instrument devised by Dr. Wollaston. It consists of a cylindrical glass tube, six inches long, nearly an inch wide, and blown out into a little ball at one end. A piston is accurately fitted to the cylinder, so as to move up and down with freedom. When the piston is at the bottom of the tube, it is forced up by causing a portion of water, previously placed in the ball, to boil by means of a spirit lamp. On dipping the ball into cold water, the steam which occupies the cylinder is suddenly condensed, and the piston is forced down by the pressure of the air above it. By the alternate application of heat and cold, the same movements are reproduced, and may be repeated for any length of time. The moving power of the steam-engine is the same as in this apparatus. The only essential difference between them is in the mode of condensing the steam. In the steam-engine, the steam is condensed in a separate vessel, where there is a regular supply of cold water for the purpose. By this contrivance, which constitutes the great improvement of Watt, the temperature of the cylinder never falls below  $212^{\circ}$ .

Dr. Ure's description of this capital improvement of Mr. Watt is worthy of a place here. In referring to the three grand improvements made by this distinguished philosopher, he says, the first is "the separate condensing chest, immersed in a body of cold water, and connected merely by a slender pipe with the great cylinder, in which the impelling piston moved. On opening a valve, or stop-cock of communication, the elastic steam which had floated the ponderous piston, rushed into the distant chest with magical velocity, leaving an almost perfect vacuum in the cylinder, into which the piston was forced by atmospheric pressure. What had appeared impossible to all previous engineers, was thus accomplished. A vacuum was formed without cooling the cylinder itself. Thus it remained boiling hot, ready the next instant to receive and maintain the elastic steam."—*Dictionary of Chemistry*, p. 286.



*And how do you show that so much as 900° of heat are latent in steam?*

It should be observed, that water may be heated in a Papin's digester to 400° without boiling, because the steam is forcibly compressed, and prevented from making its escape. If the mouth of the vessel be suddenly opened while things are in this state, part of the water rushes out in the form of steam, but the greater part still remains in the form of water, and its temperature instantly sinks to 212°; consequently, 188° of caloric have suddenly disappeared. This caloric must have been carried off by the steam. Now, as only about  $\frac{1}{5}$ th of the water is converted into steam, that steam must contain not only its own 188°, but also the 188° lost by each of the other four parts; that is to say, it must contain nearly  $188^\circ \times 5$ , or about 940°. Steam, therefore, is water combined with at least 940° of

Steam is of the most essential service in drying substances gradually, and without the risk of burning and injuring them. It is used for drying gunpowder, and is now likewise extensively employed for drying muslins and calicoes. In the latter case, large cylinders are filled with it, which diffusing in the apartment a temperature of 100° or 130°, rapidly dry the suspended cloth. Occasionally the cloth is made to glide in a serpentine manner closely round a series of steam cylinders, arranged in parallel rows. It is thus safely and thoroughly dried in the course of a minute. Experience has shown, that bright dyed yarns, like scarlet, dried in a common stove heat of 128°, have their colour darkened, and acquire a harsh feel; while similar hanks, laid on a steam-pipe heated up to 165°, retain the shade and lustre they possessed in the wetted state. But by far the most important advantage attending the use of steam in these cases is, that the people who work in steam drying-rooms are healthy, while those who were formerly employed in the stove-heated apartments, became soon sickly, emaciated, and diseased.



caloric, the presence of which is not indicated by the thermometer.

*Since steam, then, is water in a state of great expansion by heat, can you tell me how much greater the bulk of steam is than that of water?*

The bulk of steam at  $212^{\circ}$  is 1700 times greater than that of water at the same temperature: a cubic inch of water thus becomes a cubic foot of steam.\*

\* The consideration of this fact, with regard to the great bulk of steam, will enable the student to understand how it possesses so vast an expansive power when machinery is set in motion and impelled by it. The steam-engine, just now alluded to, is so important an instrument, and at this time in such frequent use, that it is highly desirable for every well-educated person clearly to comprehend its nature and mode of action, and, therefore, I shall add the following further description of it, taken from *Dr. Arnott's Elements of Physics*, (a book of great merit, and which I strongly recommend to every parent and student,) which is one of the best I have seen.

"The name of *steam-engine*, to most persons, brings the idea of a machine of the most complex nature, and hence intelligible only to those who will devote much time to the study of it; but he who can understand a common pump may understand a steam-engine. It is in fact only a pump in which the fluid is made to impel the piston instead of being impelled by it, that is to say, in which the fluid acts as the *power* instead of being the *resistance*. It may be described simply as a strong barrel or cylinder *c d*, with a closely fitting piston in it, as at *b*, which is driven up and down by steam admitted alternately above and below from a suitable boiler; while the end of the piston rod *a*, at which the whole force may be considered as concentrated, *c* is connected in any convenient way with the work that is to be performed. The power of the engine is of course proportioned to the size or area of the piston, on which the steam acts with a force, according to the density, of from 15 to 100 or more pounds to each square inch. In some of the Cornish mines there are cylinders and pistons of more than ninety inches in diameter, on which the pressure of the steam equals the efforts of six hundred horses.



"Sometimes the piston-rod of a steam-engine is made to act upon one end of a great vibrating beam, while at the other end, immense water-pumps are connected, which cause almost a river to gush up from the bowels of the earth. At other times acting on a crank, it is made to turn complicated



*When steam issues forcibly from the spout of a kettle, or any other vessel, you will perceive that it is*

machinery ; and one engine, stretching long arms over a great barrack or manufactory, keeps thousands of spinning-wheels in motion on one side, while it is carding the material on another, and weaving the cloth on a third. In like manner, one steam-engine in a great metropolitan brewery may be seen at the same time grinding the malt, pulling up supplies of all kinds from waggons in various situations, pumping cold water into some of the coppers, sending the boiling wort from others up to lofty cooling pans, over which it is turning the fans ; it may also be working the mash-tub, drawing water from the deep wells under ground, loading the drays—in a word, performing the offices of a hundred hands. Again, there are manufactories where this resistless power is seen with its mechanic claws seizing masses of iron, and in a few minutes delivering them out again pressed into thin sheets, or cut into bars and ribands, as if the iron had become like soft clay in the hands of the potter. One steam-engine four miles from London is at the same instant filling all the water reservoirs and baths and fountains of the finest quarter of the town. For some years now has this wonderful piston-rod, working at its crank, been turning the paddle wheels of innumerable steam-boats in all parts of the world ; and, setting at defiance the violence of the winds and waves, and the currents of the fleetest rivers, it is carrying men and civilization into the remote recesses of all the great continents. To wherever a river leads, the region, although concealed perhaps since the beginning of the world, is now called by the steam-engine from its solitude, to form a part of the great garden which civilized man is beautifying.—Such, and many more, are the prodigies which this machine is already performing, and every day is witnessing new applications of its utility.

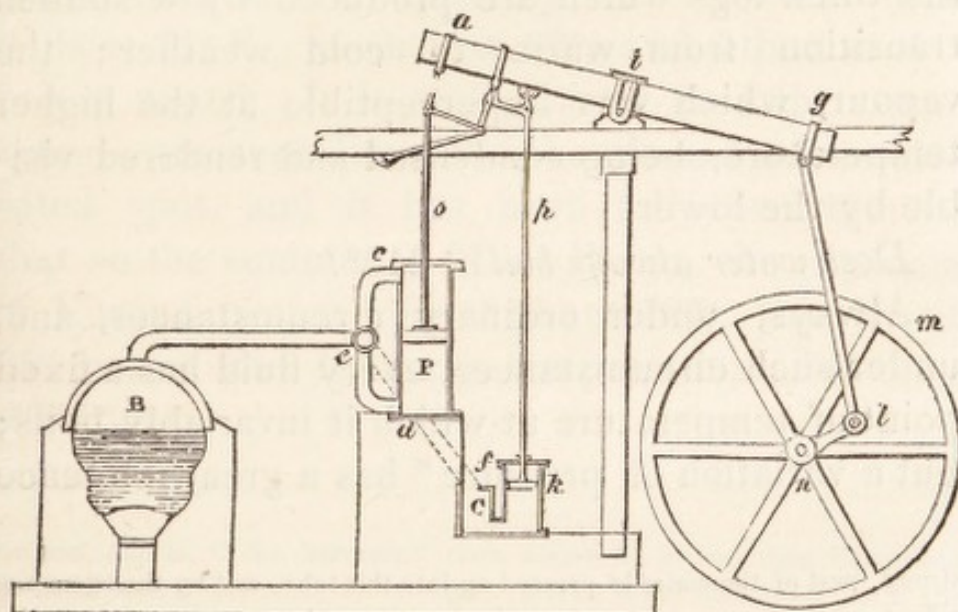
“ The following account of the parts of the steam-engine is intended, without entering into minute practical details, still fully to explain the principle or general nature of the machine. It should serve to make evident the folly of many of the modern schemes for improving the engine, and to render interesting to an attentive reader, a visit to any place where a steam-engine is in use.

“ 1st. The part which first claims attention is the great *barrel c d*, in which the *piston P* is moved up and down by the action of steam entering alternately above and below it, through the pipes *c c* and *e d*. The barrel or cylinder is bored with extreme accuracy, and the piston is padded round the edge with hemp or other soft material, so as to make it perfectly air or steam-tight. Lately pistons have been made altogether of metal, and in some cases such answer even better than the others, from working with less friction.—2d. The next part to be mentioned is the *boiler B*, which is made of suitable size and strength.—3d. The steam passes from the boiler along the pipe to *e*, and there, by any suitable *cock* or *valves*, is directed alter-



*invisible at the point at which it issues from the vessel:  
What is the cause of this?*

nately to the upper and under part of the barrel; and while it is entering to press on one side of the piston, it is allowed to escape from the other side, either to the atmosphere, for high-pressure-engines, or into—4th, the con-



denser at C, for those of low pressure.—5th. *The supply of steam* from the boiler to the cylinder is regulated by a *valve* placed somewhere in the pipe B c, and made obedient to what is called—6th, the *governor*,—a contrivance not represented here, but already described at page 65, to illustrate centrifugal force. We may recall it by saying, that it consists of two balls hanging by jointed rods like the legs of a tongs, from opposite sides of an upright spindle, which is made to revolve by connexion with some turning part of the machinery. When the spindle turns at all faster than with the desired speed, the balls fly more apart, and are made to affect the steam valve so as to narrow the passage; and on the contrary, when it turns more slowly than is desired, they collapse, and by so doing open the valve wider.—7th. *The supply of water* to the boiler is regulated by a *float* on the surface of the water contained in the boiler, which on descending to a certain point, by reason of the consumption of water, opens a valve to admit more.—8th. There is a *safety valve* in the boiler, viz. a well fitted stopper, loaded so as to open before danger can arise from the overheating of the water.—9th. *The rapidity of the combustion*, or force of the fire, may be exactly regulated by the state of the boiler and the wants of the machine, thus:—there is a large open tube (not represented here) rising from near the bottom of the boiler, through its top to the height of several feet, and when the water in the boiler is too hot, and the steam therefore too



It is owing to the circumstance of perfectly formed steam being always completely invisible. It is only when it begins to be condensed by meeting with the colder air, that it becomes visible. We have a proof also of the same fact in the thick fogs which are produced by a sudden transition from warm to cold weather; the vapour, which was imperceptible at the higher temperature, being condensed and rendered visible by the lower.

*Does water always boil at 212°?*

Always, under ordinary circumstances, and, under such circumstances, every fluid has a fixed point of temperature at which it invariably boils; but a variation of pressure\* has a great influence

strong, part of the water is pressed up into this tube, and by the agency of a float which rests on its surface, it shuts the chimney-valve or *damper*: the draught is then diminished and the fuel saved, until a brisker fire is again required.—10th. In this figure, *a i g* marks the place of the *great beam*, turning on an axis at *i*, and through which the force of the piston is usually conveyed to the remote machinery. When the object is to raise water, the pump-rods are simply connected with the end *g* of the beam, but when any rotatory motion is wanted, the end *g* is made to turn—11th. a *crank l n* by the rod *g l*; and uniformity of motion is obtained by the influence of—12th. the *great fly-wheel m* fixed to the axis of the crank.”

\* It should be observed, that all bodies upon the earth are constantly exposed to considerable pressure; for the atmosphere itself presses with a force equivalent to a weight of 15 pounds, on every square inch of surface. Liquids are exposed to this pressure as well as solids, and their tendency to take the form of vapour is very much counteracted by it. In fact, they cannot enter into ebullition at all, till their particles have acquired such an elastic form as enables them to overcome the pressure upon their surfaces; that is, till they press against the atmosphere with the same force as the atmosphere against them. Now the atmospheric pressure is variable, and hence it follows, that the boiling point of liquids must also vary. The only time at which the pressure of the atmosphere is equal to a weight of 15 pounds on every square inch of surface, is when the barometer stands at 30 inches, and then only does water boil at 212° Fahr. If the pressure



over the boiling point of all fluids. Thus, water ordinarily boils at  $212^{\circ}$ , alcohol at  $173^{\circ}$ , and ether at  $96^{\circ}$  Fahr.; but if the atmospheric pressure be wholly removed, by means of the air pump,\* fluids will boil at a temperature  $140^{\circ}$  lower than in the open air. Thus water then boils at  $72^{\circ}$  F., alcohol at  $33^{\circ}$ , and ether at  $44^{\circ}$  below zero.† It is well known that the atmospheric pressure diminishes as we ascend an elevated spot, and it has been fully ascertained, that on the summit of Mont Blanc, the pinnacle of Europe, water boils at about  $187^{\circ}$ , that is, at  $25^{\circ}$  below the ordinary temperature of boiling water.‡

be less, that is, if the barometer rises above 30 inches, then the boiling point of water, and every other liquid, will be lower than usual; or if the barometer rises above 30 inches, the temperature of ebullition will be proportionally increased. This is the reason why water boils at a lower temperature on the top of a hill than in the valley beneath it; for as the column of air diminishes in length as we ascend, its pressure must likewise suffer a proportional diminution. The ratio between the depression of the boiling point and the diminution of the atmospherical pressure is so exact, that it has been proposed as a method for determining the heights of mountains. An elevation of 530 feet makes a diminution of one degree of Fahrenheit.

The Rev. Mr. Wollaston has invented a most delicate thermometric barometer, by which it is ascertained, that even the height of a common table produces a manifest difference in the boiling point of water.

\* As the air is wholly exhausted by this pump, it of course produces a vacuum, and the fluids are then said to boil *in vacuo*.

† This proves that a liquid is not necessarily hot because it boils. It is a remarkable fact, that the heat of the hand is sufficient to make water boil *in vacuo*; and that ether, under the same circumstances, will enter into ebullition, though its temperature is low enough for freezing mercury!

‡ The following experiment affords a striking proof of the effects of diminished pressure in lowering the boiling point of fluids:—Place, over a lamp, a Florence flask, about three-fourths filled with water; let it boil briskly during a few minutes; then remove it from the lamp, and cork it tightly. The water will soon cease to boil, in consequence of the pressure



*Do vapours during their conversion into a liquid form, evolve, or give out, caloric?*

They thus evolve a great deal of caloric, as may be inferred from what has been said above respecting the quantity of latent heat they contain. The heat given out by the condensation of steam, is rendered apparent by the following experiment:—Mix 100 gallons of cold water at  $50^{\circ}$ , with 1 gallon of boiling water at  $212^{\circ}$ ; the temperature of the water will be raised about  $1\frac{1}{2}^{\circ}$ . Condense, by a common still-tube, 1 gallon of water, from the state of steam, by 100 gallons of water, at the temperature of  $50^{\circ}$ . The water will be raised  $11^{\circ}$ . Hence, 1 gallon of water, condensed from steam, raises the temperature of 100 gallons of cold water  $9\frac{1}{2}^{\circ}$  more than 1 gallon of boiling water; and, by an easy calculation, it appears that the caloric imparted to 100 gallons of cold water by 8 pounds of steam, if it could be condensed in 1 gallon of water, would raise it to  $950^{\circ}$ .\*

*What is meant by* EVAPORATION?

Evaporation, as well as ebullition, consists in the formation of vapour, and the only assignable difference between them is, that the one takes

occasioned by the steam on its surface, but if plunged into *cold* water ebullition instantly recommences, from the condensation of the vapour thus occasioned forming an imperfect vacuum over the hot water. If the vessel be now plunged into *hot* water, it will immediately cease to boil, because the re-application of heat occasions the formation of fresh steam, and, therefore, a renewal of the pressure on the surface of the hot water.

\* One gallon of water in the form of steam will heat 18 gallons of cold water up to 100 degrees.



place quietly, the other with the appearance of boiling. Evaporation takes place at common temperatures, as may be proved by exposing water in a shallow vessel to the air for a few days, when it will gradually diminish, and at last disappear entirely.\*

*Are all fluids susceptible of evaporation, and is there any general law which regulates the facility with which different liquids evaporate?*

Most fluids, if not all of them, undergo this gradual dissipation; and it may also be observed in some solids, as, for example, in camphor. The law you refer to is, that those liquids, whose boiling point is lowest, always evaporate with the greatest rapidity. Thus, alcohol, which boils at a lower temperature than water, evaporates also more freely; and ether, whose point of ebullition is yet lower than that of alcohol, evaporates still more rapidly.†

\* The real cause of evaporation is not yet determined. It was once supposed to be owing to a chemical attraction between the air and water, and the idea has some plausibility, since a certain degree of affinity does, to all appearance, exist between them. But it is, nevertheless, impossible to attribute the effect to this cause. For evaporation takes place equally *in vacuo* as in the air. Moreover, it is an established fact, that the atmosphere positively retards the process, and that one of the best means of accelerating it, is by removing the air altogether.

† The chief circumstances that influence the process of evaporation are the extent of surface exposed, and the state of the air as to temperature, dryness, stillness, and density. Every one knows that a high temperature promotes evaporation. Again, when water, for example, is covered by a stratum of dry air, the evaporation is rapid, even when its temperature is low. Thus, in some dry cold days in winter, the evaporation is exceedingly rapid; whereas it goes on very tardily, if the atmosphere contains much vapour, even though the air be very warm. Evaporation is obviously far slower in still air than in a current, because the air immediately in contact with the water soon becomes moist, and thus a check is put to



*When fluids evaporate spontaneously, is caloric absorbed, or evolved?*

It is, of course, absorbed, and cold is therefore always generated by evaporation;\* indeed, by the rapid evaporation of water a sufficient degree of cold may be generated, to freeze the water itself which has been thus partially evaporated!† Liquids which evaporate more rapidly than water, cause a still greater reduction of temperature. The cold produced by the evapo-

evaporation; but if the air is removed from the surface of the water when it has become charged with vapour, and its place supplied with fresh dry air, then the evaporation continues without interruption. The density or pressure of the atmosphere has also a great influence over evaporation: the greater the density the less the evaporation, and *vice versa*.

\* Since a large quantity of caloric passes from a sensible to an insensible state during the formation of vapour, it necessarily follows that cold should be generated by evaporation. Thus, if a few drops of ether be allowed to fall upon the hand, a strong sensation of cold will be excited during the evaporation; or if the bulb of a thermometer, covered with lint, be moistened with ether, the production of cold will be marked by the descent of the mercury. By pouring a succession of drops of ether on the surface of a thin glass tube containing water, a cylinder of ice may be formed at Midsummer.

† It is on the principle of the evaporation of water being carried on much more rapidly under a diminished pressure, that Mr. Leslie's very ingenious method of freezing water by its own evaporation, is founded. In this method, the water to be congealed is contained in a shallow vessel B, which is supported above another vessel C, containing strong sulphuric acid, or dry muriate of lime; or even parched oatmeal. Any substance, indeed, that powerfully attracts moisture, may be applied to this purpose. The whole is covered by the receiver of an air-pump, which is rapidly exhausted; and as soon as this is effected, crystals of ice begin to shoot in the water, and a considerable quantity of air makes its escape, after which the whole of the water becomes solid. The rarefaction required is to about 100 times; but to support congelation after it has taken place, 20, or even 10 times are sufficient. The sulphuric acid becomes very warm; and it is remarkable, that if the vacuum be kept up, the ice itself evaporates. In five or six days, ice of an inch in thickness, will entirely disappear.

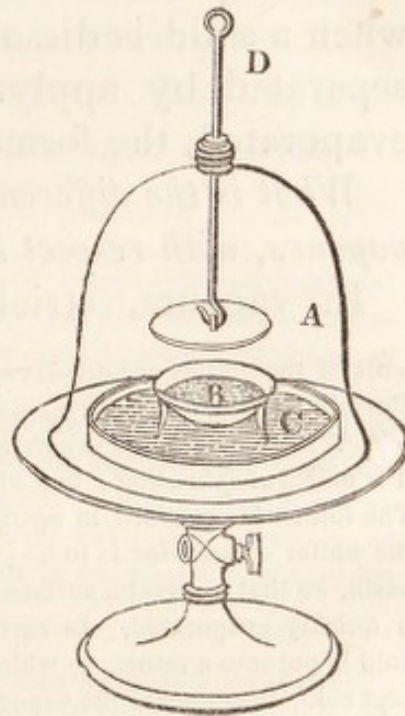


ration of ether in the vacuum of the air-pump,\* is so intense as to freeze mercury.†

*To what important purposes does evaporation serve?‡*

An eligible manner of making this interesting experiment is to cover the vessel of water with a plate of metal or glass A, fixed to the end of a sliding wire D, which must pass through the neck of the receiver, and be, at the same time, air tight, and capable of being drawn upwards. The receiver being exhausted, the water B will continue fluid, till the cover is removed, when, in less than five minutes, needle shaped crystals of ice will shoot through it, and the whole will soon become frozen.

In this process, if it were not for the sulphuric acid, an atmosphere of aqueous vapour would fill the receiver; and, pressing on the surface of the water, would prevent the further production of vapour. But here, the steam which rises is condensed by the sulphuric acid the moment it is formed.



\* For a description of the manner in which the air-pump acts, see the end of this chapter.

† The action of Dr. Wollaston's *Cryophorus* (or *Frost-bearer*,) is founded on the same principle as Mr. Leslie's method of freezing water, just noticed. It consists of two glass balls, A B, perfectly free of air, and joined together by a tube, (see figure 3). One of the balls A, contains a portion of distilled water, while the other parts of the instrument, which appear empty, are full of aqueous vapour, which checks the evaporation from the water by the pressure it exerts upon it. But when the empty ball B is plunged into a mixture of snow and salt, or any other freezing mixture, all the vapour within it is condensed. Evaporation commences from the surface of the water in the other ball, and, though at a distance of two or three feet, it is frozen solid in the course of a very few minutes.

‡ "The principle of cooling by evaporation is well understood by the caravans who cross the great Desert of Arabia. These people have occasion for a large quantity of water, which they carry with them on camels, in bottles of earthenware, and which in passing over the burning sands of that country, would become very disagreeably hot, were it not for the following expedient, which is universally adopted by them. When they lay in their stock of water, each bottle is enfolded in a linen cloth, and some of the company are appointed to keep these cloths constantly wet during the journey; by which means a perpetual evaporation is produced, and the con-



Its uses are numerous and important. For example, many of the operations of chemistry depend on the tendency which bodies have to pass off in vapour at different temperatures. Thus, when a solid is dissolved in a fluid, they can be separated by applying heat; the latter will be evaporated, the former will remain in the vessel.\*

*What is the difference of constitution in gases and vapours, with respect to caloric?*

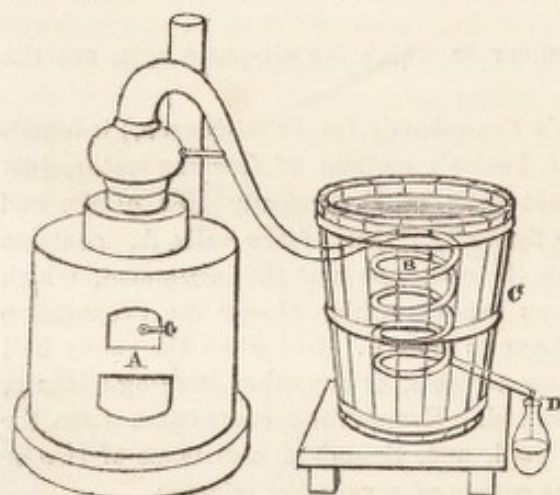
In vapours, strictly so called, such as the

tents of the bottles are preserved at a cool and refreshing temperature."—*Paris's Medical Chemistry*, p. 205.

\* When this process is carried on without wishing to preserve the fluid it is called *evaporation*; but when it is to be kept it is termed *distillation*. The former is practised in open, the latter in closed vessels. Thus, when the matter *in solution* is to be procured, the liquid is heated in a shallow basin, so that as great a surface as possible may be exposed, by which it is quickly evaporated. In carrying on distillation on a small scale, the fluid is put into a retort, to which a receiver is adapted, and which must be kept cold, to condense the vapour that flows into it. In conducting it on a

large scale, the fluid is put into a still A, and the vapour is made to pass through a spiral tube, or *worm* B, placed in a tub with cold water, called a *refrigeratory*, C. In this worm the vapour is condensed, and escapes at the open end D, when it is collected in vessels.

In referring to the important natural phenomena dependant on the evaporation and condensation of vapour, it should be observed, that evaporation and rarefaction are the grand measures employed by the God of



NATURE to temper the excessive heat of the torrid zone; and in milder climates, the summer heats are assuaged by the vapours copiously raised from every river and field, while the wintry cold is moderated by the condensation of atmospheric vapours in the form of snow. Again, the equilibrium of animal temperature is maintained by the copious discharge of vapour from the lungs and skin; the suppression of which excretion is a common cause of some of the most formidable and intractable diseases to which mankind are subject.

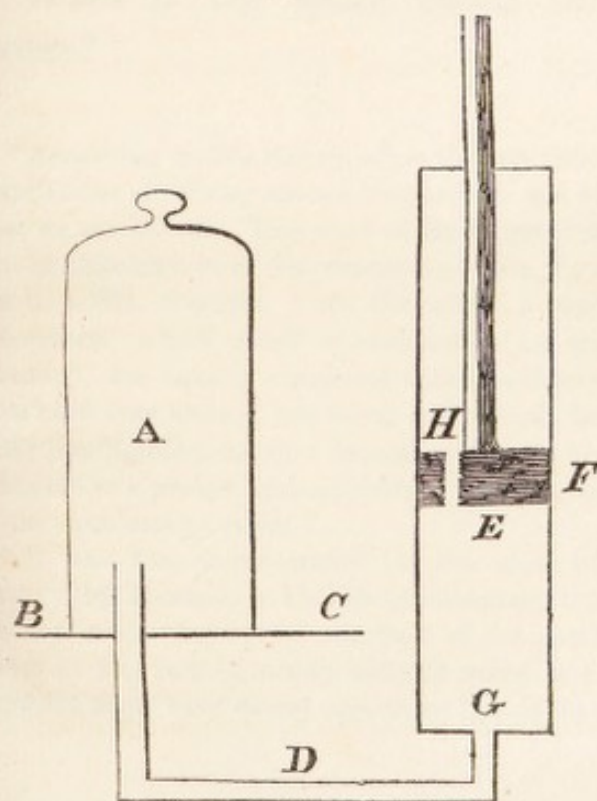


steam of water, &c. caloric is retained with but little force, as is shown by its quitting the water when the vapour is merely exposed to a lower temperature; but in gases, (which are permanently elastic fluids,) caloric is held very forcibly, and no diminution of temperature, that has ever yet been effected, can separate it from some of them.\*

\* Thus, the air of our atmosphere, in the most intense artificial or natural cold, still continues in the *aëriform* state; and hence is derived one character of gases, viz. that they remain *aëriform* under all ordinary variations of pressure and temperature.

The experiments of Sir Humphry Davy and Mr. Faraday on the liquefaction of gaseous bodies, appear to justify the opinion that gases are merely the vapours of extremely volatile liquids. These liquids, however, are so volatile, that their boiling point, under the atmospheric pressure, is lower than any natural temperature; and this is the reason why they are always found in the gaseous state.

The air-pump is an instrument which has been frequently mentioned in this chapter, and it is necessary to explain how it acts, in order that the student may fully comprehend the principle on which it is formed.



The annexed figure represents a vertical section of a pump, in its simplest form. A is the bell-glass or receiver, that is to be emptied of its air, placed on the plate of the pump, B, C. This communicates by means of a tube D, with the syringe E, in which there is the piston F, that moves upwards and downwards, but quite air-tight. At G, the opening of the pipe D, there is a valve, which allows air to flow from the receiver into the syringe, but prevents its return. In the piston there is a tube with a valve at H, which allows air to pass



from the under to the upper part of the syringe, but prevents it from going down again. The construction of this valve is very simple ; it is merely a small piece of oiled silk, tied loosely over the mouth of the tube. When the air passes through, it raises it ; but on again attempting to return, it forces it down on the tube, which thus prevents it from passing. When we wish, then, to exhaust the receiver A, by raising the piston F, the air, owing to its elasticity, expands, and is then divided between it and the syringe, the valve in the piston being shut, when it was raised, by the pressure of the air above it, which is thus kept from passing through it into the lower part of the cylinder. On again forcing the piston down, the valve at G is shut, while that at H is opened ; the air, therefore, below being prevented from returning into the receiver, escapes at H. When the piston is raised the valve at H is shut, and that at G is opened, the air in the receiver is therefore, again divided between it and the syringe, and on again forcing the piston down, the air drawn from the receiver, is expelled at H. In this way, by alternately raising and depressing the piston, the greater part of the air may be removed. For a view of the air-pump in common use, see figure 4, in the plate at page 1.





## CHAPTER V.

## OF LIGHT.

*What is the NATURE OF LIGHT?*

Different opinions are entertained on this subject. The philosopher Huygens considered it as a subtile fluid filling space, and rendering bodies visible by the undulations into which it is thrown.\* Sir Isaac Newton, on the contrary, considered light as a material substance, consisting of small particles constantly separating from luminous bodies, moving in straight lines, and rendering bodies luminous by passing from them and entering the eye.†

*What is the space called through which light moves?*

\* According to this theory, when the sun rises it agitates this fluid, the undulations gradually extend themselves, and at last, striking against our eye, we see the sun. This view of the subject appears to be gaining ground among philosophers of the present day. Dr. Young, in his *Natural Philos.* vol. ii. p. 631, observes, "On the whole, it appears that the few optical phenomena, which admit of explanation by the corpuscular system (of Newton), are equally consistent with this theory; that many others which have been long known, but never understood, become by these means perfectly intelligible; and that several new facts are found to be thus, only, reducible to a perfect analogy with other facts, and to the simple principles of the undulatory system."

† It was first demonstrated (in the view of those who embrace this theory) by Roemer, a Danish philosopher, that light takes about eight minutes in moving across one-half of the earth's orbit; consequently it moves at the rate of nearly 200,000 miles in a second! In my opinion, there are many very strong objections to this theory of Sir Isaac Newton.



A medium: thus, air and other gaseous substances, are called *rare*, while water, and transparent liquids and solids, are termed *dense* media.

*Does a ray of light pass in the same direction through rare and dense media?*

No; when it passes through the same medium, or perpendicularly from one medium into another, it continues to move without changing its direction; but when it passes obliquely from one medium to another of a different density, it always bends a little from its old direction, and assumes a new one. It is then said to be *refracted*. When it passes into a *denser* medium, it is refracted *towards* the perpendicular; but when it passes into a *rarer* medium, it is refracted *from* the perpendicular.\*

*What happens when light strikes a polished opaque body?*

It is *reflected*, and at the same angle at which it falls on the polished object.†

\* In general, the quantity of refraction is proportional to the density of the medium; but if the medium be combustible, the refraction is greater than it would otherwise be. It was the knowledge of this law, that led Newton to suspect that both the diamond and water contained combustible matter, at a time when chemists universally considered these substances as simple or elementary. From this law of the refractive power of combustible bodies we may, in many cases, infer their chemical constitution; and the principle has been happily applied for discovering the purity of essential oils. Thus Dr. Wollaston found that genuine oil of cloves has a refractive power of 1.535, while that of an inferior quality did not exceed 1.498.

† Therefore, the angle of *reflection* is always equal to the angle of *incidence*.



*What is meant by certain bodies REFRACTING DOUBLY?*

When a ray of light passes through a crystallized body, provided the primitive form of the crystal be neither a cube nor a regular octahedron, it is split into two distinct rays, one of which is refracted in the ordinary way, while the other suffers an extraordinary refraction. Hence, when an object is viewed through such a crystal it appears double, and, therefore, such bodies are said to *refract doubly*!

*Is light a simple body, that is, are the rays of light indivisible?*

No; light is separable by a prism into seven primary rays or colours, as well as into others, which appears to be distinguished by certain chemical powers. For instance, if a ray of light in passing through a small hole, with a prism near it, be made to fall on a sheet of white paper, a *spectrum* is produced, composed of seven distinct colours, viz.—*red, orange, yellow, green, blue, indigo, violet.*\*

\* This separation of the rays is produced by the difference in their refrangibility. Thus, the red is least refracted; it is, therefore, least bent from the straight line, and is consequently lowest in the spectrum; the others are situated in the order of their powers of refraction; the violet being most so, is at the top. That light is composed of these different rays, is also proved by taking a quantity of the colours, in due proportion, and mixing them, by which white is produced; or if the rays, instead of being thrown on paper, so as to form a spectrum, be made, after separation, to pass through a lens, they are collected into a focus, and white light is produced.

“The solar rays, both direct and diffused, possess the property of exciting heat as well as light. This effect takes place only when the rays are absorbed; for the temperature of transparent substances through which



*Is there any difference in the power of ILLUMINATION in these rays?*

They have very different illuminating powers. Thus, if a small object is placed at either end of the spectrum, it is seen indistinctly, but if brought towards the centre, it becomes much more distinct, the greatest illuminating power being between the bright yellow and the pale green.\*

*What was Sir Isaac Newton's opinion with respect to the cause of the different colours of bodies?*

That it is owing to their power of absorbing all the primitive colours, except the peculiar one which they reflect, and of which colour they therefore appear to our eye.†

they pass, or of opaque ones by which they are reflected, is not affected by them. Hence it happens, that the burning glass and concave reflector are themselves nearly or quite cool, at the very moment of producing a strong heat by collecting the sun's rays into a focus. The extreme coldness that prevails in the higher strata of the air, arises (in some degree) from the same cause. The rays pass on unabsorbed through the atmosphere; and the lower parts of it would be as cold as the upper, did they not receive caloric, by communication from the earth." *Dr. Turner's Elements of Chemistry*, p. 64.

\* The *heating* powers of the rays follow a different order. If the bulb of a very sensible air thermometer be moved in succession, through the different coloured rays, it will be found to indicate the greatest heat in the red rays; next in the green: and so on, in a diminishing progression, to the violet. Dr. Herschell first ascertained these facts, and his attention was directed to the subject by the following circumstance. In viewing the sun by means of large telescopes, through differently coloured darkening glasses, he sometimes felt a strong sensation of heat with very little light, and at other times, he had a strong light with little heat, differences which appeared to depend on the colour of the glasses which he used.

† Thus, red glass transmits all the rays but the red one; blue cloth absorbs all but the blue one, which it reflects. A body which transmits or reflects all the rays is colourless, while one which absorbs them all is black.



*Is not solar light capable of producing great chemical changes?*

Yes. A familiar instance of this is the blackening of indelible or marking ink, the traces of which are at first invisible, but soon become black on exposure to sun-shine, or even to daylight, from the decomposition of the salt of silver which it contains.\*

*Then solar light is composed of three distinct rays: have the goodness to recapitulate them.*

They are 1st, the luminous rays, affording light; 2nd, the calorific, causing heat; and 3rd, the chemically-acting ray.

*Are you aware of any marked effects which light has on the vegetable and animal creation?*

I am sensible that the agency of light exerts a remarkable influence over both the vigour and colour of vegetables and animals. Plants, for instance, may be made to vegetate tolerably well

According to this theory of colour, it is altogether a chemical phenomena. Light consists of different elements, and colour is occasioned by the different affinities possessed by other bodies for the different component parts of light. Colours, chemically speaking, are properties produced by the union of some ray or rays of light with particular bodies, from their having a greater or less affinity for them.

It should not be concealed, however, that this theory of different coloured bodies only reflecting certain rays, is not without objections. Thus, it may with propriety be said, if *black* bodies absorb *all* the rays of light, it is difficult to explain how they are seen; on the other hand, white bodies cannot reflect all the rays undivided, or, according to the theory, they too would not be seen any more than light itself is seen.

\* The prismatic rays have different powers in inducing these changes. When, for example, a spectrum is produced, and a line is drawn with the ink, in the different rays, and exposed to sun-shine, that in the violet ray is soonest blackened.

More examples of the chemical powers of light will be exhibited in the subsequent parts of this volume.



in the dark; but then their colour is always white, they have scarcely any taste, and contain but a very small proportion of combustible matter. In a very short time, however, after their exposure to light, their colour becomes green, their taste is rendered much more intense, and the quantity of combustible matter is considerably augmented. The colour of animals depends materially on the same agency, as is proved by the striking difference of colour existing between the animals of the frigid and torrid zone.\*

*Have not certain bodies the property of absorbing the rays of light, of retaining them for some time, and of again evolving them unchanged, and unaccompanied by sensible heat?*

Yes. Thus, in an experiment of Du Fay, a diamond exposed to the sun, and immediately covered with black wax, shone in the dark, on removing the wax, at the expiration of several months. Bodies, gifted with this property, are called *solar phosphori*. Such are Canton's,† Baldwin's, and the Bolognian phosphori. To the same class belong several natural bodies, which retain light, and give it out unchanged. Thus, the sea is occasionally, when agitated, a natural solar phosphorus; putrid fish have a

\* Dr. Paris very correctly observes, "Nor is man himself insensible to the same action, hence the pale, sallow, and sickly appearance of those persons who are excluded from 'the light of heaven.'" *Medical Chemistry*, p. 226.

† A composition made by heating to redness a mixture of calcined oyster shells and sulphur. It is made by mixing three parts of calcined oyster



similar property;\* and the glow-worm belongs to the same class.†

shells in powder, with one of flowers of sulphur, when the mixture is rammed into a crucible, and ignited for half an hour. The bright part of this mixture will, on exposure to the sun-beam, or to the common day-light, or to an electrical explosion, acquire the faculty of shining in the dark, so as to illuminate the dial of a watch, and make its figures legible.

\* It appears from Dr. Hulme's experiments and observations (*Philos. Trans.* p. 1790,) that the quantity of light emitted by dead animal substances is not in proportion to the degree of putrefaction in them, as is commonly supposed; but, on the contrary, the greater the putrescence, the less light is evolved. It would seem, that this element, endowed with pre-eminent elasticity, is the first to escape from the condensed state of combination in which it had been imprisoned by the powers of life; and is followed, after some time, by the relatively less elastic gases, whose evolution constitutes putrefaction.

† The following remarks of Dr. Ure respecting *solar phosphori*, are worthy of much notice, as, indeed, are most of the observations of that enlightened philosopher. "Some philosophers," says he, "refer the origin of all luminous phenomena to the sun, whose beams are supposed to penetrate, and combine with the different forms of terrestrial matter. But we learn from scripture, that light pre-existed before this luminary, and that its subsequent condensation in his orb was a particular act of Almighty power. The phosphorescence of minerals, buried since the origin of things in the bowels of the earth, coincides strictly with the mosaic account of the creation. We shall, therefore, regard light, the first-born element of chaos, as an independent essence, universally distributed through the mineral, vegetable, and animal world, capable of being disengaged from its latent state by various natural and artificial operations." *Dictionary of Chemistry*, p. 570.



## CHAPTER VI.

## OF ELECTRICITY\* AND GALVANISM.

*What opinion is commonly entertained respecting the NATURE OF ELECTRICITY?*

It is now very generally regarded, like the other imponderable elements (pages 40, 97) as a highly subtile elastic fluid, too light to affect our most delicate balances, moving with inconceivable velocity, and present in all bodies.†

*How are bodies made to exhibit electrical phenomena?*

By being excited: and the best mode of exciting them is by friction.

*And can all bodies be excited so as to be made to exhibit electrical phenomena by friction?*

Yes; but there is a great difference among bodies with regard to the ease with which they

\* The term electricity has its origin from the greek word *electron*, signifying amber, in which substance some of the facts of electricity were first observed. Of course, we shall here advert only to the chemical agencies of electricity and galvanism, and to so much of their general history, as is necessary in order to enable the student fully to understand those agencies. For a detailed account of the subject, a reference may be made to *Cuthbertson and Cavallo's Treatises on Electricity*, and *Wilkinson and Bostock on Galvanism*.

† It is one of the most active principles in nature. It is the cause of thunder and lightning; the phenomena of galvanism are produced by it; and it exerts so marked an influence over chemical changes, as to have given plausibility to the opinion that it is the cause of them.



are made to excite electricity. Hence, those substances which are easily excited, are called *electrics*, or *non-conductors*; and those which are excited with difficulty are termed *non-electrics*, or *conductors*.\*

\* The following substances are *electrics* or *non-conductors*, placed in the order of their insulating power:—

- |   |  |
|---|--|
| 1. Shell Lac.   | 14. Baked Wood and Dried Vegetables.     |
| 2. Amber.   | 15. Porcelain.                           |
| 3. Resins.  | 16. Marble.                              |
| 4. Sulphur.   | 17. Massive Minerals, non-metallic.      |
| 5. Wax.   | 18. Camphor.                             |
| 6. Asphaltum.   | 19. Caoutchouc.                          |
| 7. Glass and all vitrified bodies, comprehending diamond, &c. | 20. Lycopodium.                          |
| 8. Raw Silk.  | 21. Dry Chalk and Lime.                  |
| 9. Bleached Silk.   | 22. Phosphorus.                          |
| 10. Dyed Silk.  | 23. Ice below zero of Fahr.              |
| 11. Wool, Hair and Feathers.                                  | 24. Oils, of which the densest are best. |
| 12. Dry Gases.  | 25. Dry Metallic Oxides.                 |
| 13. Dry Paper, Parchment and Leather.                         |  |

Here follows a list of *non-electrics*, or *conductors*, that is, substances which favour the rapid distribution of electricity.

- |                          |                              |
|--------------------------|------------------------------|
| 1. Copper.               | 16. Saline Solutions.        |
| 2. Silver.               | 17. Animal Fluids.           |
| 3. Gold.                 | 18. Sea Water.               |
| 4. Iron.                 | 19. Water.                   |
| 5. Tin.                  | 20. Ice and Snow above zero. |
| 6. Lead.                 | 21. Living Vegetables.       |
| 7. Zinc.                 | 22. Living Animals.          |
| 8. Platinum.             | 23. Flame.                   |
| 9. Charcoal.             | 24. Smoke.                   |
| 10. Plumbago.            | 25. Vapour.                  |
| 11. Strong Acids.        | 26. Salts.                   |
| 12. Soot and Lamp-black. | 27. Rarefied Air.            |
| 13. Metallic Ores.       | 28. Dry Earths.              |
| 14. Metallic Oxides.     | 29. Massive Minerals.        |
| 15. Dilute Acids.        |                              |



*Why are these different substances respectively called CONDUCTORS and NON-CONDUCTORS ?*

Because when an electric, as a stick of sealing wax, is rubbed and electricity excited, if a non-electric, as a piece of silver be brought near it, the electricity is conducted or carried off; if, however, an electric, such as a piece of glass, for instance, be approached, it is not carried off, but allowed to accumulate. The former, viz. non-electrics, are, therefore, said to *conduct* it, and hence, the division of bodies into *conductors* and *non-conductors*. Electrics, it has been said, do not conduct it, while non-electrics conduct; *electrics* are therefore, *non-conductors*, and *non-electrics* are *conductors*.\*

*You have mentioned FRICTION as the best means of exciting electricity, in other words, of disturbing the electrical equilibrium; but what other means are there of producing this effect ?*

The other means of exciting electricity are 1st, by the fusion of inflammable bodies; †

\* The want of power in some bodies, to show signs of electric excitation, can be easily accounted for. If we suppose that this agent exists in all objects, and becomes sensible by friction, the less quickly the excited body conducts it, the more powerfully will it retain it, and, of course, the more easily can it be made to shew it; whereas, when the object is a good conductor, almost the instant it is evolved, it will be conveyed away. Hence, though electricity becomes sensible when a metal is rubbed, yet, as the metal conducts it with amazing rapidity, it is with great difficulty it can be detected.

† If, for example, we pour melted sulphur into an insulated metallic cup, we shall find after it concretes, that the sulphur and cup will be both electrified; the former with the vitreous, and the latter with the resinous electricity; and sometimes reversely.



2dly, by *evaporation*; \* 3rdly, by *disengagement* of gas; † 4thly, by *disruption of a solid body*; ‡ 5thly, by *change of temperature*; § 6thly, by *contact of dissimilar bodies*.||

*When two substances are rubbed together what happens?*

\* If on the cap of the gold leaf electroscope we place a small metallic cup, containing a little water, and drop into it a red hot cinder, the gold leaves will instantly diverge to a very considerable angle.

† If into a platinum cup, resting on the top of the electroscope, we put a little dilute sulphuric acid, and then throw in some iron-filings, or chalk, the gold leaves will diverge as the effervescence becomes active. The same thing results from putting copper filings into nitric acid.

‡ If we suddenly break across a stick of sealing wax, cleave up a piece of dry and warm wood, or cause a bit of unannealed glass, such as a Prince Rupert's drop, to fly asunder, by snapping off a bit of its tail, the electrical equilibrium will be disturbed. It is, however, thought that most of these cases may be probably referred to friction among the molecules of the bodies.

§ Thus, a particular variety of tourmaline, which is a prismatic crystal of nine sides, terminated at one end with a three-sided, and at the other with a six-sided pyramid, when exposed to the temperature of 108° Fahr. shows no sign of electricity. But if we plunge it for some minutes into boiling water, and taking it out with small forceps, by the middle of the prism, present it to the cap of the electroscope, or to a pith ball pendulum, already charged with a known electricity, we shall find it will attract it with one of its poles, and repel it with the other. The three-sided pyramid possesses the resinous, and the six-sided the vitreous electricity. It is remarkable that when the stone is of considerable size, flashes of light may be seen along its surface.

M. Haüy made the discovery, that the property of exhibiting electrical phenomena by heat, belongs to those crystals only whose forms are not symmetrical; that is to say, of which one extremity or side does not correspond with the opposite.

|| If we take two flat discs, one of silver or copper, and another of zinc, each two or three inches diameter, furnished with glass handles, and bring them into a momentary contact by their flat surfaces, we shall find, on separating them, that they are both electrified. If we touch a disc of sulphur gently heated with the insulated copper plate, the electrical effects will be still more striking. On the excitation of electricity by contact of dissimilar chemical bodies, is founded the principle of galvanic action, and the construction of the voltaic battery.



Both of them are excited, but they are thrown into opposite states of electricity.

*Are there, then, two kinds of electricity?*

Some philosophers suppose there are two kinds, one of which they term *vitreous*, the other *resinous* electricity; the former being peculiar to glass when rubbed with a woollen cloth, and the latter to amber, sulphur, and resinous substances under similar treatment.\* But others think there is only one kind of electricity, which exists in different states, which are expressed by the terms *positive* and *negative*,† the first corresponding to the vitreous, the second to the resinous electricity just mentioned.‡

\* This view of the subject originated with a M. Dufay. He was led to this distinction by observing that two bodies, which possess the same kind of electricity, repel one another, and that substances in an opposite electrical condition attract each other. These facts are considered explicable on the supposition that a repulsive power is exerted between the particles of the same kind of electricity, which causes an excited body to repel any other which is similarly electrified. The opposite electricities, on the contrary, are supposed to attract one another; and hence, an attraction will be exerted between any two substances, one of which possesses vitreous and the other resinous electricity. An unexcited body, according to this view, contains both electricities in a state of combination, or neutralization, and cannot, therefore, exhibit any electrical attractions or repulsions. But friction, &c. disturbs this combination, or electric equilibrium, as it is often called, causing the vitreous electricity to accumulate in one body, and the resinous in the other. They are both, consequently, in an excited state, and continue to be so till each recovers that kind of electricity which it had lost.

† This is Dr. Franklin's theory, and the one generally preferred in this country.

‡ It should be observed, that when bodies contain their natural quantity of electricity, they do not manifest any electrical properties; but they are excited either by an increase or diminution in that quantity. Thus on rubbing a piece of glass with a woollen cloth, the electrical condition of both substances is disturbed; the former acquires more, the other less than its natural quantity. Hence arises the terms *plus* and *minus*, or *positive* and *negative* electricity.



*How do you discover when any substance is excited, and the kind of electricity which it possesses?*

By the electrical attractions and repulsions which it exhibits. Thus, a body is known to be in an excited state by its power of attracting light substances, or by causing two pith balls, suspended by silken threads, to repel one another when it is brought in contact with them.\* The strength of the electricity is estimated by the extent of the divergence. If a pith ball, suspended by a silken thread, is rendered positive by being touched with an excited stick of glass, it will of course be repelled by presenting a positively electrified body to it; and, on the contrary, it will be attracted by one which is negative.†

*What general law, or important fact, is founded on this circumstance of the positive body repelling the positive, and attracting the negative?*

That BODIES SIMILARLY ELECTRIFIED REPEL

\* Instruments of this kind are called electroscopes and electrometers; and one of the most sensible is that of Mr. Bennett, which is made with two slips of gold leaf, and is hence called the Gold-leaf Electrometer.

† No visible relation can be pointed out between the nature and construction of the substances, and the *species* of electricity which is developed by their mutual friction. The only general law among the phenomena is, that *the rubbing, and the rubbed body, always acquire opposite electricities*. Sulphur is vitreously electrified when rubbed with every metal except lead, and resinously with lead and every other kind of rubber. Resinous bodies rubbed against each other, acquire alternately the vitreous and resinous electricity; but, rubbed against all other bodies, they become resinously electrical. White silk acquires vitreous electricity with black silk, metals, and black cloth; and resinous with paper, the human hand, hair, and weasel's skin. When two ribands of equal surface are excited by drawing one lengthwise over a part of the other, that which has suffered friction in its whole length becomes vitreously, and the other resinously, electrical. Silk stuffs agitated in the atmosphere with a rapid motion, always take the resinous electricity, while the air becomes vitreously electrified.



EACH OTHER, and THOSE WHICH ARE DIFFERENTLY ELECTRIFIED ATTRACT EACH OTHER.

*Will you describe the common electrical machine?*

It consists of a large cylinder or plate of glass, which is made to revolve by means of a handle, and is pressed during its rotation by cushions stuffed with hair, so as to produce considerable friction.\* The positive electricity excited on the glass is conducted away by insulated bars of brass or other metal, called the prime conductor, where it is collected in considerable quantity. The advantage of this arrangement is, that the electricity, spread over the whole surface of the prime conductor, passes at once to any substance which touches one point of it.†

*On what principle is the Leyden phial constructed, which is so frequently used with the machine just described?*

Proximity to an electrified body is a cause of electrical excitement, the body having a tendency to induce an electric state opposite to its own. Thus, an excited stick of sealing-wax attracts light bodies in its vicinity, because, being

\* It must be remembered, that to excite electricity, an electric is rubbed either against another electric or a non-electric ; and the common instrument for this purpose is the electrical machine above described. In this machine, the cylinder and prime conductor are supported on non-conductors, or glass rods, in order that the electricity may not be carried off. They are, therefore, said to be *insulated*.

† It is remarkable, that many animals have the power of giving an electric shock at pleasure. Those which possess this power in the greatest degree are, the *Gymnotus Electricus* of South America, and the *Torpedo*, which occurs on the shores of the Mediterranean, and also on the coast of Britain. These animals have a supply of electricity, as is shown by touching them, by which they give a shock sufficient even to kill a small animal.



itself negative, it causes them to be positively electrified. When the inside of a glass bottle is rendered positive by contact with the prime conductors of the electrical machine, the outside of it, if in communication with the earth, becomes negative, and on this depends the construction of the Leyden phial. It is merely a glass bottle or jar, coated to within three or four inches of its top, both externally and internally, with tin-foil. Its aperture is closed by some non-conducting substance, through the centre of which passes a metallic rod that communicates with the tin-foil in the inside of the jar. The phial is charged by holding the outside of it in the hand, or placing it on the ground, while the metallic rod is made to receive sparks from the prime conductors.\*

*What circumstances are essential to the perfect success of experiments with the electrical machine?*

The machine must be connected with the earth, which is usually effected by means of a metallic chain; and a dry atmosphere is requisite.† Moist air, being a conductor, carries off the electricity almost as fast as it is excited.

\* If in this charged state, the two surfaces are made to communicate by means of some conductor, the electric equilibrium will be instantly restored. An electrical battery is composed of a series of Leyden phials communicating with one another. The battery is charged and discharged in the same manner as a single phial.

† Dry air is a non-conductor of electricity. All objects, whether conductors or non-conductors, become, in a greater or less degree, conductors when moist; hence it is that during rain, or in crowded rooms, electrical experiments do not succeed, the air and apparatus being rendered so damp, that the moment the electricity is excited, it is carried off.



*What phenomena usually accompany the passage of electricity?*

In passing from one body to another it passes with immense velocity,\* and is usually accompanied with great heat, and often with light. Thus, Dr. Watson made electricity pass four miles across the mouth of the Thames in an instant of time. The most familiar examples of the latter phenomena are exhibited in its passage through the air, when it gives rise to a spark attended by a peculiar snapping noise, if in small quantity; or to thunder and lightning, when it takes place on a larger scale.†

*What are the principal effects of electricity, and the uses to which it is applied in a chemical point of view?*

Its effects and uses in this point of view are

\* When a *Leyden jar* is discharged, the electricity travels along its wire, and that of the discharger; and it might be expected, that as the discharger is lengthened, it would require a longer time to pass along it; this is not, however, the case. Thus, if the communication be made by means of a chain, fixed to the walls of a room, and at each corner be connected with a bladder, full of an explosive mixture of oxygen and hydrogen, when the jar is discharged by it, the whole of the bladders are exploded at the same instant, even though many feet separate.

† The heat accompanying an electrical discharge is often so great as to set fire to bodies: thus, if cotton, besmeared with powder of resin, has a spark passed through it, it is kindled, provided the machine is in good condition.

Dr. Turner correctly observes, in his *Elements of Chemistry*, page 75, that "the production of heat and light invariably ensues when electricity meets with an impediment to its progress, as in passing through a non-conductor. On the contrary, it passes along perfect conductors, such as the metals, without any perceptible warmth, or light, provided the extent of their surface is in proportion to the quantity of electricity to be transmitted by them; but if the charge is too great in relation to the extent of the conducting surface, an intense degree of heat will be produced."



numerous. It occasions remarkable changes on gaseous bodies,—causing the union of some, and the decomposition of others;\* it accelerates evaporation; it proves a stimulus to the animal frame, as in suspended animation, &c.:† in fine, it has a remarkable influence in modifying, exalting, or destroying, the chemical powers of matter generally.‡

\* From this property of electricity, it proves a valuable means of analysis, because by the transmission of sparks through gases, some are made to enter into union, and are probably condensed, while others, if compound, have their ingredients separated; so that by marking the condensation or enlargement, the composition of the substances may be discovered.

† In applying it in cases of palsy, muscular contractions, pains, &c. the part of the body to be subjected to its influence, is merely made part of the chain of communication, by which a Leyden jar is discharged. Thus, in passing it through the arm, the jar being charged, is held in the hand, and applied to the shoulder; and in carrying it through the leg, a chain being tied around the thigh, is connected with the jar, which is then to be charged, and by applying the knob to any part of the foot, the electricity is transmitted through the extremity, which is then made a part of the chain of communication. An easy method of electrifying, particularly when it is desired to bring the body generally under its influence, is to make the person stand on an electrical stool, and take hold of the conductor. As he is insulated, the electricity in passing from the machine into him does not fly off, but is accumulated; and it may be withdrawn from any part by another approaching a metallic rod, fixed in a glass handle.

‡ “Most of the substances that act distinctly upon each other electrically are likewise such as act chemically, when their particles have freedom of motion; this is the case with the different metals, with sulphur and the metals, with acid and alkaline substances; and the relations of bodies are uniform; those that have the highest attracting powers being in the relation of positive, in arrangements in which chemical changes go on. Thus, zinc is positive with respect to iron, iron with respect to copper, copper with respect to silver, and so on in all combinations in which oxygen is capable of being combined with the metal; but copper is positive with respect to iron in compound menstrua containing sulphur; the electrical power being in all cases apparently connected with the power of chemical combination.”

“All the acid crystals, upon which I have experimented, when touched by a plate of metal, render it positive. And in voltaic combinations with



*Thunder and lightning are considered electrical phenomena: Can you explain how they are produced?*

The aqueous vapour which arises from the surface of the earth, as it is condensed, forms clouds, which become electrified, and the earth being in an opposite state, if they approach, an electric spark passes between them. Electricity also often flies from one cloud to another, the one having been positively, the other negatively electrified. This is the cause of lightning, and the vibration produced in the air occasions thunder, which is more or less loud according to the quantity of electricity, and the distance at which it is heard.\*

single plates or arcs of metals, the metal is negative on the side opposed to the acid, and positive on the side or pole opposed to the alkali.

“Bodies that exhibit electrical effects previous to their chemical action on each other, lose this power during combination. Thus, if a polished plate of zinc is made to touch a surface of dry mercury, and quickly separated, it is found positively electrical, and the effect is increased by heat; but if it be so heated as to amalgamate with the surface of the mercury, it no longer exhibits any marks of electricity.”—*Sir Humphry Davy, Elements of Chemical Philosophy*, vol. i. p. 158.

\* Sir Humphry Davy's remarks on this subject may be read with advantage. He says, “As electricity appears to result from the general powers or agencies of matter, it is obvious, that it must be continually exhibited in nature, and that a number of important phenomena must depend upon its operation. When aqueous vapour is condensed, the clouds formed are usually more or less electrical; and the earth below them being brought into an opposite state, by induction, a discharge takes place when the clouds approach within a certain distance, constituting lightning, and the undulation of the air, produced by the discharge, is the cause of thunder, which is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place, where the report is heard from the point of the discharge. It may not be uninteresting to give a further illustration of this idea: electrical effects take place in no sensible time; it has been found, that a discharge through a circuit of four miles is instantaneous; but sound moves at the rate of about twelve miles in a minute. Now, supposing the lightning to pass through a space of



*Is then the electricity discharged in the heavens, the same as that given out by an electrical machine?*

Yes: this was proved by Dr. Franklin in the following simple manner. He elevated into the air a silk kite, from which there descended a cord containing a metallic wire, attached to a conductor, supported on a glass rod. By this he was enabled to charge a Leyden jar, which, when discharged, produced the same effect as common electricity.

*What precautions does a knowledge of the laws of electricity point out as proper to be taken in order to avoid an injury during a violent thunder storm?\**

It teaches us, that in such a case the lowest ground is the safest situation, and a horizontal posture, the least dangerous; that the neighbourhood of trees, or buildings, should be avoided, particularly of trees, the living juices of which are calculated to conduct the electricity, and make part of a circuit; that in a house, the cellars are the safest places, and that in a room the person should stand as far as possible from the fire.†

some miles, the explosion will be first heard from the point of the air agitated nearest to the spectator; it will gradually come from the more distant parts of the course of the electricity; and last of all, will be heard from the remote extremity; and the different degrees of the agitation of the air, and likewise the difference of the distance, will account for the different intensities of the sound, and its apparent reverberations and changes."—*Elements of Chemical Philosophy*, vol. i. p. 140.

\* It is thought that in a thunder storm, when the sound instantly succeeds the flash, the persons who witness the circumstance, are in some danger; when the interval is a quarter of a minute, they are secure.

† The cause of the fire being a dangerous situation in these cases, is explained thus: In an exhausted receiver electricity passes very rapidly: on



*What is meant by the term GALVANISM?*

Galvanism is the name given to the phenomena excited or produced by the galvanic apparatus.\*

*What are the conditions necessary to the excitement of Galvanic electricity?*

All that is required is the simple contact of *different* conducting bodies with each other.†

this principle, a current of heated and rarefied air passing up the chimney is a good conductor, and therefore there is danger near the fire-place.

One of the most useful applications of our knowledge of the laws of electricity is the means which it has pointed out of protecting buildings from being destroyed by lightning, which consists in erecting what are called *conductors*. These are merely copper or iron rods, the thickness depending on the size of the building, fixed to the outer walls, reaching to a certain height above the highest point, and descending into the earth a little below its foundation, and terminating in a pool of water. It has been found that a conductor will protect from lightning a circular space, the diameter of which is four times the length of the rod itself, measured from the highest point of the object to which it is fixed. Its height ought, therefore, to be, taking it from the highest part of the building, rather more than a fourth of the diameter of the building itself.

Since pointed bodies receive electricity much more easily than blunt ones, conductors ought therefore to be terminated by a number of points, that they may draw towards them the electricity which is discharged from the clouds, and a metal ought also to be used that is not liable to be affected by the weather; hence they are generally made of copper. In fixing a conductor for the present purpose, it is necessary to use a substance that is a non-conductor, otherwise, instead of defending it would be the means of destroying the building, by transmitting the electricity through it. Therefore, it is attached to iron staples, but covered with cloth and pitch to make them non-conductors. Conductors should always be made to take the shortest course from the top to the bottom of the building, and all the parts of the roof covered with metal should be attached to it by means of rods, that the lightning may be carried off from them.

\* It is sometimes called *Galvanic*, or *Voltaic Electricity*. Galvanism derives its name from Galvani, an Italian philosopher, and professor of anatomy at Bologna, who in the year 1791, being engaged in a course of experiments on animal irritability, observed accidentally the contractions, which are excited in the limbs of frogs, by applying a conductor of electricity between a nerve and a muscle.

† It should be noticed, that for the excitation of ordinary electricity, a class of substances are required, called *electrics*, by the friction of which



*What is the simplest Galvanic arrangement called?*

*A simple Galvanic circle; which consists of three conductors, two of which must be perfect conductors, and one an imperfect conductor, or vice versa, that is, one perfect conductor, and two imperfect conductors.\**

the electric fluid is accumulated, and from which it may be collected by a different class of bodies termed *non-electrics* or conductors, (see page 105); for the excitement of Galvanic action the conditions are quite different, since the class of bodies termed *electrics*, have now no longer any share in the phenomena.

\* The annexed tables, taken from Sir Humphry Davy's *Elements of Chemical Philosophy*, (vol. i. p. 148,) contain some series of both kinds, arranged in the order of their powers; the substance which is most active being named first in each column. Among the good or perfect conductors are the metals and charcoal. The imperfect conductors are water, and saline or acid solutions.

*Table of some Electrical Arrangements, which, by combination, form Voltaic Batteries, composed of two perfect Conductors and one imperfect Conductor.*

Zinc, Iron, Tin, Lead, Copper, Silver, Gold, Platina, Charcoal.	Each of these is the positive pole to all the metals below it, and negative with respect to the metals above it in the column.	Solutions of nitric acid, .... muratic acid, .... sulphuric acid, .... sal ammoniac, .... nitre, .... other neutral salts.
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*Table of some Electrical Arrangements consisting of one perfect Conductor and two imperfect Conductors.*

Solution of sulphuret of potass, .... of potass, .... of soda.	Copper, Silver, Lead, Tin, Zinc, Other metals, Charcoal.	Nitric acid, Sulphuric acid, Muriatic acid, Any solutions containing acid.
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*How is the power of A SIMPLE GALVANIC CIRCLE shewn?*

Its power is inconsiderable, but it may be shewn in the following way:—If a piece of zinc is laid upon the tongue, and a piece of silver under it, no sensation is excited, so long as the metals are kept apart; but, on bringing them into contact, a metallic taste is distinctly perceived. Here we have an example of the arrangement of two perfect conductors (the metals) with one imperfect one (the tongue, or rather the fluids which it sustains.) It is considered that the metallic taste arises from the excitement of a small quantity of electricity by the contact of the metals, and its action on the nerves of the tongue.\*

In all combinations in which the fluids act chemically by affording oxygen, the positive pole is always attached to the metal which has the strongest affinity for oxygen; but when the fluid menstrua afford sulphur to the metals, the metal which has the strongest affinity for sulphur will be positive. Thus, in a series of copper and iron plates introduced into a porcelain trough, the cells of which are filled with water or acid solutions, the iron is positive, and the copper negative; but when the cells are filled with solution of sulphur and potass, the copper is positive, and the iron negative.

In all combinations in which one metal is concerned, the surface opposite to the acid is negative, and that in contact with the solution of alkali and sulphur, or of alkali, is positive.

\* A piece of zinc, immersed under water which is freely exposed to the atmosphere, oxidizes very slowly; but when placed in the same situation, in contact with a piece of silver, its oxidation is much more rapid. By immersing iron and silver (also in contact with each other) under diluted muriatic, the action of the acid upon the iron is considerably increased; and hydrogen gas is evolved from the water, not only where it is in contact with the iron, but where it touches the silver. These facts explain, why, in the sheathing of ships, it is necessary to use bolts of the same metal which forms the plates; for if two different metals be employed, they both oxidate or rust very speedily, in consequence of their forming, with the water of the ocean, a simple Galvanic circle.—See Dr. Henry's *Elements of Chemistry*, vol. i. p. 166.



*What is a COMPOUND GALVANIC CIRCLE OR BATTERY?*

Galvanic batteries are formed by multiplying those arrangements which compose simple circles. Thus, if plates of zinc and of silver, and pieces of woollen cloth of the same size as the plates and moistened with water, be piled on each other, in the order of zinc, silver, cloth; zinc, silver, cloth; and so on, for twenty or more repetitions, we obtain a Galvanic battery.\*

*Is the power of the Galvanic battery much greater than that of the simple circle?*

It is very much greater, and may be rendered intense by increasing the number of alternations of zinc, silver, and cloth. The power of the battery is sufficient to give a smart shock, as may be felt by grasping in the hands, which should be previously moistened, two metallic rods, and touching with these the upper and lower extremities of the pile.†

*What is the construction of the Galvanic battery now in general use?*

It is a long narrow trough, made of glazed earthenware, and divided into partitions or cells of the same material. Each cell contains a plate

\* This is sometimes called the *Voltaic Pile*, from Signor Volta, its discoverer.

† The sensations excited by the battery are very peculiar. If a metallic ball be placed at each end, and the hands, after being wetted, are put on them, there is a thrilling in the fingers and arms, which becomes painful if the battery be large; at the same time convulsive movements in the muscles are excited. It is necessary, however, for the success of this experiment, that the hands be wet, and the greater the extent of moistened surface, the more powerful are the effects.



of zinc, and another of copper, which do not touch each other, but communicate merely through the medium of the fluid in which they are immersed. The zinc plate of one cell is connected with the copper of the adjoining one by means of a slip of copper. All the plates are attached to a piece of wood, and may thus be introduced into the liquid of the trough, or removed from it at pleasure.\*

*Is the galvanic influence different from that of ordinary electricity?*

No; it is considered identical with it.

*Why is it considered so?*

Because of the striking resemblances existing between the phenomena occasioned by the agency of the electric fluid, and those produced by galvanism. For example, the sensation produced by the galvanic shock, is extremely similar to that which is excited by the discharge of a Leyden jar. Both influences, also, are propagated through a number of persons, without any perceptible interval of time. Again, those bodies which are conductors of electricity, are likewise conductors of the galvanic fluid. This fluid

\* These Galvanic batteries are now so common, being to be seen in almost every chemist's shop, that it is thought unnecessary to introduce a plate of one here.

Dr. Wollaston has suggested an additional improvement to the battery described above. He recommends that each cell should contain one zinc and two copper plates, so that both surfaces of the first metal are opposed to one of the second. In consequence of this arrangement, the plates of copper communicate with each other, and the zinc between them with the copper of the adjoining cell. An increase of one half the power is obtained by this method.



passes through air, and certain other non-conductors, in the form of sparks, accompanied with a snap or report; and, like the electric fluid, it may be made to inflame gun-powder, phosphorus, and mixtures of hydrogen and oxygen gases.\*

*What are the chemical effects of galvanism?*

They are striking and important. The most remarkable action exerted by the galvanic fluid is in disuniting the elements of several combinations, that is, in effecting the decomposition of substances. By its agency we have been enabled to ascertain the decomposition of some bodies, till then reckoned simple, and new bodies have also by its aid been discovered, which have themselves proved powerful means of analysis.

*What bodies have been decomposed by it?*

The substance first decomposed by it was water. When two gold or platina wires are connected with the opposite poles of a battery, and their free extremities are plunged into the same cup of water A, but without touching each other, hydrogen gas is disengaged at the negative wire B, and oxygen at the positive side C, (See

\* The following resemblances between these two fluids, may be added to those above stated. The Galvanic apparatus is capable of communicating a charge to a Leyden jar, or even to an electrical battery. If the zinc end of a pile (whether it be uppermost or the contrary) be made to communicate with the inside of a jar, it is charged positively. If circumstances be reversed, and the copper end be similarly connected, the jar is charged negatively. The shocks do not differ from those of a jar or battery, charged to the same intensity by a common electrical machine. The chemical changes produced by Galvanic and common electricity, so far as they have hitherto been examined, are precisely similar.



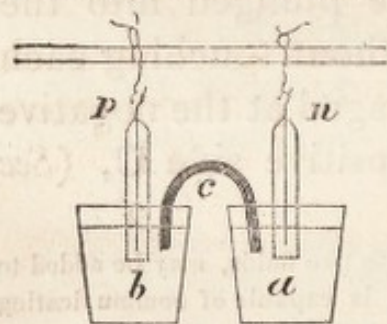
figure 5, in the plate at page 1). \* By collecting the gases in separate tubes, as they escape, they are found to be quite pure, and in the exact proportions which, by their union, compose water, viz. two measures of hydrogen to one of oxygen.†

\* It should be observed, that the two ends of the Galvanic pile are always in opposite states of electricity. The zinc, or most oxidable termination, exhibiting the *plus* or *positive*; the copper, or less oxidable, being in the *minus* or *negative* state. This has, consequently, given rise to the distinction of the ends of the trough, and of the wires coming from them, into *positive* and *negative*. By the positive wire, then, is to be understood that from the zinc or most oxidable metal, and which exhibits the plus or positive electricity; by the negative is meant that from the copper, or least oxidable end, and which is in the minus or negative state.

It is a grand law of electro-chemical decomposition, established by Sir H. Davy, that metals, inflammable bodies, alkalies, earths, and oxides, are determined to the negative surface or pole, and oxygen, chlorine, iodine, and acids, to the positive pole.

† The above effects take place only when the wires employed are of a metal which is not readily susceptible of oxidation, such as gold or platina; if a more oxidable metal be employed, the result is somewhat different, since the hydrogen gas appears as usual at the negative pole, but the oxygen, instead of escaping, combines with the metal (of the wire,) and converts it into an oxide.

It is a most extraordinary fact, that these gases may be thus obtained from two quantities of water, not immediately in contact with each other.



Thus, if two glass tubes, *p* and *n*, about one-third of an inch in diameter, and four inches long, having each a piece of gold wire sealed hermetically into one end, and the other end open, be filled with distilled water, and placed inverted in separate glasses, filled, also, with the same fluid, and the two glasses *a*, *b*, are made to communicate by the interposition of moistened thread, as shewn at *c*, as soon as the wires, projecting from the sealed ends of the tubes be connected, the one with the *positive*, the other with the *negative* end of the trough, gas will be immediately evolved, as in the above experiments. Now, since these gases must necessarily arise from the decomposition of one and the same particle of water, and since that particle must have been contained either in the tube *p* or in the tube *n*, it is evident



*But are not other compound bodies, such as salts and acids, readily decomposed by the same means?*

Yes. In Sir Humphry Davy's experiments he employed two agate cups, N, and P, *figure 6*, the first communicating with the negative, the second with the positive pole of the battery; the cups being connected together by the fibres of a peculiar flexible mineral called amianthus A. On putting a solution of sulphate of potass into N, and distilled water into P, the acid very soon passed over to the latter, while the liquid in the former, which was at first neutral, became distinctly alkaline.\* The acid in this experiment must, therefore, have passed, in an imperceptible form, along the connecting amianthus, from the vessel N to the vessel P.

*In another experiment performed by Sir Humphry Davy, he demonstrated in a still more striking manner the remarkable power of the galvanic battery in effecting decomposition: Do you know what I refer to?*

You refer to the experiment in which he showed, that the galvanic influence is so powerful as even to suspend the operation of affinity,

that either the oxygen, or the hydrogen gas, must have passed invisibly from *p* to *n*, through the intervening substance *c*.

Mr. Nicholson and Sir A. Carlisle first pointed out the power of the Voltaic pile in decomposing water.

\* If the process be reversed by placing the sulphate of potass in P, and the distilled water in N, the alkali passes over to the negative cup N, leaving pure acid in the positive. That the acid in the experiment related above in the text, and the alkali in this experiment, actually passed along the amianthus, although in an imperceptible form, is certain; for, on one occasion, when nitrate of silver was substituted for the sulphate of potass, the whole of the amianthus leading to N, was coated with a film of revived silver.



so entirely, as to enable an acid to pass through an alkaline solution, or an alkali through water containing a free acid, without a combination taking place between them! Thus, (*figure 7*,) solution of sulphate of potass, having been put into the negative cup N, solution of pure ammonia into I, and pure water into P, a battery composed of 150 pairs of 4-inch plates were set in action, and in a very short time sulphuric acid was found in the water of the positive cup P, though to have reached this, it must have been transferred from N through the intermediate solution of ammonia I.\*

*Sir H. Davy afterwards experimented on the fixed alkalies, potassa and soda: What was the result?*

He proved that they are not simple substances,

\* Muriatic and nitric acids were in like manner made to pass through strong alkaline solutions; and, on reversing the experiment, alkalies were transmitted directly through acid liquids without entering into combination with them.

“Such are the decomposing powers of electricity,” says Sir Humphry Davy, “that not even insoluble compounds are capable of resisting their energy; for even glass, sulphate of baryta, fluor spar, &c., when moistened and placed in contact with electrified surfaces from the Voltaic apparatus, are slowly acted upon, and the alkaline, earthy, or acid matter carried to the poles in the common order. Not even the most solid aggregates, nor the firmest compounds, are capable of resisting this mode of attack: its operation is slow, but the results are certain; and sooner or later, by means of it, bodies are resolved into simpler forms of matter.”

In the experiment with the vessels N, I, P, above detailed, it is necessary, however, that the solution, contained in the intermediate vessel I, should not be capable of forming an insoluble compound with the substance intended to be transmitted through it. Thus, sulphuric acid, in its passage from sulphate of potass in the negative cup through the vessel I, containing a solution of pure baryta, is detained by the barytes, and falls down in the state of an insoluble compound—the sulphate of barytes.



but compounds of metallic bases, (which he called *potassium* and *sodium*,) and oxygen.\*

*What is the opinion generally received in regard to the manner in which galvanism acts in effecting decomposition, and causing the evolution of different bodies at the different wires? †*

Substances by mere contact assume opposite electric conditions; and it has been proved by experiment, that by touching metals with substances which have a tendency to enter into union, they acquire different states of electricity, according to the nature of the substance with which they are brought in contact.‡ Acids com-

\* In these experiments, a small piece of potass, made a conductor by exposure to the air, so as to become moist, was placed on a platinum cup connected with the negative wire of a Galvanic battery. The moment the communication was completed, by touching it with the positive one, it began to fuse at the points of contact, at the same time there was a violent effervescence on the surface, and at those parts next the cup, minute globules, having a high metallic lustre, appeared, some of which burned, while others became covered with a white crust. In his first attempts, Sir H. Davy did not succeed in collecting the metallic matter, owing to its being inflamed; but he afterwards discovered, that by carrying on the action under the distilled oil of naphtha, the combustion was prevented, and he was thus enabled to procure a sufficient quantity to ascertain some of its properties. He found that the effervescence was occasioned by the disengagement of oxygen. The metallic globules (potassium) when heated in air, and in oxygen, were inflamed, oxygen was consumed, and potass was generated. The inference, therefore, was conclusive, that he had succeeded in decomposing the alkali, and proved it to be a compound of oxygen and a metallic base, to which he gave the name of potassium.

Similar experiments were performed with soda, and the same results obtained, the soda disengaging oxygen, and yielding a metallic matter, which was at once inferred to be its base, and called *sodium*.

† In other words, What is the theory of the changes produced by Galvanic electricity?

‡ For example, various dry acids, being touched on an extensive surface by a plate of copper insulated by a glass handle, the copper was found after contact to have become positively electrified, and the acid negatively.



municate to the metal a positive, and bases a negative condition, by which, of course, the acids themselves become negative, and the base positive. Other bodies act in the same way, thus, oxygen is itself a negative, and hydrogen and other inflammables a positive. From this it is evident, that substances may be divided into two classes, electro-positives, and electro-negatives, and as these are constantly subject to the laws of electric attraction and repulsion, they must, when united and then brought under the influence of electrified objects, be separated, and occupy different situations, according to their electric conditions. Electro-positives will be repelled by positive and attracted by negative bodies, while electro-negatives will be repelled by negatives, and attracted by positive ones, and hence, when subjected to the galvanic action, the former will collect around the negative, and the latter around the positive wires.\* In this

On the contrary, making the experiments with dry earths in a similar manner, the metal became negative. The alkalies gave less distinct results, owing to their attraction for moisture. Bodies, moreover, possessing opposite electrical energies towards one and the same body, are found to possess them with regard to each other. Thus, when lime and oxalic acid were brought into contact, the earth was found to be positive, and the acid negative. Sulphur appears to be in the positive state. Oxygen, as above remarked, and judging from those compounds in which it is loosely combined, is negative; and hydrogen, by the same test, positive.

On these facts Sir H. Davy has founded his opinion, that all bodies possess natural electric energies, which are inherent in them whether they are in a state of combination or not; some bodies being naturally negative, and others naturally positive.

\* In applying this theory to the decomposition of water, for instance, the hydrogen of this compound, being itself positively electrified, is repelled by the positive wire and attracted by the negative one; while, on the con-



way the changes produced by the agency of galvanism are usually accounted for.

*Connected with these circumstances, is an ingenious hypothesis of Sir H. Davy: What is it?*

He suggests that chemical attraction, and the phenomena of electricity, are owing to the same cause,—that the same power which communicates attractive and repellent properties to masses of matter, will, when acting upon the ultimate particles of different bodies, induce them either to separate or combine, according as their natural electric energies are the same or different.\*

trary, oxygen, being negative, is repelled by the negative wire and attracted by the positive one: Again, the flame of a candle, which consists chiefly of ignited charcoal, when placed between a positive and negative surface, bends towards the latter; but the flame of phosphorus, consisting chiefly of acid matter, when similarly placed, takes a direction towards the positive surface. So also in the case of neutral salts, the negative acid is attracted by the positive wire; and the positively electrified alkali by the negative wire.

There is a question connected with this subject, which will naturally arise in the mind of the enquiring student; it is, If all bodies which have a chemical attraction for each other have different electric conditions, how does it happen that bodies of the *same* class combine? Thus, it is well known that sulphur, carbon, phosphorus, unite with metals, and even metals with one another, though they all belong to the same class, that is, they are electro-positives. The reason of this is, that though all objects may be divided into the two classes of electro-positives, and electro-negatives, yet those in the same class are, to a certain extent, in opposite conditions *when compared with each other*. For example, in the following table of electro-positives, each substance would give electricity to any one below it; they must, therefore, be in opposite states with respect to each other, when placed in contact.

Silver,  
Copper,  
Iron,  
Lead,  
Zinc.

\* Many facts may be brought forward in support of this opinion of its



*What is the best galvanic arrangement for exhibiting the chemical agency of this fluid?*

A battery composed of an extensive series of small plates.\*

very distinguished author; yet it is considered as far from being established. It is certain that the chemical attraction between two bodies may be destroyed, by giving one of them an electrical state opposite to its natural one, thus, zinc or iron, when negatively electrified, will not unite with oxygen: on the contrary, the tendency to union may be increased, by exalting the natural electrical energies.

"This view," says Sir H. Davy, "of the possibility of the dependance of electrical and chemical action upon the same cause, has been much misrepresented. It has been supposed that the idea was entertained, that chemical changes were occasioned by electrical changes; than which nothing is further from the hypothesis which I have ventured to advance. They are conceived, on the contrary, to be *distinct* phenomena; but produced by the *same power*, acting in one case on masses, in the other case on particles."—See his *Elements of Chemical Philosophy*, p. 165.

\* No advantage is derived from using plates of a large size, since the decomposing power of the Voltaic apparatus is dependent on the number of the plates rather than on their dimensions. The enormous battery of Mr. Children, consisting of 20 double plates, 4 feet by 2, decomposed water very slowly. An acid solution should be employed for exciting the battery, and its strength should be such as to cause a moderate long-continued action, in preference to a violent and temporary one. Any of the stronger acids, as the nitric, sulphuric, and muriatic, may be used for the purpose; but the last produces the most permanent effect, and is therefore preferable. The proportion should be one part of acid to 16 or 20 of water; or if the series is extensive, the acid may be still further diluted with advantage.

A distinction is made by philosophers between *intensity* and *quantity* of electricity. By the former is meant its power of passing through a certain stratum of air, or other ill-conducting medium; by the latter, the absolute quantity of electric power in any body. In the Voltaic pile, the *intensity* of the electricity increases with the number of alternations, but the *quantity* is increased by extending the surface of the plates. For demonstrating the chemical agencies of Galvanism we require the intensity of electricity, but for the ignition or fusion of metals, quantity.

The most powerful combination that exists in which number of alternations is combined with extent of surface, is in the magnificent battery in the laboratory of the Royal Institution. It consists of 200 porcelain troughs, connected together in regular order, each composed of ten double plates, and containing in each plate thirty-two square inches; so that the whole number of double plates is 2000, and the whole surface 128,000 square inches. This battery, when the cells were filled with 60 parts of water



*How are the phenomena of the galvanic pile, and all similar arrangements, accounted for?*

It may be correctly stated, that there are three different theories concerning the action of the pile. The first is that which originated with Volta; the second is a theory of Dr. Wollaston; and the third is that entertained by Sir H. Davy. Volta conceived that the electricity was set in motion, and the supply kept up, solely by the contact of the metals. He regarded the interposed solutions merely as conductors, by means of which the electricity, developed by each pair of plates, was conveyed from one part of the apparatus to the other.\* Dr. Wollaston

mixed with one part of nitric acid, and one part of sulphuric acid, afforded a series of brilliant and impressive effects. When pieces of charcoal about an inch long and one sixth of an inch in diameter, were brought near each other (within the thirtieth or fortieth part of an inch,) a bright spark was produced, and more than half the volume of the charcoal became ignited to whiteness, and by withdrawing the points from each other, a constant discharge took place through the heated iron, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form in the middle. When any substance was introduced into this arch, it instantly became ignited; platina, (for the fusion of which a most intense heat is required,) melted as readily in it as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all entered into fusion; fragments of diamond, and points of charcoal and plumbago, rapidly disappeared, and seemed to evaporate in it, even when the connection was made in a receiver exhausted by the air-pump; but there was no evidence of their having previously undergone fusion.

\* Volta therefore disregarded the chemical changes going on between the metals and interposed fluids; but it is evident that these changes constitute an important, if not an essential, part of the process. For it is clearly ascertained that no sensible effects are produced by a combination formed of substances which bear no chemical action on each other; that the action of the pile is always accompanied by the oxidation of the zinc; and that its energy is almost in exact proportion to the rapidity with which the oxidation takes place.



believes that the chemical changes going on between the metals and the fluids in contact with them, are the primary cause of the electric phenomena. Sir H. Davy is of opinion that the electrical action is commenced by the contact of the metals, and kept up by the chemical phenomena.\*

*Have not some physiologists supposed that the nervous fluid,† as it is called, and the electrical fluid are the same?*

Yes. The consideration of the formation of the electrical or Galvanic apparatus of the *gymnotus electricus*, or electrical eel, and the *torpedo*, has had great effect in leading some physiologists to entertain this opinion; for in these animals, the Galvanic power resides in organs which consist of a number of alternations of different substances, in a manner similar to those constituting the Voltaic pile.‡ And it is very remarkable, that in these animals the supply of nerves to the electrical organs is unusually great, being ten

\* Sir H. Davy is fully convinced that the chemical changes are an essential part of the process, and that without them no considerable degree of Galvanic excitement can ever be produced; but he infers from numerous experiments that there is no reason to question the fact, originally stated by Volta, that the electric equilibrium is disturbed by the contact of the metals without any chemical action taking place between them, and, therefore, he rejects Dr. Wollaston's hypothesis, that this action is the *primary* cause of the phenomena.

† That is, the power on which the nervous energies of the body depend.

‡ It is meant, that in the two animals mentioned (see page 110,) there are organs which, by their structure, bear a great analogy with the usual Galvanic arrangement of good and bad conductors.



times more, proportionably, than to any other part of the body.\*

*What is meant by the term ELECTRO-MAGNETISM?*

\* On the organ being frequently called into action, the animals are observed to become very much debilitated.

It has even been conjectured, that the reason why some of the secretions of the body are acid and the others alkaline, which is the case, is that the secretory organs are in opposite states of electricity. It has been supposed, also, that the brain possesses some analogy to a Voltaic apparatus, and serves the purpose of producing and distributing electricity, by means of the nerves, to the various parts of the body. This, however, is only conjecture. Baron Humbolt proved that contractions were excited in an animal by placing the nerves and muscles in certain situations, with respect to each other, without employing any metallic substance; on this principle a pile was constructed of alternate layers of muscular fibre and brain, separated by a porous body soaked in salt water.

The proper use of Galvanism is often of the utmost service in some severe chronic diseases, and I ought not to neglect this opportunity of again expressing my opinion, that its efficacy is much greater in some complaints than the profession generally appear to apprehend. It is sometimes of the most essential use in palsy, rheumatism, deafness, disorders peculiar to females, and chronic inflammation of particular structures, &c.; but in habitual asthma its powers may safely be rated very high, and much superior to any other known remedy. For an ample account of its effects in this distressing malady, I beg to refer the reader to my *Treatise on Domestic Medicine*, p. 229.

The following view of the differences between Galvanism and Electricity are extracted from *Mr. La Beaume's Observations on Galvanism*, p. 15, a book that may be perused with much advantage by all invalids, who have been led to suppose that the agency of this fluid might be serviceable to them. These differences consist, 1st, in their developement; 2dly, in their state; 3dly, in their action; and, 4thly, in their effects.

“ 1st. The developement of the Electric fluid is obtained by *mechanical* friction; that of the Galvanic fluid by a *chemical* action.

“ 2dly. The Electric fluid exists in a *highly elastic* state; and its particles are strongly repulsive of each other, and not disposed to form a permanent union with other bodies. The Galvanic fluid, on the contrary, has the *strongest tendency* to form new combinations; which tendency, as Sir Humphry Davy observes, is so powerful as to counteract some of the strongest chemical affinities. Electricity may be compared to an agent in a state of great *dilution*, or *expansion*, Galvanism to an agent of great *concentration* and *intensity*. The former has been compared to the flame of a candle, the latter to the flame of the blow-pipe.



It has been recently discovered that electricity, whether excited by the common electrical machine, or by the Voltaic pile, has the power of communicating magnetic properties to the common metals, and this fact forms the basis of the new science of *electro-magnetism*. Thus, Sir H. Davy rendered a common needle magnetic by placing it across a wire along which a charge from a common Leyden battery was transmitted.\*

“ 3dly. The Electric fluid, in its immediate action, causes great commotion in its passage from one body to another, its particles being mutually repulsive: whereas Galvanism enters more readily into bodies, and without creating *any* great commotion, on account of its tendency to form new combinations.

“ 4thly. The Electric fluid is more powerful in its *immediate*, than in its ultimate effects: the Galvanic fluid, on the contrary, is more powerful in its *ultimate* than in its immediate effects. Hence is deduced the superiority of the medicinal energy of Galvanism; and from this important fact has arisen the idea, that where electricity *ends* Galvanism *begins*.”

\* Professor Oersted, of Copenhagen, discovered in 1819, that an electric current, such as is supposed to pass from the positive to the negative pole of a Voltaic battery along a wire which connects them, causes a magnetic needle placed near it to deviate from its natural position, and assume a new one, the direction of which depends upon the mode of conducting the experiment. On placing the wire above the magnet and parallel to it, the pole next the negative end of the battery always moves westward, and when the wire is placed under the needle, the same pole goes towards the east. If the wire is on the same horizontal plane with the needle, no declination whatever takes place; but the magnet shows a disposition to move in a vertical direction, the pole next the negative side of the battery being depressed when the wire is to the west of it, and elevated when it is placed on the east side. Those who wish to pursue this subject may consult with advantage the observations of Mr. Faraday, in *Quarterly Journal*, vol. xii. and of Sir H. Davy in the *Philosophical Transactions* for 1821. The original memoir of Oersted may be found in the *Annals of Philosophy*, vol. xiii. and New Series, vol. ii.



## CHAPTER VII.

## OF CHEMICAL NOMENCLATURE.

*On what principle is the present denomination of chemical substances founded?*

That of calling simple bodies by names characteristic of their most striking qualities, and of naming compound bodies from the elements which compose them.\*

*What illustrations can you give of the adoption of this idea in regard to simple substances?*

Thus, in the three principal electro-negative bodies (see page 138) *oxygen*, *chlorine*, and *iodine*: *chlorine* is the term employed from the greenish yellow colour of that gas, being derived from the Greek word *χλωρος*, *green*; so the name *iodine* results from the violet colour of its vapour, from *ιωδης*, *violaceous*, or *like a violet*.† Among the electro-

\* Till the year 1786, the names applied by discoverers to the substances which they made known, were universally employed. Some of these names, which originated amongst the alchemists, were of the most barbarous kind; few of them were sufficiently definite or precise, and most of them were founded upon loose analogies, or upon false theoretical views. Towards the latter end of the last century, many philosophers felt that a reform in the nomenclature of chemistry was necessary, and in 1787, the French chemists Lavoisier, Morveau, Berthollet, and Fourcroy, presented to the world a plan for an almost entire change in the denomination of chemical bodies, founded on the idea above described. This nomenclature is now universally adopted.

† The word *oxygen* is also of Greek origin, and signifies *generator of acids*. This, indeed, is not a correct application, but it has been thought better to retain this word, than to introduce a new one.



positive bodies (not metallic,) we may instance the simple bodies *hydrogen* and *azote*: the former is derived from ὕδωρ, *water*, because it enters into the composition of that fluid; the latter from α, *privative*, and Ζωή, *life*, because it is incapable of supporting life.\*

*How are the combinations of the electro-negative bodies, for example, oxygen and chlorine, with other substances divided?*

Into two classes, viz. those which possess acid properties, and those which do not.

*And how is the nomenclature fixed for those bodies which possess acid properties?*

The name of the base of the compound is taken for the generic term, and the syllables *ic* and *ous* are added according to the relative proportions of oxygen which the base contains: thus the principal combinations of sulphur with oxygen, forming acids, are called *sulphuric* and *sulphurous* acids.†

\* *Azote* is now more frequently called *nitrogen*, from its entering into the composition of nitre and nitric acid.

For the metals, the termination *um* has been selected, as platinum, palladium, &c.; for the alkalies and earths, that of *a*, as potassa, soda, lithia. We have, therefore, *potassium* for the metallic base of the alkali potassa, and *cinchonia*, and *quina* for the alkaline principle of the Peruvian bark.

The compounds arising from the union of the metals with each other are termed *alloys*, except in those cases in which mercury is an ingredient, when the resulting compound is denominated an *amalgam*.

† It will be perceived, that the former termination denotes the *maximum*, the latter the *minimum* of oxygenation. In the same way we say *nitric* acid and *nitrous* acid, for the two compounds of nitrogen with oxygen, the former containing one proportion more of oxygen than the latter. The term *hypo* is sometimes prefixed to acids, to distinguish those which are intermediate, containing a less quantity of acid than the next above it: thus, *hypo nitrous* acid signifies an acid which contains less oxygen than the *nitrous*.



*How are those compounds named belonging to the second class, that is, those which do not possess acid properties?*

They are denoted by the termination *ide*. For example, when oxygen is thus combined with mercury, the compound is termed an *oxide*; and if chlorine is combined with the metal, a *chloride*.\*

*But the elementary substances, oxygen, chlorine, &c., may unite with other bodies in more than one proportion, the compounds still not possessing acid properties; for instance, it is generally supposed there are three oxides of lead;† do you know how they are distinguished?*

In order to distinguish these different properties of oxygen or chlorine, we prefix the first syllable of the Greek *ordinal* numbers, and say for the first oxide, or lowest degree of oxidation, the *protoxide*; for the second oxide, the *deutoxide*; and for the third oxide, *tritoxide*. In any such compound, that which contains the largest possible quantity of oxygen is called the *peroxide*, so that in the present case the tritoxide of lead is the peroxide, and if a metal has only two known oxides, the first is called the protoxide, and the other often the peroxide. In the same way, chemists say the *proto-chloride*, *deuto-chloride*, and *per-chloride*.

\* So the combinations of iodine and metals are called *iodides*.

† The first, or prot-oxide, is the common lytharge, which is yellow; the second, or deut-oxide, is the red lead; and the third, or per-oxide, is of a brown or puce colour.



*There are secondary compounds, which the acids form with the alkalies, earths, and metallic oxides: how are these denominated?*

When the acid in combination with the base is in the lowest state of acidification, as expressed by the termination *ous*, the resulting salt is designated by the termination *ite*, added to the first syllable of the acid; thus, sulphurous acid forms sulphites, phosphorous acid, phosphites, &c. When the acid is at its maximum of acidification, as announced by its termination *ic*, the salts are made to end in *ate*; thus, the sulphuric, phosphoric, and nitric acids, &c., form sulphates, phosphates, and nitrates, &c.\*

*Salts, however, may be composed of different properties of the same acid and base, for instance, there are two sulphates of potassa, and two carbonates of the same alkali: how are these designated?*

Where two proportions of acid are combined with one of base, the term *bi* is prefixed; where three, *tri*, and so on: we therefore speak of the bi-sulphate of potassa, the bi-carbonate of potassa; and the binoxalate and quadroxalate of potassa.† The compounds of the electro-positive

\* For example, there is a sulphite of potassa, and a sulphate of potassa; by the former we understand the union of sulphurous acid with potassa, and by the latter that of sulphuric acid with the same alkali.

† Formerly, the prefix of the terms *super* and *sub* constituted the mark of distinction in this case; but since the reception of the atomic theory which teaches us that where two bodies unite in more than one proportion, the second, third, &c. are multiples of the first, these terms have received a modified meaning: and as the simplest and most regular form of combination is when the acid and base unite atom to atom, the generic name is assigned to it without any additional distinction; thus, when an atom of



substances with each other are distinguished by the addition of the termination *uret*; the union of sulphur with phosphorus is, consequently, a *sulphuret* of phosphorus, and the union of carbon with iron, a *carburet* of iron.\*

lime unites with an atom of sulphuric acid, the product is a *sulphate* of lime; but if two or more atoms of base be attached to one of acid, it is, in such a case, proposed that the syllable *sub* should be prefixed; so that the term which originally served merely to express a certain quality arising from the predominance of the base, is now used to denote a definite proportion of the ingredients.

\* And as these also may combine in more than one proportion, the syllable *bi* is prefixed to such of their combinations as contain twice the quantity of the substance which is supposed to modify, or is the adjective of the other: thus, *bi-sulphuret* of phosphorus signifies a combination of phosphorus and sulphur, containing twice the quantity of sulphur which the sulphuret contains.



## CHAPTER VIII.

OF THE FOUR ELECTRO-NEGATIVE ELEMENTS, VIZ.  
OXYGEN, CHLORINE, IODINE, AND FLUORINE.\*

*What are the properties of OXYGEN GAS? †*

It is colourless, has neither taste nor smell, refracts light very feebly, and is a non-conductor

\* There is a new elementary body of the electro-negative class, (forming the fifth substance of this class,) which is called *Bromine*, from the Greek name *βρομος*, *fætor*, because it possesses a very offensive smell; but as it has been very recently discovered, and we are not yet fully acquainted with its properties, I have not thought it advisable regularly to notice it as one of the present class of substances.

Bromine (or brome) appears under the form of a blackish-red liquid, when viewed in masses and by reflected light, but of a hyacinthine red when a thin film of it is interposed between the light and the eye. Its taste is peculiarly strong. It attacks organic substances, as wood, cork, &c., and particularly the skin, which it tinges yellow and corrodes. This hue disappears after some time; but if the contact of the brome has continued somewhat long, the colour wears off only with the epidermis. It acts with great energy on the animal functions: a drop let fall into the beak of a bird was sufficient to kill it. It is volatile: when a drop of it is put into a vessel, this is immediately filled with the peculiar deep ruddy vapours, very similar to the fumes of nitrous acid. It boils at 116° Fabr., and the specific gravity, taken on a minute quantity, was found to be 2.966. The vapours of bromine do not support combustion. This substance is soluble in water, alcohol, and particularly in ether: sulphuric acid floats above it, but dissolves a very minute portion of it. Oil of olives acts in a slow manner.

It does

† This gas was discovered by Priestley in 1774, and by Scheele a year or two after, without previous knowledge of Priestley's discovery. Priestley called it *dephlogisticated air*, and Scheele *empyreal air*. It has been also termed *vital air*. The generally received name of *oxygen* originated with the celebrated French chemist Lavoisier, who erroneously considered it the essential principal or sole cause of acidity, and hence the name, which is derived from *ὄξυς*, *acid*, and *γεννάω*, *I generate*.



of electricity. It is rather heavier than atmospheric air,\* is sparingly soluble in water, is essential to the support of animal life,† and eminently supports combustion.‡ It possesses all

It does not redden tincture of litmus, but speedily deprives it of colour, nearly as chlorine would do.

The action of bromine on the metals, presents the most striking points of resemblance between it and chlorine. Antimony and tin burn when brought in contact with bromine. Potassium, on uniting with it, disengages so much heat and light that a detonation ensues sufficiently violent to break the vessel and project the materials.

Brome is present in sea-water in very minute quantity. Marine vegetables and animals also contain it. The incinerated plants of the Mediterranean afford a yellow tint when the product of their lixiviation is treated with chlorine. Notable quantities of brome may be extracted from the mother waters of Kelp that afford iodine. The best method of obtaining the brome from this compound matter, is to precipitate the iodine by a salt of copper, to separate by filtration the insoluble iodine of this metal, to evaporate the liquid, and to treat the residuum with sulphuric acid and magnesia. For additional information respecting this substance see *Annales de Chim. et Phys.* vol. xxxii. p. 337, and vol. xxv. p. 323, and *Dr. Ure's Dictionary*, art. *Bromine*.

\* Chemists have differed as to its precise weight. The best authorities considered its specific gravity to be 1.1111, atmospheric air being 1.0000.

† No animal can live in an atmosphere which does not contain a certain portion of uncombined oxygen; for an animal soon dies if put into a portion of air from which the oxygen has been previously removed by a burning body. It may therefore be expected that oxygen is consumed during respiration. If a bird be confined in a limited quantity of atmospheric air it will at first feel no inconvenience; but as a portion of oxygen is withdrawn at each respiration, its quantity diminishes rapidly, so that respiration soon becomes laborious, and in a short time ceases altogether. Should another bird be then introduced into the same air, it will die in the course of a few seconds; or if a lighted candle be immersed in it, its flame will be extinguished. Respiration and combustion have similar effects. An animal cannot live in an atmosphere which is unable to support combustion; nor can a candle burn in air which is unfit for respiration.

‡ All substances that are capable of burning in the open air, burn with far greater brilliancy in oxygen gas. A piece of wood, in which the least spark of light is visible, bursts into flame the moment it is put into a jar of oxygen; lighted charcoal emits beautiful scintillations; and phosphorus burns with so powerful and dazzling a light that the eye cannot bear its impression. Even iron and steel, which are not commonly ranked among the inflammables, undergo a rapid combustion in oxygen gas.

If an iron or copper wire be introduced into a bottle of oxygen gas, with



the physical properties of common air, and is, therefore, permanently elastic, and capable of indefinite expansion and compression.\* Its atomic weight is 8.

*Is it not then a very important substance?*

It is not only a highly important body, but is perhaps the most widely diffused and energetic in nature.†

a bit of lighted charcoal at the end, it will burn with a bright light, and throw out a number of sparks. The bottom of the bottle should be covered with sand, that these sparks may not crack it. If the wire, coiled up in a spiral like a corkscrew, as it usually is in this experiment, be moved with a jerk the instant a melted globule is about to fall, so as to throw it against the side of the glass, it will melt its way through in an instant, or, if the jerk be less violent, lodge itself in the substance of the glass. If it be performed in a bell glass, set in a plate filled with water, the globules will frequently fuse the vitreous glazing of the plate, and unite with it so as not to be separable without detaching the glaze, though it has passed through perhaps two inches of water.

During every combustion in oxygen gas, the gas suffers a considerable diminution in volume; and all bodies, by combustion in this gas, acquire an addition to their weight, this increase being in proportion to the gas absorbed, viz. about one-third of a grain for every cubic inch of gas.

\* When suddenly and strongly compressed, not only heat is evolved, but the gas *becomes luminous*, a property belonging to no other simple gas except chlorine.

† It has a very powerful attraction for most of the simple bodies; and there is not one of them with which it may not be made to combine. The act of combining with oxygen is called *oxidation*, and the bodies, after having united with it, are said to be *oxidized*. The compounds so formed are divided by chemists into acids and oxides. The first division includes those compounds which possess the general properties of acids; and the second comprehends those in which that character is wanting. The phenomena of oxidation are variable. It is sometimes produced with great rapidity, and with an evolution of heat and light. Ordinary combustion, for instance, is nothing more than rapid oxidation; and all inflammable or combustible matters derive their power of burning in the open air from their affinity for oxygen. On other occasions it takes place slowly, and without any appearance either of heat or light, as is exemplified by the rusting of iron when exposed to a moist atmosphere. Different as these processes may appear, oxidation is the result of both; and both are owing to the same circumstance, namely, to the presence of oxygen in the atmosphere.



*Is it a perfect electro-negative substance?*

Yes: it is the most perfect we possess, always appearing at the positive pole, when any compound which contains it is exposed to the action of galvanism.

*There are two substances in nature, which are very widely diffused, of which oxygen forms a large proportion: What are they?*

Common or atmospheric air, and water. It forms about a fifth of our atmosphere; and water contains as near as may be 89 per cent. of it.\*

*How do you procure oxygen gas?*

It may be readily procured from many substances. It is very frequently obtained from the black oxide of manganese, heated red hot in a gun-barrel, or exposed to a gentle heat in a retort with half its weight, or somewhat more, of strong sulphuric acid.† To obtain it of the

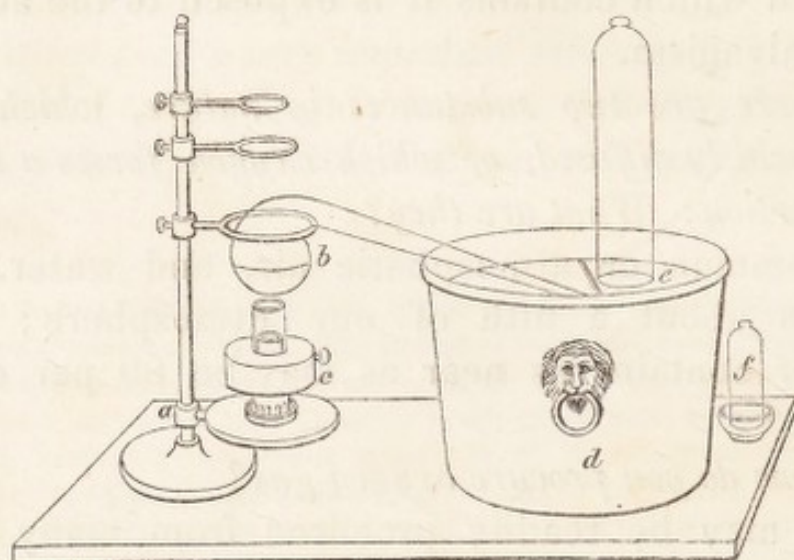
\* The composition of atmospheric air will be found fully noticed in the next chapter, immediately after the description of *Nitrogen*, and that of water, after *Hydrogen*.

† As manganese is often contaminated with a small proportion of carbonate of lime, it is advisable, before using it, to wash it with muriatic or nitric acid diluted with 15 or 20 parts of water; then with distilled water; and afterwards to dry it at a moderate heat. One pound of manganese is capable of furnishing from 40 to 50 wine pints of gas.

In procuring the gas in this way, the manganese is introduced into a glass retort furnished with a ground stopper, when a quantity of sulphuric acid, sufficient to moisten the manganese, is added, and they are mixed together by means of a glass rod; the bottom of the retort is then gently heated by means of a lamp, and the extremity of its neck is introduced under an inverted cylinder or jar, filled with water in the hydro-pneumatic apparatus, of which a figure is here annexed. Globules of gas will soon rise through the water into the cylinder. The first portions collected must be thrown away, being principally the common air contained in the retort.



greatest purity, however, the chlorate of potash is preferable to any other substance.\*



This engraving exhibits the *Pneumatic trough*, (or *Hydro-pneumatic trough*, as it is sometimes called,) by the use of which we are enabled to collect and examine any gaseous body. It consists of a tub *d*, which may be made of wood, or japanned iron, which should be twelve or fourteen inches deep, in order to allow the glass cylinders or jars to be conveniently filled. A shelf *e*, containing several holes, is so placed as to be about an inch under the surface of the water, when the trough is filled. When any species of gas is to be collected, a jar is to be filled with water, and carefully placed, with its mouth downwards, over one of the holes. The beak of the retort *b* from which the gas is proceeding is then brought under it, when it will bubble upwards, and displace the water; and in this manner any number of jars may be successively filled with the required gas. The principle on which this mode of filling glass jars with any gas is founded is very simple: by filling a jar with water, and inverting its mouth in a trough containing the same fluid, the jar is kept full, in consequence of the pressure of the atmosphere upon the surface; and in this state the jar is ready to receive any species of gas, not soluble in water, which, by its lightness, will rise through the water, and gradually displacing it from the jar, will occupy its place: *a* is a stand supporting the retort and the lamp *c*.

When the object is to preserve any gas so collected, for future examination, each jar may be removed from the trough, without any loss of its contents, by plunging a saucer into the water, and sliding the jar into it, as in *f*, taking care that its mouth is never raised above the surface of the fluid. To transfer gas from one vessel into another, we have only to fill the jar, into which we wish to introduce it, with water, and to invert it in the trough;



*Do these substances, after having yielded oxygen gas, lose weight?*

These, and all other bodies, in yielding oxygen are found considerably diminished in weight; and calculating each cubic inch of gas to be equal to one-third of a grain, the loss of weight

then, by bringing the mouth of the jar containing the gas, under that which is filled with water, and gradually depressing the top of the former, the gas will escape, and enter the latter. This operation may be said to be merely the converse of that of pouring water into any empty vessel, that is, into one containing only air, for in this case, the water being the heavier fluid is poured from *above*, enters the vessel, and expels the air *upwards*; whereas in the other case, the gas being the lighter fluid, it is poured from *below*, ascends, and expels the water *downwards*. If our object is to introduce the gas into a bladder, we must be provided with a jar, having a stop-cock in its upper orifice, to which the bladder is to be attached. Then by opening it, and at the same time lowering the jar, perpendicularly, into the water, the air will rush into the bladder, which may be afterwards detached from the jar, and preserved for use.

\* In obtaining the gas from the chlorate of potash, the portions that first come over should be rejected, because of their being debased with the atmospheric air in the retort.

Oxygen gas may also be procured from the red oxide of lead (the common red lead used by painters,) heated either with or without half its weight of strong sulphuric acid; or from nitre made red-hot in a gun-barrel, or in an earthen retort.

In obtaining this gas from the black or peroxide of manganese by the action of sulphuric acid, the theory of the process is this:—the peroxide of manganese gives off one proportion of oxygen, and is converted into the protoxide, which unites with the sulphuric acid, forming a sulphate of the protoxide of manganese. Every 44 grains of the peroxide must, consequently, yield 8 grains of oxygen and 36 of the protoxide, which by uniting with one proportion (40) of the acid, forms 76 of the sulphate. The student should observe that the composition of these oxides is as follows:—

Protoxide consists of one proportion of manganese, = 28,  
and one proportion of oxygen, = 8 + 28 = 36.

Peroxide consists of one proportion of manganese, = 28,  
and two proportions of oxygen, = 16 + 28 = 44.

When students meet with calculations of this description, they ought, in order fully to comprehend them, to have recourse to the *Table of Atomic Weights*, at page 36, where they will see at once the proportional numbers of all the substances mentioned.



by the oxides will be found equivalent to that of the gas generated.

*What is the theory of the decomposition of the salt, when this gas is disengaged from the chlorate of potash?*

The chlorate of potash is composed of

Chloric acid.....	76	or one proportion.
Potash .....	48	or one proportion.

---

124

Chloric acid consists of

Chlorine .....	36	or one proportion.
Oxygen.....	40	or five proportions.

---

76

And potash of

Potassium .....	40	or one proportion.
Oxygen .....	8	or one proportion.

---

48

By the heat applied to the salt, the chlorine and potassium it contains, are both deprived of their oxygen, and then unite together, forming the chloride of potassium. So that 124 grains of the salt are resolved into 76 grains of the chloride of potassium, and 48 grains, or 141 cubic inches of pure oxygen.\*

\* When heat is applied to the retort containing the chlorate of potash, it first becomes liquid, though quite free from water, and then, on an increase of heat, is wholly resolved into pure oxygen gas, which escapes with effervescence, and into a white compound, (the chloride of potassium,) which is left in the retort. The retort used should be of green glass, or of white glass made without lead, and be heated to redness.

The student will perceive, that the numbers above given are the atomic weights of the different substances against which they stand. For example, *ehloric acid* is marked 76, because it consists of five proportions or atoms of oxygen,  $5 \times 8 = 40$ , and one proportion of chlorine  $= 36$ , and  $36 + 40 = 76$ .



*What are the properties of CHLORINE?*

It is a yellowish-green\* coloured gas, which has an astringent taste, and a pungent suffocating smell. It is consequently irrespirable,† but it supports combustion.‡ It is absorbed by water; destroys vegetable colours; and is condensable into a liquid, at 60°, by a pressure of four atmospheres. It is heavier than atmospheric air, its specific gravity being 2.500. Its atomic weight is 36.

*How is chlorine obtained?*

From a mixture of liquid muriatic acid and black oxide of manganese. We introduce into a stoppered retort, eight ounces of muriatic acid, and four ounces of finely powdered manganese, then apply the heat of a lamp, and the gas is evolved, which must be received in the usual manner, over water§ in the pneumatic trough, (see figure at page 142).||

\* From *χλωρος*, *green*. It was discovered by Scheele, in 1774.

† When breathed pure it instantly proves fatal, and even when largely diluted with air, it excites severe coughing, followed by head-ache, deep pain of the chest, and general derangement of the system, which continue for a considerable time. The death of Pelletier, an able French chemist, was occasioned by his accidentally inhaling a large portion of this gas: a consumption was the consequence, which in a short time proved fatal.

‡ When a lighted taper is introduced into a phial filled with it, the light continues, but of a dull red colour, and a large quantity of dark smoke rises from the flame. Phosphorus burns in it spontaneously, with a pale white light, producing a white volatile powder. Many of the metals introduced into it in filaments, or leaves, or powder, take fire, and burn spontaneously at common temperatures; such are copper, tin, arsenic, zinc, antimony, and the alkaline metals, potassium, sodium, &c. In all these cases the combustible substances unite with chlorine, forming *muriates* or *chlorides*.

§ The water should be of the temperature of 80° or 90° Fahrenheit.

|| A cheaper process for procuring this gas is, to mix intimately together,



*What is the theory of this process?*

Muriatic acid is composed of hydrogen and chlorine, and the black oxide of manganese of oxygen and manganese; on being mixed together in the proportions just named, these compounds re-act on each other, part of the oxygen of the manganese unites with the hydrogen of the muriatic acid, to form water, while the chlorine is disengaged.\*

*What quantity of this gas is water capable of absorbing?*

About twice its bulk.†

*And what is it called when condensed in water?*

Aqueous chlorine. It was formerly called *oxymuriatic acid*,‡ and sometimes *oxygenized muri-*

three parts of common salt and one of the black oxide of manganese, and to this mixture add two parts of sulphuric acid, diluted with an equal weight of water.

\* In order that the student may perfectly understand the theory of this process, I would remark that muriatic acid is composed of 36 parts or one atom of chlorine, and 1 part or one atom of hydrogen; and the black oxide of manganese (which is the peroxide) of 28 parts or one atom of manganese, and 16 parts or two atoms of oxygen. When these compounds re-act on one another, one atom of each is decomposed: the peroxide of manganese gives one atom of oxygen to the hydrogen of the muriatic acid, in consequence of which one atom of water is generated, and one atom of chlorine is disengaged; while the protoxide of manganese, (this substance being reduced from the peroxide to the protoxide from having given off an atom of its oxygen,) unites with an atom of undecomposed muriatic acid, and forms an atom of the muriate of the protoxide of manganese. Consequently, for every 44 grains of the peroxide of manganese, 74 ( $37 \times 2$ ) grains of muriatic acid disappears; and 36 chlorine, 9 water, and 73 proto-muriate of manganese, are the products of the decomposition. The affinities which determine these changes are the attraction of oxygen for hydrogen, and of the protoxide of manganese for muriatic acid.

† This gas is absorbed by water slowly, if allowed to stand over it quiescent, but rapidly when agitated. It is rapidly absorbed by mercury.

‡ Chlorine, though formerly called an acid, possesses no acid properties.



*atic acid.* Scheele, its discoverer, described it under the name of *dephlogisticated marine acid*.

*Does it destroy vegetable colours under all circumstances?*

No. When the gas is perfectly dry, it has no effect on dry vegetable colours; but with the aid of a little moisture, it bleaches them speedily into a white, or yellowish white.

*What inference is drawn from this fact?*

That the bleaching power depends on the presence and decomposition of water.\*

It has not a sour taste, nor does it redden the blue colour of plants. Its strong affinity for the metals is sufficient to prove that it is not an acid; for chemists are not acquainted with any instance of direct combination between an acid and a metal. Before an acid can be made to combine with a metal, the latter must be in the state of an oxide, but chlorine combines directly with metals. When it acts upon oxides, it either produces the expulsion of their oxygen, or causes it to enter into new combinations.

\* Muriatic acid is always generated when chlorine bleaches, and from this circumstance, and the facts above mentioned, it is inferred that water is decomposed during the process; that its hydrogen unites with chlorine; and that the decomposition of the colouring matter is occasioned by the oxygen which is liberated.

The bleaching power of chlorine is one of its most important properties, and combined with lime (forming a *chloride of lime*, formerly called *oxymuriate of lime*, or bleaching powder,) it is now extensively employed by bleachers. Linen and cotton cloths are bleached in a very short period by a warm solution of chlorine in water; but their texture is injured; for at the same time that oxygen is added to the colouring matters, muriatic acid gas is formed and dissolved in the water, which corrodes the vegetable fibres. The chloride of lime in solution bleaches effectually, and has not these injurious effects; but it appears not to be altogether free from objection, as it tends to weaken the texture of linen. Sir Humphry Davy recommends the fluid produced by the condensation of the gas in water containing magnesia diffused through it, as having the property of bleaching without injuring the vegetable fibre. According to him, it acts much more slowly and gradually, than any of the other compounds employed for the same purpose, and has been applied with success in Ireland, in whitening printed calicos: when properly used, he says, it does not destroy even reds or yellows fixed by mordants. This distinguished chemist further remarks



*Is not chlorine used for the purposes of fumigation, as well as for bleaching?*

on the present subject, "The great circumstance, in bleaching with these compounds, is that the salt remaining after the abstraction of oxygen, should not act upon the linen; linen boiled in a strong solution of the salt called muriate of lime, the substance remaining in the solution, when oxymuriate of lime is used, I have found is considerably weakened. Solution of muriate of magnesia has no action of this kind, and therefore the new bleaching liquor (just referred to) can hardly be injurious to the manufacture."

The celebrated French chemist, M. Berthollet, first thought of applying chlorine to bleach cloth. In 1785 and 1786, he made a number of experiments with this view, and explained to the world in several papers its effects on colours, and in what manner it might be employed in the arts. In the following year (1787), a knowledge of these experiments, and of their application, was obtained in England, and Messrs. Milne, of Aberdeen, and the illustrious Watt, of Birmingham, were the persons who introduced this substance into our bleaching grounds. The promptitude with which they had appropriated the discovery of Scheele, and the experiments of Berthollet, turned out of great advantage to this country. For scarcely had Mr. Watt got the process into order, when two French chemists applied to the British Parliament to obtain an exclusive right to vend and use a liquid of their invention for whitening linen and cotton; and their application, which, had it been successful, would have secured a monopoly of this process to them, was defeated by Mr. Watt being able to prove that it was already publicly known and practised. The application of the same parties, at a later period, to obtain a patent for a bleaching liquid, were defeated by Mr. Henry, of Manchester, one of the first improvers of bleaching in this country, who proved, that the composition of their bleaching liquid was not a secret, for giving up which they deserved to be paid.

When first brought into use, chlorine was employed exclusively in the state of gas: the articles to be bleached were suspended in boxes or chambers, into which the gas was conveyed, but which were capable of holding water; and to prevent the goods being injured by the gas, they were frequently let down into the water. This was both an inconvenient and insufficient practice; for the goods were not equally exposed in all parts to the gas, and were not, therefore, equally bleached, while the former were peculiarly noxious to the workmen. It was soon discovered that water might be made to absorb this gas, and by this means acquire all its bleaching powers; and the first bleaching liquid made, consisted of water impregnated with the gas. In 1789, it was further discovered, that by the addition of potash to the water, it imbibed the gas sooner, and formed a more concentrated, though not so efficacious a solution. It had this great advantage, however, that it did not part with the chlorine gas so readily to



It is considered the most powerful agent known for destroying contagious *miasmata*, and is, therefore, now extensively employed in hospitals, sick rooms, and certain workshops, for the purpose of neutralizing the contagious miasms, and offensive effluvia, so commonly present in such places.\*

*Has it an affinity for any other gas?*

Yes: it has a powerful affinity for hydrogen; indeed so strong is this attraction, that chlorine will decompose water when the mixture is exposed to the light of the sun, or to a red heat. And most compound substances, of which hydro-

the atmosphere as the water did, while it did give up the gas to the cloths; and thus it bleached them without being disagreeable or injurious to the workmen. In a short time the chloride of potash was generally used, and continued in use till it was superseded by a cheaper article—the chloride of lime, which is the substance now principally employed in bleaching. It is to Mr. C. Tennant, of Glasgow, that we are indebted for the process of combining chlorine gas with lime in a dry state, so as to make it portable at a small expense.

\* M. Labarraque, an apothecary in Paris, has the merit of bringing this use of chlorine into general notice. In combination with soda or lime, it proves invaluable as a disinfectant. An ample account of its powers may be seen in my *Modern Domestic Medicine*, pages 173 and 181, *et seq.*, but as it is an article calculated, in the above combinations, to be of the most essential service to mankind, I shall transcribe from that book the following summary of its properties:—"It clearly appears, that the chlorides of soda and lime possess striking and incontestible advantages over every other means yet employed for the destruction of noxious effluvia, and that they may be used with equal success in destroying the infection of putrid fevers, in purifying the wards of hospitals and sick rooms, in the disinfection of crowded ships and foul stables, in the prevention of putrefaction in bodies previously to interment, in the disinfection of reservoirs of urine, in the purification of putrid water, in short, in the total destruction of every species of infectious effluvia, and offensive odour." At page 173 of the same volume, there is a most interesting case related, which proves that these substances have the power of often saving life, in cases of suspended animation arising from the inhalation of noxious gases.



gen is an element, are deprived of that principle by chlorine, and therefore decomposed in like manner.\*

*Does it not also combine with oxygen?*

It combines with oxygen in four different proportions, but the affinity of chlorine for oxygen is, notwithstanding, feeble.† The first two proportions in which they unite are oxides of chlorine, viz. protoxide and deutoxide of chlorine; the last two, chloric acids, viz. chloric acid and perchloric acid.‡

*How do you procure PROTOXIDE OF CHLORINE?*

By putting chlorate of potash into a small retort, and pouring in twice as much muriatic

\* For the same reason, when chlorine, water, and some other body, which has a strong affinity for oxygen, are presented to one another, the water is resolved into its elements (oxygen and hydrogen,) the hydrogen attaches itself to the chlorine, and the oxygen to the other body.

When equal volumes of chlorine and hydrogen are mixed together, and an electric spark is passed through the mixture, instantaneous combination takes place, heat and light are emitted, and muriatic acid is generated. A similar effect is produced by flame, and by a red hot body. Light also causes them to combine. A mixture of the two gases may be preserved without change in a dark place; but if exposed to the light of day, they gradually unite.

† These principles, consequently, are never met with in nature in a state of combination. Indeed, they cannot be made to combine directly; and when they do unite, very slight causes effect their separation.

‡ The composition of these four substances is exhibited at one view thus:—

	Protoxide of chlorine ( <i>Euchlorine</i> ) consists of.....	Chlorine.	Oxygen.
	1 proportion = 36 and 1 proportion = 8		
Deutoxide (or peroxide) of chlorine, consists of.....	1 .. = 36 and 4	.. = 32	
Chloric acid ,, .....	1 .. = 36 and 5	.. = 40	
Perchloric acid ,, .....	1 .. = 36 and 7	.. = 56	

The student will perceive that the atomic weight of protoxide of chlorine is consequently 44, (that is, 36+8); of the deutoxide 68, (36+32); of chloric acid 76, (36+40); and of perchloric acid 92, (36+56).



acid as will cover it, diluted with an equal volume of water. A gentle heat is then applied, and the gas is disengaged. As it is readily absorbed by water it must be collected over mercury.\*

*What are the properties of this protoxide of chlorine?*

Its colour is much more lively, and more yellow than chlorine, and hence Sir H. Davy, who discovered this gas, called it *euchlorine*. Its smell is peculiar, and approaches to that of burnt sugar; it is not respirable; it is soluble in water, to which it imparts a yellow colour; its specific gravity is to that of common air nearly as 2.400 to 1.000.† Its atomic weight is 44.

\* The evolution of the gas by this means is explicable on the fact, that muriatic and chloric acids mutually decompose each other. "When, (says Dr. Turner, *Elements of Chemistry*, p. 244,) muriatic acid and chlorate of potassa are mixed together, a part of the muriatic acid unites with the potassa of the salt, and thus sets chloric acid free, which instantly reacts on the free muriatic acid. The result of the re-action depends on the manner in which the operation is conducted. If the chlorate of potassa is mixed with an excess of concentrated muriatic acid, the chloric acid undergoes complete decomposition: for one atom of the chloric, five atoms of muriatic are decomposed; the five atoms of oxygen contained in the former unite with the hydrogen of the latter, producing five atoms of water; while the chlorine of both oxides is disengaged. If, on the contrary, the salt is in excess, and the muriatic acid diluted, the chloric acid is deprived of a part of its oxygen only; and the products are water, protoxide of chlorine, and chlorine, the two latter escaping in the gaseous form. From the proportion of these gases, I apprehend that for each atom of the chloric, three of muriatic acid must be decomposed; and that by the re-action of their elements, they yield three atoms of water, two of pure chlorine, and two of the protoxide of chlorine." The chlorine combines with the mercury, over which it is collected, and the protoxide of chlorine is left.

† Water absorbs 8 or 10 times its volume of this gas. Euchlorine destroys vegetable colours: but it first gives the blue a tint of red.

In almost all cases of vivid combustion, there is a condensation of the bodies which unite; but in the decomposition of euchlorine by heat, we have the remarkable phenomena of an explosion, accompanied with heat



*How is the DEUTOXIDE OF CHLORINE obtained?*

By mixing 50 or 60 grains of the powdered chlorate of potash with a small quantity of concentrated sulphuric acid, so as to make a thick paste, which is of a bright orange colour. This is to be introduced into a small glass retort, and heated by warm water, the temperature of which must be kept under the boiling point ( $212^{\circ}$ ) by an admixture of spirit of wine. A bright yellowish-green gas of a still richer colour than the protoxide is disengaged, which has a peculiar aromatic odour, without any smell of chlorine, is rapidly absorbed by water, but has no sensible action on mercury. This is the deutoxide (or peroxide) of chlorine.\*

*And how is CHLORIC ACID procured?*

and light, and yet with an expansion of the elements, which are separated from each other.

Eachlorine must be collected and examined with great care, and only in small quantities at a time; a very gentle heat causes it to explode, sometimes even the heat of the hand, and its elements separate from each other with great violence.

\* The taste of the aqueous solution of deutoxide of chlorine (or chloric oxide, as it is sometimes called,) is extremely astringent and corroding, leaving for a long while a very disagreeable sensation. It is composed of one atom of chlorine and four atoms of oxygen, its atomic weight is therefore 68. Its specific gravity is 2.361.

It is not decomposed, at common temperatures, by any combustible body, except phosphorus, which occasions an explosion when introduced into it, and burns, in the liberated gases, with great brilliancy.

The chemical changes which take place in the process for procuring this gas described above, may be explained in the following manner. The sulphuric acid decomposes some of the chlorate of potash, and sets chloric acid at liberty. The chloric acid, at the moment of separation, resolves itself into deutoxide of chlorine and oxygen; the last of which, instead of escaping as free oxygen gas, goes over to the acid of some undecomposed chlorate of potash, and converts it into perchloric acid. The whole products are bisulphate and perchlorate of potash, and deutoxide of chlorine.



To a solution of pure chlorate of baryta we add by degrees dilute sulphuric acid, as long as it occasions any precipitation. This separates the baryta, and leaves the chloric acid combined with water only.

*What are its characters?*

This acid has no sensible smell; its solution in water is perfectly colourless; its taste is very acid, and it reddens litmus without destroying the colour. Light does not decompose it, and it may be concentrated by a gentle heat, without undergoing decomposition, or without evaporating.\* It gives no precipitate in solution of nitrate of silver, mercury, or lead.† It forms neutral salts with alkaline bases. It is composed of one atom of chlorine, and five atoms of oxygen.

*What are these salts called?*

CHLORATES. Formerly they were called *hyperoxymuriates*, or *hyperoxygenized muriates*.‡

*You have now described the mode of procuring chlorine, with its properties, and some of its compounds: What is its nature?*

\* At a higher temperature, this acid in part is volatilized unchanged, while another portion is converted into chlorine and oxygen.

† Muriatic acid decomposes it, and both acids, if mixed in just proportion, are changed entirely into chlorine. Chloric acid is decomposed, also, by sulphuretted hydrogen and by sulphurous acid. In the former case, chlorine and sulphur are separated, and water is formed. In the latter, sulphuric acid is formed, and chlorine set at liberty. None of the acids, which are saturated with oxygen, have any action on chloric acid.

‡ These salts will be noticed under the chapter on *Salts*.

The mode of procuring perchloric acid may be seen by referring to *Henry's Chemistry*, vol. i. p. 221, or *Ure's Dictionary*, p. 56. Its properties have been little examined.



It was formerly considered a compound of muriatic acid and oxygen,\* and hence called *oxymuriatic acid*, but it is now very generally regarded as a simple or elementary substance. It is now considered a simple body because, like oxygen, hydrogen, and other analogous sub-

\* This hypothesis originated with Berthollet and Lavoisier, but is at the present time universally given up; muriatic acid itself being as universally considered a compound of chlorine and hydrogen: for when this acid is exposed to the agency of Galvanic electricity, it is resolved into these substances; and by mixing the two gases in due proportion, and passing an electric spark through the mixture, muriatic gas is the product.

Chlorine is not changed by being transmitted through ignited porcelain tubes, nor by a succession of electrical discharges through it; nor is it affected when brought in contact with charcoal in a state of intense ignition; facts strongly confirming the opinion of its being a simple substance. The circumstance of its not being possible to separate any portion of oxygen from chlorine, or oxymuriatic acid as it was called by the French chemists, of course forms a very strong objection to their theory, and likewise to that of a few other chemists who have appeared disposed to look upon it as a compound of oxygen, and an unknown body, which they call dry muriatic acid. Explanations have been offered to account for this circumstance, but they are not in any degree satisfactory. Sir Humphry Davy very properly remarks, "To call a body which is not known to contain oxygen, and which cannot contain muriatic acid, oxymuriatic acid, is contrary to the principles of that nomenclature in which it is adopted; and an alteration of it seems necessary to assist the progress of discussion, and to diffuse just ideas on the subject."—See his *Bakerian Lecture in the Philos. Trans.* for 1808, 9, and 11.

It is, however, singular, that most of the phenomena resulting from the chemical operations in which this substance is chiefly concerned, receive nearly as consistent an explanation by the old as by the new theory. Thus, when muriatic acid gas is resolved by Galvanism into chlorine and hydrogen, it may be supposed that the *absolute muriatic acid* attaches itself to the oxygen of the water, and forms chlorine, while the hydrogen of the water is attracted to the opposite pole of the battery. When chlorine and hydrogen enter into combination, the oxygen of the former may be said to unite with the latter, and that muriatic gas is generated by the water so formed combining with the *absolute muriatic acid* of the chlorine. The evolution of chlorine, which ensues on mixing muriatic acid and the black oxide of manganese, is explained on the supposition that *absolute muriatic acid* unites directly with the oxygen of this oxide of manganese. Those who adopted the old theory considered *absolute muriatic acid* as a compound of a certain unknown base and oxygen gas.



stances, it cannot be resolved into more simple parts.\*

*What is IODINE?*

It is a simple non-metallic, electro-negative substance, exceedingly analogous to chlorine.†

*What are its PROPERTIES?*

Iodine is a solid, at the ordinary temperature of the atmosphere; of a greyish or bluish-black

\* Those who wish to read the opinions of some eminent chemists both in favour of the new theory and against it, may see them in *Nicholson's Journal*, vol. xxxi. xxxii. and xxxiv. ; *Edinburgh Philos. Trans.* vol. viii. and *Philos. Trans.* for 1818.

Dr. Ure pertinently remarks, that in Sir H. Davy's Bakerian Lecture for 1808, and that published in the Transactions of the Royal Society for 1811, the whole body of evidence is presented, "for the undecomposed nature of oxymuriatic acid gas, thence forward styled chlorine; and they will be studied in every enlightened age and country, as a just and splendid pattern of inductive Baconian logic. These views were slowly and reluctantly admitted by the chemical philosophers of Europe. The hypothesis of Lavoisier, that combustion was merely the combination of oxygen with a basis, had become as favourite an idol with the learned as the previous hypothesis of Stahl, that one phlogistic principle pervaded all combustible bodies, which was either evolved in heat and light, or quietly transferred to an incombustible, imparting that inflammability to the new substance, which its former companion had secretly lost. Stahl's idea of combustion is the more comprehensive, and may still be true; Lavoisier's, as a general proposition, is certainly false."—*Dictionary of Chemistry*, p. 312.

+ "The investigation of this singular substance will always be regarded as a great era in chemistry. It was then that chemical philosophers first felt the necessity of abandoning Lavoisier's partial and incorrect hypothesis of oxygenation, and of embracing the sound and comprehensive doctrine of Sir H. Davy on chemical theory, first promulgated in his masterly researches on *Chlorine*." *Dr. Ure, in his Dictionary*, p. 529.

Sir Humphry Davy first ascertained the simple or elementary nature of iodine. "When M. Clement showed iodine to me, (says Sir H. Davy,) he believed that the hydriodic acid was muriatic acid; and M. Gay Lussac, after his early experiments, made originally with M. Clement, formed the same opinion, and maintained it, when I first stated to him my belief, that it was a new and peculiar acid, and that iodine was a substance analogous in its chemical relations to chlorine."—*See Sir H. Davy's Paper on the Analogies between the undecomposed Substances, in the Journal of Science*, vol. i. p. 284.



colour, and metallic lustre. It is often in scales similar to those of micaceous iron ore, sometimes in rhomboidal plates, very large and brilliant. It is soft and friable to the touch; its taste is very acrid, though it is very sparingly soluble in water; it gives a deep brown stain to the skin, but this disappears as the iodine evaporates; in odour, and power of destroying vegetable colours, it resembles very dilute aqueous chlorine. It is a deadly poison.\* Its atomic weight is 124, and its specific gravity 4.948.

*How is iodine procured?*

From *kelp*, by the action of sulphuric acid and black oxide of manganese.†

\* It is a non-conductor of electricity; and possesses, in a high degree, the electrical properties of oxygen and chlorine. Exposure to the direct solar rays, or to strong shocks of electricity, does not change its nature; it may be passed through red-hot tubes, or over intensely ignited charcoal, without any appearance of decomposition, nor is it affected by the agency of Galvanism. It melts at  $227^{\circ}$ , and is volatilized under the common pressure of the atmosphere at the temperature of  $350^{\circ}$ . The specific gravity of its vapour is 8.678, and its colour a beautiful violet; hence its name, from *ἰώδης*, *violaceous*.

Although it is a deadly poison in a considerable dose, yet it is at present much employed in medicine, being considered of superior efficacy in some complaints, especially in chronic swellings of various kinds. It undoubtedly possesses great power in promoting the absorption of some tumours, but requires to be exhibited with extreme caution, on account of its highly debilitating tendency.

† Iodine was accidentally discovered in 1812, by M. Courtois, a manufacturer of saltpetre at Paris. In his processes for procuring carbonate of soda from the ashes of sea-weeds, he found the metallic vessels much corroded; and in searching for the cause of this corrosion, he noticed that sulphuric acid threw down dark-coloured matter, which was converted by the application of heat into a beautiful violet vapour. Struck with its appearance, he gave some of the substance to M. Clement, who recognised it as a new body, and in 1813 described some of its properties in the Royal Institution of France. Its real nature was soon after determined, first by Sir H. Davy, and then by M. Gay Lussac.



*What is the most delicate test for iodine?*

Starch. It forms with starch a compound (iodide of starch) insoluble in water, and which has a fine deep blue colour.\*

*What are the principal COMBINATIONS OF IODINE?*

It possesses an extensive range of affinity, but

It is from the incinerated sea-weed, or kelp, that iodine in quantities is to be obtained, and Dr. Wollaston communicated the following formula for extracting it. Dissolve the soluble part of kelp in water. Concentrate the liquid by evaporation, and separate all the crystals that can be obtained. Pour the remaining liquid into a clean vessel, and mix with it an excess of sulphuric acid. Boil this liquid for some time. By this means a great quantity of muriatic acid and of sulphuretted hydrogen, which impede the collection of the iodine, are previously removed. Then decant off the clear liquid, and strain it through wool. Put it into a small flask, and mix it with as much black oxide of manganese as you have used before of sulphuric acid. Apply to the top of the flask a glass tube, shut at one end. Heat the mixture in the flask, and the iodine sublimes into the glass tube.

Dr. Ure has favoured us with an approved process for obtaining iodine in considerable quantities from the residuums of soap manufactories, where kelp is chiefly used in the manufacture of hard soap. This process is detailed in the 50th volume of the *Philosophical Magazine*, and in his *Dictionary of Chemistry*, p. 531.

Iodine is found in small quantities in many mineral waters, in marine vegetables, and in some sea weeds, especially the *algæ aquaticæ* of Linnaeus. The *fucus saccharinus* yields it most abundantly; and in order to obtain it by a cheap and easy process, M. de Claubry has recommended that we should submit this *fucus*, dried and reduced to powder, to distillation with sulphuric acid. M. Vauquelin has found it also in a mineral brought from the neighbourhood of Mexico, which was labelled *virgin silver in serpentine*: 100 parts of this mineral yielded, on analysis, 18.5 of iodine.

\* According to Professor Stromeyer, of Göttingen, this test is so delicate, that a liquid containing one 450.000 of its weight of iodine, receives a blue tinge, from a solution of starch. But it is necessary to observe, first, that in using this test, the iodine must be in a free state; for it is the iodine itself only, and not its compounds, which unite with starch: and, secondly, that the solution should be quite cold at the time of adding the starch; for boiling water decomposes the blue compound, and consequently removes its colour.



its principal combinations are with oxygen, chlorine, and hydrogen.\*

*How many compounds does it form with oxygen and with chlorine?*

With oxygen it combines in two proportions, forming *iodic* † and *iodous acids*, and with

\* Iodine in combining with hydrogen forms *hydriodic acid*, which will be described under Hydrogen, as it is contrary to the principles of my arrangement to describe a compound at large before the simple substances of which it is composed have been fully noticed. Iodine also unites with azote, sulphur, and phosphorus, which, for the same reason, I shall notice under the history of those substances.

† Iodine has no direct action with oxygen; they do not even combine when heated in contact; but when iodine is brought into contact with the protoxide of chlorine (euchlorine,) an immediate action ensues; the chlorine of the protoxide unites with one portion of iodine, and its oxygen with another, forming two compounds, a volatile orange-coloured matter, the chloride of iodine, and a white solid substance, which is *iodic acid*. On applying heat, the former passes off in vapour, and the latter remains. Sir H. Davy first succeeded in obtaining it in a pure state, and his description of the process he employed may be seen in the *Philosop. Trans.* for 1815, or the student may refer to *Dr. Ure's Dictionary*, p. 38.

The *iodic acid* of Sir Humphry Davy is a white semi-transparent solid. It has a strong astringent sour taste, but no smell. Its density is considerably greater than that of sulphuric acid, in which it rapidly sinks. At a temperature of about 500°, (Dr. Ure says 620°,) it melts, and is resolved into iodine and oxygen. It deliquesces in the air, and is, of course, very soluble in water. It first reddens and then destroys vegetable blue colours, and bleaches other vegetable colours. It acts powerfully on inflammable substances: with charcoal, ammonia, sulphur, sugars, and similar combustibles, it forms mixtures which detonate when heated. It appears to form combinations with all the fluid or solid acids which it does not decompose. It is decomposed by the sulphurous, phosphorous, and hydriodic acids, and by sulphuretted hydrogen. Iodine in each case is set at liberty, and may be detected as usual by starch. The muriatic and iodic acids decompose each other, water and chloriodic acid being generated.

The proportion of the elements of *iodous acid* has not been experimentally ascertained. It is a yellow liquid of an oily consistence, of a density greater than water, and possessing an odour somewhat resembling that of euchlorine. It reddens vegetable blues, but does not destroy them. It volatilizes rapidly at 112° Fahr. and evaporates slowly at common temperatures.



chlorine in one proportion, forming *chloriodic acid*.\*

*What is the atomic weight of IODIC ACID, and what are the salts called which it forms with metallic oxides?*

Iodic acid is composed of 5 atoms of oxygen and 1 atom of iodine: its atomic weight is therefore 165. Its salts are called IODATES.†

*What is FLUORINE?*

The unknown‡ radical or base of *fluoric acid*.§

*If it is an unknown base, it cannot have been exhibited in a separate state: then why is it assumed to be a simple electro-negative substance?*

Because when fluoric acid is exposed to the action of Galvanism, hydrogen gas is given out at the negative wire, and the platinum wire of the positive pole is coated with a chocolate

\* *Chloriodic acid* was also discovered by Sir H. Davy. He formed it by admitting chlorine in excess to known quantities of iodine, in vessels exhausted of air, and repeatedly heating the sublimate. Operating in this way, he found that iodine absorbs less than one-third of its weight of chlorine. The colour of the product is orange-yellow when the iodine is fully saturated with chlorine, but is of a reddish-orange if the iodine be in excess. Chloriodic acid is a very volatile solid. When exposed to the air it deliquesces. Its solution in water possesses acid properties, and gradually destroys vegetable blue colours. Gay Lussac calls it *chloride of iodine*, conceiving that the acidity of its solution arises from the presence of muriatic and iodic acids, which he supposes to be generated by the decomposition of water. Sir H. Davy's opinion, however, is generally considered the more probable, namely, that it dissolves in water without decomposition, and is, consequently, an acid. The composition of chloriodic acid is not precisely known.

† These compounds, like the chlorates, yield pure oxygen by heat, and deflagrate when thrown on burning charcoal.

‡ The strong affinities and decomposing agencies of fluorine, have hitherto prevented it from being exhibited in a separate state.

§ Fluoric acid is a peculiarly corrosive liquid, obtained from *fluor spar*, commonly called *Derbyshire spar*. See next chapter, article *Hydroeen*,



powder. Hence Sir H. Davy has supposed, that the fluoric acid, like the muriatic, is composed of hydrogen and a peculiar base, possessing, like oxygen and chlorine, a negative electrical energy, and hence determined to the positive surface. To this base he has given the name of *fluorine*, which is generally adopted.\* The atomic weight of this substance is usually considered to be 132.

\* The following experiments afford further proof of the existence of fluorine:—

1. When fluoric acid and potassium are brought into contact, a violent action takes place; a solid white substance is formed, and a quantity of hydrogen gas is disengaged. If the fluoric acid be free from water, (which the result of experiments instituted to determine the point, lead us to believe it is,) it is obvious that this result is best explained by supposing the fluorine and the potassium to combine and form the solid substance, while the hydrogen, previously united to the fluorine in the acid, makes its escape in the form of gas.

2. Muriatic acid is a compound of chlorine and hydrogen gas, the combination of it with ammonia is called *muriate of ammonia*. When potassium is heated with muriate of ammonia, chloride of potassium is found, and a quantity of gas disengaged. This gas is a mixture of ammonia and hydrogen, and consists of two volumes of ammonia, and one volume of hydrogen gas. Now when fluuate of ammonia is treated with potassium, a similar effect is produced: a white saline substance is formed, and gas is evolved consisting of ammonia and hydrogen, in the proportion of two volumes of the former to one volume of the latter. Since the effects in these two cases are similar, the fair inference seems to be that the products are similar. The dry substance is probably a fluoride of potassium, while the hydrogen was previously united with the fluorine, and constituted with it fluoric acid.



## CHAPTER IX.

OF THE SIX NON-METALLIC ELECTRO-POSITIVE  
ELEMENTS, VIZ. HYDROGEN, NITROGEN, CARBON,  
BORON, SULPHUR, AND PHOSPHORUS.\*

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*What is HYDROGEN?*

It is a highly inflammable gas, and is the lightest body known.†

*How is it procured?*

It can be procured only by the decomposition of water, of which it forms an essential constituent. The most convenient method of procu-

\* These are sometimes called *simple non-metallic acidifiable bodies*. The reader will do well to remember, that the electro-positive class comprehends all the objects of chemical science, with the exception of the *imponderable elements*, and the five substances described in the preceding chapter. See page 4.

Among the above six simple acidifiable (or undecomposed inflammable) bodies, hydrogen is distinguished from all the rest by very singular properties. Sulphur and phosphorus are the most analogous to each other. All these substances are capable of combining with oxygen, and carbon, with chlorine. In their electrical relations, as well as chemical powers, they are opposed to oxygen and chlorine.

† That is, of course, the lightest species of ponderable matter. If not discovered by Mr. Cavendish, it was first examined by him in 1766. It was formerly called *inflammable air*, from its great combustibility, and also *phlogiston* from the supposition that it was the matter of heat; but the name *hydrogen* derived from *ὕδωρ*, *water*, is now universally employed. It is a simple or undecomposed substance, and Sir H. Davy remarks, "Its extreme lightness, and the small quantities in which it enters into combination, render it unlikely that it should be resolved into other forms of ponderable matter, by any instruments or processes at present within our power."



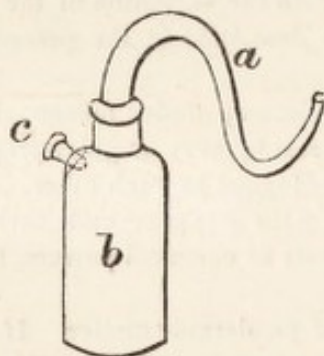
ring it is, to pour sulphuric acid, previously diluted with five or six times its weight of water, on iron or zinc filings. An effervescence will ensue, (occasioned by the decomposition of the water,) and the escaping gas may be collected in the usual manner in the pneumatic trough.\*

*What are its properties?†*

It is a colourless gas, and has neither odour nor taste when perfectly pure, but as commonly procured, has a disagreeable smell. It is very sparingly absorbed by water; is highly inflammable,‡ and extremely light, its specific gravity

\* It may likewise be obtained by passing the vapour of water over metallic iron heated to redness, as in the figure at page 166. This is done by putting iron wire into a gun-barrel open at both ends, to one of which is attached a retort containing pure water, and to the other a bent tube. The gun-barrel is placed in a furnace, and when it has acquired a full red heat, the water in the retort is made to boil briskly. The gas, which is copiously disengaged as soon as the steam comes in contact with the glowing iron, passes along the bent tube, and may be collected in convenient vessels, by dipping the free extremity of the tube into the water of a pneumatic trough.

To obtain the gas very pure, pieces of pure redistilled zinc, or harpsichord iron wire, must be used as in the process described above in the text. In procuring the gas in this way, a gas-bottle, represented in the annexed figure, known by the name of a *proof* and *tube*, is usually employed: *c* is a tubulated orifice for permitting the introduction of the acid into the proof bottle *b*, containing the zinc or iron filings; and *a*, a curved tube, which is ground into the opening of the bottle through which the gas escapes. As the gas escapes it is collected



in inverted jars in the pneumatic apparatus.

† It possesses all the physical properties of common air, being elastic, and capable of indefinite compression and dilatation; but has hitherto resisted all attempts to compress it into a liquid.

‡ Its inflammability may be shewn thus:—Fill with this gas a bladder which is furnished with a stop-cock, and with a small pipe, of diameter less than that of a common tobacco pipe. Press the air out through the



being 0.0694, atmospheric air being 1.0000.\* It is incapable of supporting either combustion or

pipe, and, on presenting a lighted candle, the stream will take fire, and continue to burn with a pale and feeble flame, not well adapted to the purpose of artificial light. This forms the philosophical candle of Dr. Priestley. Again, if the jars in which this gas is collected, are made with a stop-cock at the top, a brass pipe with a small aperture may be screwed to the cock, and on pressing a jar, filled with the gas, into the water, and opening the cock, the gas will be forced out in a stream, which may be set on fire. On this principle are founded the artificial fire-works without smell or smoke. They consist of pipes, having variously sized apertures, some of which have a rotatory motion; and to give greater brilliancy or variety of colour to the flame, the hydrogen gas is impregnated either with sulphuric ether, or some other substance that admits of being readily diffused through it.

But hydrogen, although eminently inflammable, requires, like other combustibles, the aid of a supporter for enabling its combustion to take place. Thus, if a narrow jar filled with hydrogen be lifted perpendicularly, with the bottom upwards, and a lighted taper be suddenly introduced, the taper will be extinguished, but the gas will burn at the surface, in contact with the air. The phenomena are different when the hydrogen is previously mixed with a due quantity of atmospheric air. Then the approach of flame not only sets fire to the gas near it, but the whole is kindled at the same instant;—a flash of light passes through the mixture, and is followed by a violent explosion. The best proportion for the experiment is two measures of hydrogen, to five or six of air. The explosion is far more violent when pure oxygen is used instead of atmospheric air, particularly when the gases are mixed together in the ratio of one measure of oxygen to two of hydrogen.

\* It is 16 times lighter than oxygen, and 14.4 times lighter than common air. Being the lightest body known, it is consequently the best material for filling balloons. A balloon is merely an air-tight bag, made of some very light material, so that when filled with hydrogen gas, it is lighter than its own bulk of air, consequently, when left to itself, it rises, just as a cork would do from the bottom of a jar of water. The extreme lightness of hydrogen may be shown by the following experiment. Fill, with hydrogen gas, a bladder furnished with a stop-cock; and adapt to this a common tobacco pipe. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles. These bubbles, instead of falling to the ground, like those commonly blown by the mouth, will rise rapidly into the air. The experiment may be varied by filling the bladder with a mixture of two parts of hydrogen gas, and one of oxygen gas. Bubbles blown with this mixture, take fire on the approach of a lighted candle, and detonate with a loud report. It is proper, however, not to set them on fire, till they are completely detached from the bowl of the pipe;



respiration.\* The number representing hydrogen may be considered as unity.†

*With what substances does hydrogen combine? ‡*

ITS PRINCIPAL COMBINATIONS are with oxygen, chlorine, and iodine; but it likewise unites with several other bodies.§

otherwise the contents of the bladder will be exploded, with considerable danger to the operator.

\* An animal soon perishes when confined in hydrogen gas; but death ensues from a deprivation of oxygen rather than from any noxious quality of the hydrogen, since an atmosphere composed of a due proportion of oxygen and hydrogen may be respired without inconvenience.

† Hydrogen is an important principle in animal and vegetable bodies; and exists in larger or smaller quantities in all organized compounds. It is the body which gives the power of burning with flame to all the substances used for the economical production of heat and light.

‡ It is singular that if a long glass tube be held over the flame of Dr. Priestley's philosophical candle (described at page 162,) moisture will speedily bedew its sides, and harmonic tones will soon begin to sound. Mr. Faraday, in an ingenious paper inserted in the 10th number of the *Journal of Science*, states, that carbonic oxide produces, by the action of its flame, similar sounds, and that therefore the effect is not due to the affections of aqueous vapour, as had formerly been supposed. It shows, that the sound is nothing more than *the report of a continued explosion*, agreeably to Sir H. Davy's just theory of the constitution of flame. Vapour of ether, made to burn from a small aperture, produces the same sonorous effect as the jet of hydrogen, of coal gas, or olefiant gas, on glass and other tubes.

Dr. De la Rive suggested (*Journals of Royal Institution*, vol. i. p. 259.), that this sound might be owing to a brisk vibratory motion of the glass, occasioned by the successive formation and condensation of small drops of water on the sides of the glass tube, and the air rushing in to replace the vacuum formed. But Mr. Faraday's explanation is considered more probable.

§ Hydrogen combines with all the substances named below, but only the first three will be described in this place. Combined with

Oxygen,	it forms water.
Chlorine,	.. muriatic acid.
Iodine,	.. hydriodic acid.
Cyanogen,	.. prussic acid.
Carbon,	.. { subcarburetted and carburetted hydrogen.



*What happens when two volumes of hydrogen and one of oxygen are fired or exploded?*

They wholly disappear, and WATER IS FORMED.\*

*This, then, proves the nature or composition of water synthetically, or by SYNTHESIS: can you show it analytically, or by ANALYSIS?*

Yes. If a portion of water is exposed to the action of a powerful Voltaic battery, it is decomposed; oxygen appears at the positive, and hydrogen at the negative metallic surfaces; and by means of platina wires, hermetically sealed into glass tubes, the products are collected, and

Nitrogen, it forms ammonia.

Phosphorus, .. { subphosphuretted and  
phosphuretted hydrogen.

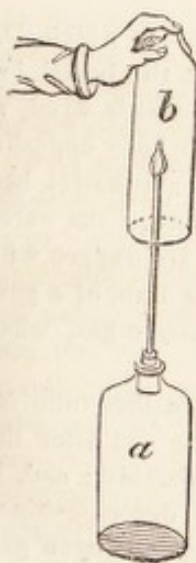
Sulphur, .. { sulphuretted and  
subsulphuretted hydrogen.

Arsenic, .. arsenuretted hydrogen.

Tellurium, .. telluretted hydrogen.

Potassium, .. potassuretted hydrogen.

\* The nature of water may also be proved by *synthesis* (or composition) in the following manner. Into a glass bottle *a*, supplied with a cork through which a tube passes, as here represented, introduce a small quantity of iron filings, and pour upon them diluted sulphuric acid. In flame the hydrogen gas which will issue from the orifice of the tube, and hold an inverted jar *b* over the flame. In a short time its interior surface will be covered with a very fine dew, which is pure water, produced from the combustion of the hydrogen gas, evolved from the materials in the bottle, and the oxygen gas of the atmosphere. The hydrogen gas should be allowed to pass off for some little time, before it is inflamed, in order to drive the atmospheric air from the bottle, the presence of which might otherwise occasion explosion.



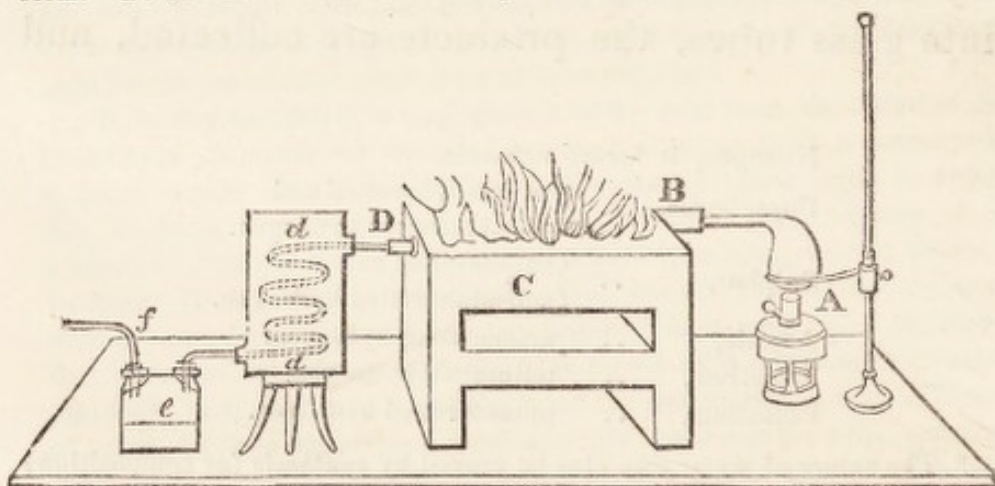
The composition of water was first ascertained by Cavendish and Lavoisier, in 1781.



in the proportions which, by their union, compose water.\*

\* The mode of effecting the decomposition of water by electricity is shown in the chapter on **ELECTRICITY**, at page 122, and the figure 5, in plate at page 1, is there referred to as tending to illustrate the subject, to which description I would therefore refer the reader. By analyzing water by means of electrical influence, we are presented with its two component principles, oxygen and hydrogen, mixed together in the state of gas; but the analysis may also be effected in another manner, which presents us with one of its ingredients only (the hydrogen), in a separate and distinct form. Of the second kind of experiment the following are interesting examples.

Procure a gun-barrel, the breech of which has been removed, so as to form a tube open at each end. Fill this with iron wire, coiled up in a spiral form. To one end of the barrel adapt a small glass retort A, partly filled



with water, and to the other a bent glass tube B, the open end of which, D, terminates under the shelf of the pneumatic cistern. Let the barrel be placed horizontally (or rather with that end, to which the retort is fixed, a little elevated) in a furnace C, which has two openings in its body opposite to each other. Light a fire in the furnace; and, when the gun-barrel has become red-hot, apply a lamp under the retort. The steam of the water will pass over the red-hot iron, and will be decomposed. Its oxygen will unite with the iron; and its hydrogen will be obtained in the form of a gas. This is the readiest and cheapest mode of procuring hydrogen gas, when wanted in considerable quantity.

The same experiment may be repeated, substituting an earthen tube for a gun-barrel, and weighing the iron accurately, both before and after the experiment. The iron will have gained weight very considerably; and, if attention be paid to the weight of the water that escapes decomposition, by an addition to the apparatus e, and to the weight of the hydrogen gas



*Is water the sole product of the combustion of hydrogen gas, or does it generate any other product?*

It is the sole product.

*What is the atomic weight of water?*

This fluid is considered a binary compound of 1 atom of oxygen and 1 atom of hydrogen; adding the weights of these atoms together (viz.  $8 + 1$ ,) an atom of water will consequently weigh 9. But *by volume*, these gases combine to form water in the proportions of two volumes of hydrogen and one of oxygen.\*

obtained, it will be found, that the weight gained by the iron, added to that of the hydrogen gas, will make up exactly the weight of the water that has disappeared.

Another interesting mode of decomposing water, is by the action of living vegetables, either entire, or by means of their leaves only. In this case, it is not the hydrogen, but the oxygen, that is obtained in a gaseous state. Fill a clear glass globe with water, and put into it a number of green leaves, from almost any tree or plant. A sprig or two of mint will answer the purpose quite well. Invert the glass, or place it with its mouth downwards, in a vessel of water. Expose the whole apparatus to the direct rays of the sun, which will then fall on the leaves surrounded by water. Bubbles of air will soon begin to form on the leaves, and will increase in size, till at last they rise to the top of the vessel. This process may be carried on as long as the vegetable continues healthy; and the gas, when examined, will prove to be oxygen gas, nearly pure. In this experiment, the hydrogen combines with the plant, to the nourishment and support of which it contributes, while the oxygen is set at liberty.

\* It has been demonstrated by experiment, that 100 parts of pure water consist of 88.9 of oxygen and 11.1 of hydrogen, (others say, 87.4 and 12.6,) which is so near the proportion of 1 to 8 as to justify the adoption of that ratio. This fact, and that of these gases combining, in the formation of water, in the proportion of two volumes of hydrogen and one of oxygen, are the data from which it is inferred that oxygen gas is just 16 times heavier than hydrogen. The atomic weights of oxygen and hydrogen are deduced from the same analysis. As no compound of these substances is known which has a less proportion of oxygen than water, it is supposed to contain one atom of each of its constituents. This view of the atomic constitution of water is considered justified by the strong affinity which its elements evince for one another, as well as from the proportions with which



*Is not WATER an important CHEMICAL AGENT?*

It is one of the most powerful chemical agents we possess.\*

*To what is its chemical agency owing?*

they respectively combine with other bodies. Consequently, regarding the atom of hydrogen as unity, eight will be the relative weight of an atom of oxygen.

The processes described at page 162 for forming hydrogen gas will now be perfectly intelligible. Lavoisier first demonstrated the nature of water by analysis in the way pointed out at page 166. It is founded on the fact that iron at a red heat decomposes water, the oxygen of that liquid uniting with the metal, and hydrogen gas being set free. That the hydrogen which is evolved when zinc or iron is put into dilute sulphuric acid must be derived from the same source, is obvious from the consideration that of the three substances, iron, sulphuric acid, and water, the last is the only one which contains hydrogen. The product of the operation, besides hydrogen, is the sulphate of the protoxide of iron, if iron is used, or of the oxide of zinc, when zinc is employed. The knowledge of the combining proportions of these substances will readily give the exact quantity of each product. The combining proportions, or atomic weights, are,

Water (8 oxygen + 1 hydrogen).....	9
Sulphuric acid .....	40
Iron .....	28
Protoxide of iron (28 iron + 8 oxygen) .....	36
Sulphate of the protoxide of iron (40 + 36).....	76

Hence, for every 9 grains of water which is decomposed, 1 grain of hydrogen will be set free; 8 grains of oxygen will unite with 28 grains of iron, forming 36 of the protoxide of iron; and the 36 grains of the protoxide will combine with 40 grains of sulphuric acid, forming 76 of the sulphate of the protoxide of iron. A similar calculation may be employed when zinc is used, merely by substituting the atomic weight of zinc (34) for that of iron.

According to Mr. Cavendish, an ounce of zinc yields 676 cubic inches, and an equal quantity of iron 782 cubic inches of hydrogen gas.

The action of diluted sulphuric acid on metallic zinc affords an instance of what was formerly called *disposing affinity*: see page 11. Zinc cannot decompose water at common temperatures; but as soon as sulphuric acid is added, the decomposition of the water takes place rapidly, though the acid merely unites with the oxide of zinc. The acid was therefore said to exert a disposing affinity in this instance.

\* Thus the solubility or insolubility of bodies in this fluid composes a large part of the science of chemistry. The habitudes of water with heat are important, and have been detailed under Caloric, at page 40.



Partly to the extensive range of its own affinity, and partly to the nature of its elements.\*

*What are the properties of water?*

It is well known to be a transparent colourless liquid, which, when pure, has neither taste nor smell. It is a powerful refractor of light, conducts heat very slowly, and is an imperfect conductor of electricity. It is compressible by very strong pressure.†

\* There are few complex chemical changes which do not give rise either to the production or decomposition of water. Independently of the elements of which it is composed, it combines directly with many bodies, and often entirely loses its fluid form. Sometimes it is contained in a variable ratio, as in ordinary solution; in other compounds it is present in a fixed definite proportion, as is exemplified by its union with several of the acids, the alkalies, and all salts that contain water of crystallization. These combinations are termed *hydrates*; thus, the strongest liquid sulphuric acid is a compound of one atom of the real dry acid and one atom of water; and its proper name is *hydrous sulphuric acid*, or *hydrate of sulphuric acid*. Dr. Turner properly remarks, (*Elements of Chemistry*, p. 166.) "The adjunct *hydro* has been sometimes used to signify the presence of water in definite proportion; but it is advisable, to prevent mistakes, to limit its employment to the compounds of hydrogen."

In many instances, when combined with various solid bodies, it is retained by so powerful an affinity, as not to be separated by a very high temperature. The pure alkalies, potassa and soda, retain, for example, even after fusion, about  $\frac{1}{5}$  their weight of water, which can only be separated by some body having a stronger affinity for the alkali. In all *hydrates*, at least one atom of water must be present, or it must be contained in them in such quantity, as to bear the proportion of 9 at least to the weight of the atom or atoms with which it is united. Thus, if the weight of the atom of potassa be 48, we cannot have a true binary compound of water and potassa, in which the former bears to the latter a less proportion than that of 9 to 48. And if, in any instance, water is obtained from a compound in a proportion less than that of the weight of the atom of water, to the weight of the atom or atoms of the body with which it is associated, we may conclude that it is held mechanically and accidentally, and not as a true chemical constituent. Such appears to be the nature of the union of water with certain neutral salts (common salt and sulphate of potassa for example) which contain only 1 or 2 per cent. of their weight of water.

† Its specific gravity, and capacity for caloric, as we have already stated, are called 1, or 1.000, from its being used as the standard of comparison.



*Does the air of the atmosphere contain any water?*

Yes: water is contained in atmospheric air, even during the driest weather. This may be shown by exposing to a dry air, in a shallow vessel, a little subcarbonate of potassa, or common salt of tartar: in a few days it will have become moist, or *deliquiated*.\*

Water retains its fluidity under the ordinary pressure of the atmosphere, at any degree of temperature between  $32^{\circ}$  and  $212^{\circ}$  Fahr. but under  $32^{\circ}$  it crystallizes and becomes solid, or is changed into ice; and above  $212^{\circ}$  assumes an æriform character, or becomes steam, expanding to 1700 times its ordinary bulk. Water is seldom, if ever, found pure. The waters that flow within or upon the surface of the earth contain various earthy, saline, metallic, vegetable, or animal particles, according to the substances over or through which they pass. The purest water which can be found as a natural product, is procured by melting freshly fallen snow, or by receiving rain in clean vessels in the open country. But this water is not perfectly pure; for if placed under the exhausted receiver of an air-pump, or boiled briskly for a few minutes, bubbles of gas escape from it. The air obtained in this way from snow-water, is much richer in oxygen gas than atmospheric air.

Recently boiled water has the property of absorbing a portion of all gases, when its surface is in contact with them, but the quantity absorbed varies considerably with respect to different gases. The quantity of the different gases which a certain volume of water absorbs, may be seen in *Dr Ure's Dictionary*, article *Gas*; in *Dr. Henry's Elements of Chemistry*, and *Mr. Dalton's New System of Chemical Philosophy*. The degree of barometrical pressure has considerable influence on the absorption of gases by liquids. M. de Saussure has shown, that in liquids the quantities of gases absorbed are as the compressions; while in solid bodies, on the contrary, as the gases become less dense, the absorption seems to increase.

\* It has already been remarked, that water exposed to the air, in a shallow vessel, slowly disappears, being taken up by the atmosphere. Saussure states the quantity of water in a cubic foot of air, charged with moisture at  $65^{\circ}$  Fahr. to be 11 grains. It has been shown by several chemists that the same bulk of all gases contains, at the same temperature, the same quantity of water; they therefore give up the same quantity to deliquescent salts. The portion of humidity, which they thus abandon, is called *hygrometric water*.

As Dr. Henry observes, *Elem. Chemistry*, vol. i. p. 256, Several bodies



*In what way is it ascertained how much moisture the atmosphere contains at different times?*

There are several methods of ascertaining this point, but the readiest way is by the instrument called an *Hygrometer*. Mr. Daniel's hygrometer is considered by far the best yet offered to the public.\*

absorb water from the atmosphere, which can scarcely be supposed to have an affinity for it, and again give it up, on the application of a gentle heat. Such are almost all substances in the state of powder; porous paper; soils which have been artificially dried; parched oatmeal; and even the filings of metals. Some powders retain the moisture they have absorbed, till a considerable heat is applied. The nature of this combination is not exactly understood.

The subject of rain is closely connected with that of the power of the atmosphere to suspend moisture, for its phenomena depend on the great variation of this power at different times. Dr. Hutton, of Edinburgh, was probably the first person who published a correct notion of the cause of rain. He maintained from the phenomena that the quantity of vapour capable of entering into the air increases in a greater ratio than the temperature; and hence he fairly inferred, that whenever two volumes of air of different temperatures are mixed together, each being previously saturated with vapour, a precipitation of a portion of vapour must ensue, in consequence of the *mean* temperature not being able to support the *mean* quantity of vapour. The cause of rain can, therefore, no longer be an object of doubt. For if two measures of air, of unequal temperatures, by the ordinary currents of the winds are intermixed, when saturated with vapour, a precipitation ensues. If the masses are under saturation, then less precipitation takes place, or none at all, according to the degree. Also, the warmer the air, the greater is the quantity of vapour precipitated in like circumstances. Hence the reason why rains are heavier in summer than in winter, and in warm countries than in cold.

\* It depends on the principle explained under Caloric, at page 53, that whenever a body in the atmosphere has a temperature below that at which the quantity of watery vapour in the air around can be maintained in the aëriform or invisible state, dew forms on the body. By cooling a bulb of glass until moisture begins visibly to settle upon it, and then noting the temperature on an enclosed thermometer, the proportion of water mixed with the air is discovered. See *Mr. Daniel's Meteorological Essays*, which contain the best information extant on the subjects of rain and dew.



*Is much heat evolved during the combustion of hydrogen gas?*

Yes; a very large quantity. Authors differ respecting the exact quantity of caloric thus set at liberty, but many calculate that the combustion of a pound of hydrogen gas evolves heat sufficient to melt 300 pounds of ice.\*

\* Lavoisier assigned 295lb of ice as the quantity melted by the combustion of a pound of hydrogen; Mr. Dalton 320lb, and Dr. Crawford 480lb.

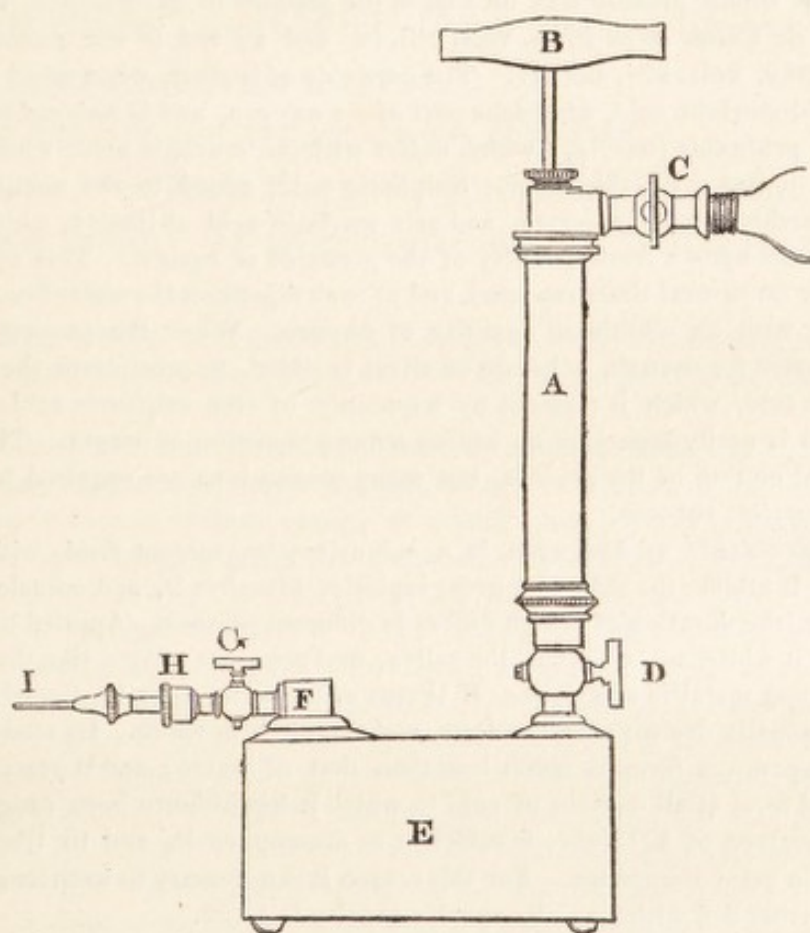
It has been already observed, that when hydrogen and oxygen are mixed in proper proportions, and heat applied, they explode. If, after being mixed, they be allowed to flow in a small stream, and kindled, they excite a very intense heat, indeed the most intense that can be produced. This constitutes what is called the *oxyhydrogen blow-pipe*. When the gases were first used for this purpose by Dr. Hare, of Philadelphia, they were kept in separate vessels, and forced out by a column of water, a pipe proceeding from each, and terminating by a common aperture. Mr. Newman has lately constructed a superior apparatus, into which the mixture is forced by a condensing syringe, and from which it again issues when the stop-cock is opened. It consists of a strong copper box E, into which the gases are condensed, to which there is adapted a stop-cock G, terminated by a very fine aperture I. A is the barrel of the condensing syringe, by which the gases are thrown from a bladder communicating with the cock C, into the box. B is the handle of the piston; and H a ball and socket joint, by means of which the jet I, of which there should be two or three different sizes, can be turned in any direction. When the box E is full, having shut the cock D, the syringe is removed, and on opening the cock G, the gas issues with great force and may be kindled. When this apparatus was first used, dangerous explosions often happened, owing to the flame rushing backwards into the box, and setting fire to the gases; but this is now prevented by what are called safety tubes, which are merely a number of very fine tubes, or, which answers equally well, several folds of fine wire gauze, both of which allow the gas to escape, but prevent the admission of the flame. These are placed in a small box attached to the perforated metal cup F. There is occasionally, also, in the same part, a small reservoir with oil, through which the gas passes, and which, should the flame by any means get through the gauze, puts a stop to its progress inwards.

Gold, when exposed on pipe-clay to the flame of the ignited gases, is surrounded with a *halo* of a lively rose colour, and soon volatilized. Stout iron wire is rapidly burnt. Platinum is not only fused the moment it is brought in contact with the flame, but the melted metal runs down in drops.



*We have now spoken of the union of oxygen and hydrogen in such proportions as form water: do they unite in any other proportions?*

It was ascertained in 1818, by M. Thenard, that they combine in proportions different from those which constitute water, forming a fluid possessed of remarkable properties, and which



Palladium melts like lead. Silix instantly melts into a deep orange-coloured glass, which was partly volatilized. Pure lime becomes a wax-yellow vitrification: a lambent purple flame always accompanies its fusion. And it fuses the most refractory native compounds, as rock crystal, diamond, sapphire, Peruvian emerald, &c. For further information on this point, see *Berzelius on the Blow-pipe*, *Dr. Clarke on the Blow-pipe*, and a small work by Mr. Griffin, of Glasgow.



has been called *deutoxide* or *peroxide of hydrogen*.<sup>\*</sup> It contains two atoms of oxygen to one of hydrogen, and its atomic weight is therefore 17.

*How is it procured?*

By the action of muriatic acid on peroxide of barium. The process is complicated.<sup>†</sup>

<sup>\*</sup> It is sometimes called *oxygenated water*.

<sup>†</sup> The whole process may be read in the Memoir of M. Thenard, in the *Annal. de Chim. et de Phys.* vols. viii. ix. and x; and in the *Annals of Philosophy*, vols. xiii. and xiv. The peroxide of barium, when acted upon by liquid muriatic acid, abandons part of its oxygen, and is reduced to the state of protoxide (baryta,) which unites with the muriatic acid, while the oxygen unites with the water. Sulphuric acid, added to the compound fluid, carries down the baryta, and sets muriatic acid at liberty, which is ready to act upon a fresh quantity of the peroxide of barium. This operation may be several times repeated, and at each repetition the water becomes charged with an additional quantity of oxygen. When the process has been carried far enough, sulphate of silver is added, to precipitate the free muriatic acid, which it replaces by a quantity of free sulphuric acid; but the latter is easily separated by adding a due proportion of baryta. This is a general outline of the process, but many precautions are required to insure its perfect success.

The *deutoxide of hydrogen* is a colourless transparent fluid, without odour. It attacks the skin with great rapidity, bleaches it, and occasions a smarting, the duration of which differs in different persons. Applied to the tongue, it whitens it, thickens the saliva, and produces a taste like that of some strong metallic solutions. If litmus or turmeric paper be dipped into it, it gradually destroys their colour, and makes them white. Its tendency to the vapourous form is much less than that of water; and it preserves its liquid form at all degrees of cold to which it has hitherto been exposed. A temperature of 59° Fahr. is sufficient to decompose it, and to liberate oxygen in great abundance. For this reason it is necessary to keep its glass tubes surrounded with ice. Its specific gravity is 1.452.

It is decomposed with great facility by many substances. Light acts tardily upon it, but the metals, tin, iron, antimony, and tellurium, bring it back rapidly to the state of water. The metals which have a strong affinity for oxygen are oxidized at the same time that they decompose it, such as potassium, sodium, arsenic, molybdenum, manganese, zinc, tungsten, and chromium; while others, such as gold, silver, platinum, iridium, osmium, rhodium, palladium, and mercury, liberate its oxygen (in a way not easily explained) without themselves undergoing any change.



*The combinations of hydrogen with oxygen having now been noticed; will you tell me what compound is formed by ITS UNION WITH CHLORINE?*

MURIATIC OR HYDROCHLORIC ACID \* GAS.

*How is muriatic acid gas formed?*

By the direct union of its elements. When equal measures of chlorine and hydrogen are mixed together, and an electric spark is passed through the mixture, instantaneous combination takes place, heat and light are emitted, and muriatic acid is generated.†

*What are the properties of this gas?*

It has a very pungent smell, and an acid corrosive taste. It is colourless, but when brought

\* *Hydrochloric acid gas* is the name given it by Gay Lussac, and generally used by the French chemists. Sir H. Davy objects to it. See page 169.

† A similar effect is produced by flame, by a red-hot body, and by spongy platinum. Light also causes them to unite. A mixture of the two gases may be preserved without change in a dark place; but if exposed to the diffused light of day, a gradual combination ensues, and is completed in the course of 24 hours. The results in all these cases are the same, 1 in volume of hydrogen unites to 1 volume of chlorine, or 1 in weight of the former to 36 of the latter: hence the atomic weight of muriatic acid is 37.

To procure this gas in considerable quantities, let six parts of pure and well dried sea salt be put into a glass retort, to the beak of which is luted, in a horizontal direction, a long glass tube artificially refrigerated, and containing a quantity of ignited muriate of lime. Upon the salt pour at intervals, five parts of concentrated oil of vitriol, through a syphon funnel, fixed air-tight, in the tubulure of the retort. The free end of the long tube being recurved so as to dip into the mercury of a pneumatic trough, the gas will issue in great abundance.

The nature of muriatic acid gas may be proved by analysis, as well as synthesis. If some pure grain tin be kept melted for some time, in a little curved tube containing muriatic acid gas over dry mercury, the tin will be converted into the same substance as that produced by its direct action on chlorine, (*Libavius's liquor*) and the hydrogen gas, when accurately measured, will be found to be equal to one half the volume of the muriatic acid gas.



into contact with common air, it occasions a white cloud.\* It does not support combustion or respiration; is heavier than atmospheric air,† and is not chemically changed by heat.‡ It is readily decomposed by galvanism, hydrogen appearing at the negative, and chlorine at the positive pole. It is rapidly absorbed by water.§ Its atomic weight is 37.

*Is it absorbed in large quantity by water?*

Yes; Sir Humphry Davy found that at 40° Fahr: water absorbs about 480 times its bulk of muriatic acid gas, forming a solution of specific gravity 1.2109. ||

\* This is owing to its union with aqueous vapour which is always present in the atmosphere.

† Gay Lussac states its specific gravity at 1.278, and Dr. Thomson at 1.284366.

‡ It is merely changed in bulk by alterations in temperature; it experiences no change of state.

§ This is one of its most striking properties. A drop or two of water, admitted to a large jar full of this gas, causes the whole of it instantly to disappear. On opening a long wide jar of muriatic acid gas under water, the absorption of the gas takes place so instantaneously, that the water is forced up into the jar with the same violence as into a vacuum.

|| According to Mr. Kirwan, an ounce-measure troy of water absorbs 800 cubical inches (*i. e.* 421 times its bulk) of muriatic acid gas; and the water by this absorption is increased about one-third its original volume. Dr. Thomson states (*First Principles of Chemistry*, vol. i. p. 85,) that at 68° F. one cubic inch of water absorbs 417.822 cubic inches of muriatic acid, and its volume becomes 1.3433 cubic inches. Hence 100 grains of this acid contain 103 cubic inches of gas. Its specific gravity is 1.1958, and it consists of 40.39 real acid, and 59.61 water.

Since water in absorbing 480 times its bulk of this acid gas, becomes of specific gravity 1.2109, 481 parts consequently occupy only 1.42 in bulk, a condensation of about 340 into one. The consequence of this approximation of the particles is the evolution of their latent heat; and accordingly the heat produced in the condensation of the gas is so great, that it melts ice almost as rapidly as the steam of boiling water does, or as it would be melted by a red-hot iron. Hence also, in passing the gas from the beak of



*How is LIQUID MURIATIC ACID usually prepared?*

From the decomposition of common salt by sulphuric acid, by which process muriatic acid gas is disengaged, which is absorbed by water in a Woolfe's apparatus, thus forming liquid muriatic acid.\*

*What are the properties of liquid muriatic acid?*

When pure it is a colourless liquid;† it is not decomposed by the contact of combustibles

a retort into a Woolfe's apparatus containing water to be impregnated, it is necessary to surround the bottles with cold water or ice, if we wish a considerable condensation.

\* The process is described at page 175. Sir H. Davy was among the first to give a just explanation of this decomposition. Sea-salt was formerly supposed to be a compound of muriatic acid and soda; and, on this supposition, the soda was believed merely to quit the muriatic acid, and unite with the sulphuric acid. But according to the experiments of Sir H. Davy, and Gay Lussac and Thenard, sea-salt in its dry state consists, not of muriatic acid and soda, but of chlorine and sodium, the metallic base of soda. It is therefore a chloride of sodium. The proportion of its constituents are

Chlorine 1 atom = 36

Sodium 1 atom = 24

The constituents of liquid sulphuric acid are

Dry Acid 1 atom = 40

Water 1 atom = 9 { because it is composed of 1 hydrogen  
and 8 oxygen.

When liquid sulphuric acid is added to the chloride of sodium, one atom of water is resolved into its elements; the hydrogen unites with chlorine, forming muriatic acid, which escapes in the form of gas; while soda is generated by the combination of the oxygen with sodium, which combines with the sulphuric acid, and forms sulphate of soda, which is left in the retort. The water contained in the liquid sulphuric acid is therefore essential to the success of the operation. The affinities which determine the change are the attraction of chlorine for hydrogen, of sodium for oxygen, and of soda for sulphuric acid.

† Muriatic acid has long been known under the name of *spirit of salt*. As commonly sold it has a yellow colour, and is always impure. The usual impurities are nitric acid, sulphuric acid, and oxide of iron. The presence of nitric acid may be inferred if the muriatic acid has the property of



bodies; when diluted with water, an elevation of temperature is produced;\* and if heated in a retort, or gas bottle, muriatic acid gas is disengaged. It emits white suffocating fumes, which consist of muriatic acid gas, become visible by contact with the moisture of the atmosphere. It combines readily with alkalies, and with most

dissolving gold leaf. Iron may be detected by the ferroproussiate of potassa, and the sulphuric acid by muriate of baryta, the suspected muriatic acid being previously diluted with three or four parts of water. To provide against the presence of nitric acid, the sea-salt is first ignited, to decompose any nitric acid it may contain. The other impurities may be avoided by employing a Woolfe's apparatus. A few drachms of water are put into the first bottle, to retain the muriate of iron and sulphuric acid which pass over, and the muriatic acid gas is condensed in the second.

Dr. Henry says, (*Elements of Chemistry*, vol. i. p. 274) "the yellowish hue of muriatic acid may proceed, either from a portion of chlorine, or of muriate of iron, but most commonly of the latter. This colour is instantly destroyed by a few drops of muriate of tin; but this addition, instead of diminishing, obviously increases the impurity of the acid."

\* The elevation of temperature produced is, however, much less remarkable than that occasioned by diluting sulphuric acid.

Pure concentrated muriatic acid freezes at 60° Fahr: and boils at 110° F. or a little higher, giving off pure muriatic acid gas in abundance.

It is decomposed by substances which yield oxygen readily. Thus several peroxides, such as those of manganese, cobalt, and lead, effect its decomposition. Nitric acid acts on the same principle. A mixture of nitric and muriatic acid, in the proportion of one measure of the former to two of the latter, is called *Aqua Regia*, from its power of dissolving gold and platinum. When these acids are mixed together, the solution immediately becomes yellow; and on heating the mixture, pure chlorine is evolved, and the colour of the solution deepens. On continuing the heat, chlorine and nitrous acid vapours are disengaged. At length the evolution of chlorine ceases, and the residual liquid is found to be a solution of muriatic and nitrous acids, which is incapable of dissolving gold. To Sir H. Davy we are also indebted for the explanation of these facts, which is, that nitric and muriatic acids decompose one another, giving rise to the production of water and nitrous acid, and the separation of chlorine; which muriatic and nitrous acids may be heated together without mutual decomposition. It is hence inferred, that the power of nitro-muriatic acid in dissolving gold is owing to the chlorine which is liberated.



of the earths; and is specifically heavier than water.\*

*Is the affinity of IODINE for HYDROGEN considerable or not?*

\* Its ordinary specific gravity is about 1.160. In winter, Dr. Thomson states, it may be obtained of sp. gr. 1.212. When of 1.203, it contains 40.659 per cent. real acid; and is constituted of six atoms water, and one atom of acid; but it can with difficulty be kept of such strength in warm weather. In order to ascertain the quantity of real acid in liquid acid, of various specific gravities, Dr. Ure has offered the following simple formula. *Multiply the decimal part of the number denoting the specific gravity by 147, the product will be nearly the per-centage of dry acid; or, when we wish to learn the per-centage of acid gas, the multiplier must be 197.*

*An example.* The specific gravity being 1.160, as directed in the London Pharmacopœia; required the proportion of dry acid in 100 parts.

$$0.160 \times 147 = 23.520 = \text{real acid.}$$

or

$$0.160 \times 197 = 31.520 = \text{acid gas.}$$

The correspondence between the specific gravity, and the quantity of real acid, which liquid muriatic acid contains, is shewn by the following Table, given by Sir H. Davy in his *Elements of Chemical Philosophy*.

*Table showing the quantity of real Acid in Liquid Muriatic Acid of different Specific Gravities. (Temp. 45° Fahr. Barom. 30.)*

Specific Gravity.	100 Grains contain of Muriatic Acid Gas.	Specific Gravity.	100 Grains contain of Muriatic Acid Gas.
1.21	42.43	1.10	20.20
1.20	40.80	1.09	18.18
1.19	38.38	1.08	16.16
1.18	36.36	1.07	14.14
1.17	34.34	1.06	12.12
1.16	32.32	1.05	10.10
1.15	30.30	1.04	8.08
1.14	28.28	1.03	6.06
1.13	26.26	1.02	4.04
1.12	24.24	1.01	2.02
1.11	22.3		

Dr. Thomson has given the following Table, shewing the specific gravities of liquid muriatic acid of different densities. He observes, that muriatic acid composed of 1 atom acid, and 16 atoms of water, or that which contains 20.442 per cent. of real acid, seems to be the most intimate combination of acid and water; for its boiling point, according to Dalton, is a maximum, being 232°, while acid, either stronger or weaker, boils at a lower temperature. (*First Principles of Chemistry*, vol. i. p. 87.)



It has a very strong affinity for hydrogen.\*

*What is the result of this combination?*

A peculiar acid called HYDRIODIC ACID.†

*How is it procured?*

By transmitting a mixture of hydrogen and the vapours of iodine through a red-hot porcelain tube, when a direct combination takes place between them, and hydriodic acid gas is formed.‡

*What is the best mode of preparing it in quantity?*

By the action of moistened iodine and phos-

*Table exhibiting the specific gravity of Muriatic Acid of determinate strengths.*

Atoms of Acid.	Atoms of Water.	Acid in 100.	Specific Gravity.
1	6	40.659	1.203
1	7	37.000	1.179
1	8	33.945	1.162
1	9	31.346	1.149
1	10	29.134	1.139
1	11	27.206	1.1285
1	12	25.517	1.1197
1	13	24.026	1.1127
1	14	22.700	1.1060
1	15	21.512	1.1008
1	16	20.442	1.0960
1	17	19.474	1.0902
1	18	18.590	1.0860
1	19	17.790	1.0820
1	20	17.051	1.0780

\* They have no action on each other at ordinary temperatures, but when exposed to a red heat in a tube, they unite together readily.

† Hydriodic acid is often found in nature in combination with potassa and soda. It is in the form of hydriodate of potassa, or soda, that iodine exists in sea-water, and in many marine animals and plants.

‡ According to Gay Lussac, we can easily obtain an aqueous hydriodic acid very economically, by passing sulphuretted hydrogen gas through a mixture of water and iodine in a Woollf's bottle. On heating the liquid obtained, the excess of sulphur flies off, and leaves liquid hydriodic acid.



phorus on each other, the phosphorus being in excess, and the mixture distilled in a retort.\*

*What are its properties?*

It is a colourless gas, having a sour taste, and a smell resembling that of muriatic acid gas. Its specific gravity is about 4.4. It reddens vegetable blue colours without destroying them, and is plentifully absorbed by water.† Its atomic weight is 125.

\* If four parts of iodine be mixed with one of phosphorus, in a small glass retort, applying a gentle heat, and adding a few drops of water from time to time, hydriodic acid gas comes over, which must be collected in the mercurial bath. In this mode of preparing it, an iodine of phosphorus is formed, which instantly reacts upon the water: mutual decomposition ensues; the oxygen of the water unites with the phosphorus, and the hydrogen with the iodine, and phosphoric and hydriodic acids are the results.

In coming into contact with mercury, this gas begins to be decomposed, and if the contact be prolonged a sufficient time, or agitation be used, the decomposition is complete. The iodine unites with the mercury, leaving its hydrogen at liberty, in volume exactly equal to one-half of the original bulk. It is decomposed, in a similar manner, by all metals, except gold and platinum. Chlorine, on the other hand, unites to its hydrogen, and precipitates the iodine. From these experiments, as Dr. Ure remarks, (*Chemical Dictionary*, p. 36) it evidently consists of vapour of iodine and hydrogen, which combine in equal volumes, without change of their primitive bulk. Its composition, by weight, is therefore 8.61 of iodine + 0.0694 hydrogen, which is the relation of their gasiform densities; and if 8.61 be divided by 0.0694, it will give the prime equivalent, or atomic weight of iodine 124 times greater than hydrogen; and as the prime of oxygen is eight times more than that of hydrogen, on dividing 124 by 8, we have 15.5 (according to Dr. Thomson's scale) for the prime equivalent of iodine; to which, if we add 0.125, the sum 15.625 (equal to 125 on the hydrogen scale) represents the equivalent of hydriodic acid.

† Liquid hydriodic acid is fuming, and has a density of 1.7. It is readily decomposed. Thus, on exposure during a few hours to the atmosphere, the oxygen of the air forms water with the hydrogen of the acid, and sets iodine free. The solution is found to have acquired a yellow tinge from the presence of uncombined iodine, and a blue colour is occasioned by the addition of starch.



*What are the salts called which it forms with the alkalies and other oxides?*

HYDRIODATES.\*

*Does not hydrogen combine also with fluorine?*

Yes; forming FLUORIC or HYDRO-FLUORIC ACID.†

*What are the properties of Fluoric acid?*

It is a colourless fluid, having the appearance of sulphuric acid, but is much more volatile.‡

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

All the hydriodates have the property of dissolving abundance of iodine; and thence they acquire a deep reddish-brown colour. They part with it on boiling, or when exposed to the air after being dried.

The hydriodates of potassa and zinc are of considerable importance in medicine. They are of superior efficacy in reducing the size of certain tumours, and in allaying some kinds of local pain and uneasiness.

† Dr. Henry observes (*Elem. of Chem.* vol. i. p. 281) "Though it has not yet been demonstrated that hydrogen is the acidifying principle of this acid, yet there appears every reason to believe that in the same manner as hydro-chloric (muriatic) acid is constituted of chlorine united with hydrogen, this acid also consists of a peculiar base belonging, like chlorine, to the electro-negative class of bodies, and rendered acid by combination with hydrogen. To this basis, though not yet exhibited in a separate state, the name of *fluorine* has been given, and the acid has been termed *hydro-fluoric*."

It may be procured by putting the powder of crystallized fluor spar (a mineral found abundantly in Derbyshire) into a silver or leaden alembic, and pouring over it its own weight of sulphuric acid. There must then be adapted to the alembic a silver or leaden tube, terminating in a receiver of the same metal, surrounded by ice. On applying a moderate heat to the alembic, the fluoric acid will rise in vapours which will condense in the receiver into an intensely active liquid; a dry mass, the sulphate of lime, being found in the retort. When obtained, it must be preserved in leaden or silver bottles, with air-tight stoppers of the same material. Its volatility, however, is such that it is difficult to confine it.

‡ It was discovered in 1771, by Scheele. Gay Lussac first obtained it in a pure form. It is in all respects a powerful acid. It has a strong sour taste, reddens litmus paper, and forms salts with alkalies, which are called *Fluates*.



Its specific gravity is 1.0609, and it has a very strong affinity for water.\* It is of all known substances the most destructive to animal matter; † and its vapour is extremely pungent.

*What effect has it on glass?*

It instantly corrodes and dissolves it. ‡

\* Its density may be increased to 1.25 by gradual additions of water. Its affinity for this fluid is so strong, that when a drop of it falls into water much heat is produced, and a hissing noise similar to what is occasioned by plunging a red-hot iron into that liquid.

† When applied to the skin it instantly destroys it, and produces very painful wounds. Sir H. Davy's description of his attempt to investigate the nature of this acid by the agency of the galvanic battery, is very interesting, and shews its marvellous activity. "I undertook (he says) the experiment of electrizing pure liquid fluoric acid with considerable interest, as it seemed to offer the most probable method of ascertaining its real nature; but considerable difficulties occurred in executing the process. The liquid fluoric acid immediately destroys glass, and all animal and vegetable substances; it acts on all bodies containing metallic oxides; and I know of no substances which are not rapidly dissolved or decomposed by it, except metals, charcoal, phosphorus, sulphur, and certain combinations of chlorine. I attempted to make tubes of sulphur, of muriate of lead, and of copper, containing metallic wires, by which it might be electrized, but without success. I succeeded, however, in boring a piece of horn silver in such a manner that I was able to cement a platina wire into it by means of a spirit lamp; and by inserting this in a tray of platina, filled with liquid fluoric acid, I contrived to submit the fluid to the agency of electricity in such a manner that, in successive experiments, it was possible to collect any elastic fluid that might be produced. Operating in this way with a very weak voltaic power, and keeping the apparatus cool by a freezing mixture, I ascertained that the platina wire at the positive pole rapidly corroded, and became covered with a chocolate powder; gaseous matter separated at the negative pole, which I could never obtain in sufficient quantities to analyze with accuracy, but it inflamed like hydrogen. No other inflammable matter was produced when the acid was pure."—*Philosophical Transactions* for 1813 and 1814.

‡ Hence it has been used for etching on glass. In etching in this manner, thick clear crown-glass receives a complete coating of melted wax, and, when perfectly cold, the drawing is executed with a fine steel point. Whatever parts of the drawing are intended to be corroded by the acid, should be perfectly free from the least particle of wax. When the drawing (whatever it may be) is finished, the glass is exposed to the action of fluoric acid, or fluoric acid gas, in a square leaden box, or receiver, and the parts divided by the graver are perfectly etched in the course of a minute or two.



*We now come to speak of NITROGEN, or AZOTE.  
How is it procured?\**

The readiest mode of procuring it is to abstract it from atmospheric air by the combustion of phosphorus.† It may also be obtained from animal matters, as glue, or muscular fibre, subjected in a glass retort to the action of nitric acid, diluted with 8 or 10 times its weight of water.‡

When fluoric acid acts on glass, the transparency of the glass is instantly destroyed, caloric is evolved, and the acid boils, and in a short time disappears entirely, producing a peculiar colourless gas, called *Fluosilicic Acid Gas*. It is considered a compound of fluoric acid and silica. It is always formed when fluor-spar and sulphuric acid are heated together in a glass vessel. It is possessed of extraordinary properties. Its specific gravity is 3.632 (air being 1.000). It is consequently about 48 times denser than hydrogen. When brought into contact with water, it instantly deposits a white gelatinous substance, which is hydrate of silica; it produces white fumes in passing into the atmosphere. It is not affected by any of the common combustible bodies; but when potassium is strongly heated in it, it takes fire, and burns with a deep red light; the gas is absorbed, and a fawn-coloured substance is formed, which yields alkali to water with slight effervescence, and contains a combustible body. The washings afford potassa, and a salt, from which the strong acid fluid previously described, may be separated by sulphuric acid.

\* It was discovered in 1772, by Dr. Rutherford, Professor of Botany in Edinburgh.

† In this manner of obtaining it, a piece of phosphorus is burnt in a jar full of air, inverted over water. The strong affinity of phosphorus for oxygen enabling it to burn till the whole of that gas is consumed. The product of the combustion, phosphoric acid, is at first diffused through the residue in the form of a white cloud; but as this substance is rapidly absorbed by water, it disappears entirely in the course of half an hour. The residual gas is nitrogen, containing a small quantity of carbonic acid and vapour of phosphorus, both of which may be removed by agitating it briskly with a solution of pure potash.

‡ In this experiment, the retort containing the animal matter and dilute nitric acid, is exposed to a heat of 100°, when the gas is disengaged, and may be collected over water. Its source has been satisfactorily traced to the animal substance, no part of it proceeding from the nitric acid.



*What are its properties?*

Nitrogen possesses all the physical properties of common air. It does not support respiration or combustion;\* and is without taste or smell. It is lighter than common air, its specific gravity being 0.9722; and is not absorbed by water.†

*What is the nature of nitrogen?*

It is considered a simple or undecomposed body. There are circumstances, however, that lead chemists to suppose it may be a compound substance, though no means hitherto tried have succeeded in decomposing it.‡

*Does it not form a large proportion of our atmosphere?*

It constitutes four-fifths of the volume of atmospheric air.§

Nitrogen gas may also be obtained by other methods which it is not necessary to particularize here.

\* Although no animal can live in it, yet it exerts no injurious action either on the lungs or on the system at large, the privation of oxygen gas being the sole cause of death.

It immediately extinguishes a lighted candle, and all other burning substances. Even phosphorus, in a state of active inflammation, is instantly extinguished when immersed in nitrogen gas.

† Or it is so very slightly absorbed by water that it does not take up more than  $\frac{1}{5}$ th part of its volume.

‡ The strongest arguments for the compound nature of nitrogen are derived from its slight tendency to combination; and from its being found abundantly in the organs of animals which feed on substances that do not contain it. Its uses in the economy of the globe are little understood; this likewise is favourable to the idea that its real chemical nature is as yet unknown, and that it is not actually an undecomposable substance.

§ The real composition of atmospheric air was discovered about the same time by Scheele and Lavoisier. The ancient philosophers considered it one of their four elements, which were *air*, *earth*, *fire*, and *water*. From the latest and most accurate experiments, the proportion of oxygen in atmospheric air is by measure about 21 per cent.; the remainder, amounting to 79 per cent., is nitrogen. Air is considered also to contain a minute



*Are the proportions of oxygen and nitrogen always the same in atmospheric air?*

quantity of carbonic acid gas, namely, about one part in a thousand. It appears that a small proportion of carbonic acid exists in it at all altitudes which have been hitherto attained.

The composition of atmospheric air may be proved by *synthesis* and *analysis*. It may be proved by the former method, by mixing four parts of nitrogen gas with about one part of pure oxygen, when they will constitute a mixture resembling exactly atmospheric air. That the oxygen obtained artificially for this purpose is the same chemical substance as that found in the air, is shown by the phenomena of the calcination of mercury. If running mercury be preserved, in a heat at which it boils slowly, in a retort, the beak of which is plunged in mercury, and the process be continued for some days, there will be a gradual diminution of the air, and after a certain time, the remainder will not support flame, and a part of the mercury will be found converted into a red powder. It will have gained in weight as much as the air has lost; and the red powder, if heated to ignition, will give off a quantity of oxygen, that, added to the residual elastic substance, will reconstitute common air, and it will be restored to the state of mercury. And this oxygen, if a part of it be compared with the oxygen procured in other modes from mineral substances or artificial compounds, is found in no respect different; its specific gravity, refractive power, and chemical properties, are precisely identical. These phenomena attending the calcination of mercury proves the composition of air analytically.

There are various other methods of analyzing atmospherical air. In the *Eudiometer* of Seguin, the rapid combustion of phosphorus is employed with this view. A glass tube, open at one end only, about an inch in diameter, and eight or ten high, is filled with, and inverted in, mercury. A small bit of phosphorus, dried with blotting paper, is then introduced, and, by its inferior specific gravity, rises to the top of the tube where it is melted, by bringing a red-hot poker near to the outer surface of the glass. When the phosphorus is liquefied, a measured portion of the air to be examined is admitted, by a little at once, into the tube. The phosphorus inflames at each addition, and the mercury rises. When all the air under examination has been added, the red-hot poker is again applied to ensure the completion of the process, and the residuary gas is transferred into a graduated measure, where its bulk is carefully ascertained. In this instance, about  $\frac{1}{40}$ th the volume of the residuary gas is to be deducted from the apparent quantity of azotic gas, because, in this case also a small portion of phosphorus is dissolved by the latter, and occasions a trifling expansion. With this deduction, atmospheric air loses pretty accurately 21 parts out of every 100; and contains, therefore, 21 *per cent.* of oxygen, and 79 of azote, by measure.



They appear to be always the same in all places, however distant.\*

\* The knowledge of the composition of the air, and of the importance of oxygen to the life of animals, naturally gave rise to the notion that the healthiness of the air, at different times, and in different places, depends on the relative quantity of this gas. It was therefore supposed, that the purity of the atmosphere, or its fitness for communicating health and vigour might be discovered by determining the proportion of oxygen; and hence the origin of the term *Eudiometer*, which is applied to the apparatus for analyzing the air. But this opinion has been proved to be fallacious. It appears, on the contrary, that the composition of the air is not only constant in the same place, but is the same in all regions of the earth, and at all altitudes. Air collected at the summit of the highest mountains, such as Mont Blanc and Chimborazo, contains the same proportion of oxygen as that of the lowest valleys. The air of Egypt was found by Berthollet to be similar to that of France. The air which Gay Lussac brought from an altitude of 21,735 feet above the earth, had the same composition as that collected at a short distance from its surface. Even the miasmata of marshes, and the effluvia of infected places, owe their noxious qualities to some principle of too subtile a nature to be detected by chemical means, and not to a deficiency of oxygen. Seguin examined the infectious atmosphere of a hospital, the odium of which was almost intolerable, and could discover no appreciable deficiency of oxygen, or other peculiarity of composition.—See *Henry's Elements of Chemistry*, vol. i. p. 298.

There are several kinds of *Eudiometers* in use. Dr. Priestley discovered that *nitrous gas*, or *nitric oxide gas*, combines readily with oxygen, and is precipitated in the form of nitric acid, and this fact was the basis on which he constructed the first instrument of this kind. His method was very simple: a glass vessel, containing an ounce by measure, was filled with the air to be examined, which was transferred from it to a jar of an inch and a half diameter, inverted in water; an equal measure of fresh nitrous gas was added to it; and the mixture was allowed to stand two minutes. If the absorption was very considerable, more nitrous gas was added, till all the oxygen appeared to be absorbed. The residual gas was then transferred into a glass tube two feet long, and one-third of an inch wide, graduated to tenths and hundredths of an ounce measure; and thus the quantity of oxygen absorbed was measured by the diminution that had taken place. Sir H. Davy has proposed the use of a saturated solution of sulphate of iron, impregnated with nitrous gas, as an eudiometer; in which case the apparatus of Dr. Hope (see figure 8, in plate at page 1,) will afford a convenient mode of applying it.

Scheele, in his eudiometrical researches, employed liquid *sulphuret of potassa*, a substance which has the property of absorbing oxygen, but not nitrogen. It therefore acts on atmospheric air, only so long as any oxygen



*How is it considered to exist in the atmosphere;—chemically combined with oxygen, or not?*

Chemists are divided in opinion on this point; some believing it to be simply mixed with oxygen to form atmospheric air, others that there is a real chemical union between these gases.\*

gas remains, and may be employed as the means of ascertaining the quantity of this gas in any portion of air. For applying this test, Dr. Hope, Professor of Chemistry in Edinburgh, invented an instrument, represented in figure 8. It consists of a small bottle, holding about three ounces, into which the graduated glass tube *a* is carefully fitted by grinding. It also has a ground stopper at *b*. To use it, the phial is filled with the solution, and the tube *a*, containing the air to be examined, fitted into its place. On inverting the instrument, the gas ascends into the bottle, where it is to be brought extensively into contact with the liquid by brisk agitation;—an absorption ensues; and to supply its place, the stopper *b* is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation repeated; and these operations are renewed alternately, till no further diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be apparent, and its amount may be measured by the graduated scale engraved on the tube. Dr. Henry has objected to this form of apparatus. If, says he, the tube *a*, and the stopper *b*, are not both very accurately ground, the air is apt to make its way into the instrument to supply the partial vacuum, occasioned by the absorption of oxygen gas. This absorption causes a diminished pressure within the bottle; and, consequently, towards the close of each agitation, the absorption goes on very slowly. Besides, the eudiometric liquid is constantly becoming more dilute, by the admission of water through *b*. To obviate all these difficulties, Dr. Henry substitutes for the glass bottle, one of elastic gum, as shown in figure 9, in plate at first page.

\* The greater number of chemists regard it as a chemical compound, chiefly from the uniformity of its composition, and from the fact that its several ingredients do not separate and arrange themselves according to their respective gravities. But Mr. Dalton has formed a different hypothesis, which is that of the various elastic fluids constituting the atmosphere, the particles of one have neither attractive nor repulsive power towards those of another; but that the weight or pressure, upon any one particle of any fluid mixture of this sort, arises solely from the particles of its own kind. According to this theory, oxygen, azotic, and carbonic acid gases (or indeed any number,) may exist together under any pressure, and at any tem-



*What are the properties of atmospheric air?*

It is invisible; \* is without taste or smell when pure, and is not sensible to the touch, unless when it is in motion. It gravitates; † is highly

perature, while each of them, however paradoxical it may appear, occupies the whole space allotted for all. Although this theory does not agree with certain facts, yet several very able chemists consider it encumbered with fewer difficulties than that which views the constituents of the atmosphere as held united by chemical affinity.

\* It is invisible, except by the blue colour it reflects when in very large masses, as is seen in the sky or region above us, or on viewing extensive landscapes.

† The weight or density of the atmosphere differs according to the height of the place at which it is taken. This is obvious from the consideration that those portions of it which are next the earth sustain the whole pressure of the atmosphere, while the higher strata bear only a part of it. Therefore, as we ascend, the atmosphere decreases in density in a geometrical proportion to equal ascents. At the level of the ocean it is adequate to sustain a column of water having the altitude of 34 feet, or one of mercury of the height of 30 inches, and it presses with the weight of about 15 pounds on every square inch of surface. But at three inches high, the density of the atmosphere is one half what it is at the earth's surface, or equal to a column of mercury of 15 inches; at six miles, the barometer would stand at  $\frac{1}{4}$  the usual height, or at  $7\frac{1}{2}$  inches. Hence the greatest part of the atmosphere is always within 15 or 20 miles of the earth's surface. It is not known to what height the atmosphere extends; but from calculations founded on the phenomena of refraction, its height is supposed to be about 45 miles. How far it extends beyond this point is a subject for speculation. Many philosophers suppose matter to be infinitely divisible, and if so, it is evident that there ought to be no limit to the extent of the atmosphere; it should, on that hypothesis, pervade all space, and accumulate about the sun, moon, and planets, forming around each an atmosphere, the density of which should depend on their respective forces of attraction. But, as Dr. Henry remarks, (*Elem. of Chem.* vol. i. p. 287,) we have no evidence of the existence of similar matter round any other planet; and, on the contrary, it has been ascertained by the observations of Captain Kater, that no retardation of the motion of Venus can be perceived in her progress towards the sun, as would happen if the latter were encompassed by a refracting atmosphere. The approach, also, of Jupiter's satellites to the body of that planet is uniformly regular, till they appear in actual contact, showing that there is not that extent of atmosphere, which Jupiter should attract to himself from an infinitely divisible medium filling all space. These observations are favourable, as Dr. Wollaston remarks, to



elastic, and is not condensable by any degree of cold into the dense fluid state.\*

*Since the chemical properties of the atmosphere are owing to the presence of oxygen gas, and this gas is consumed by the respiration of man and animals, and by combustion, (processes incessantly going on,) how is it that this important substance oxygen is continually renewed in the atmosphere?*

the existence of particles of matter no longer divisible, for if an elastic fluid like our atmosphere consist of such particles, we can scarcely doubt that all other bodies are similarly constituted; and may without hesitation conclude that those equivalent quantities, which we have learned to appreciate by proportionate numbers, do really express the relative weights of elementary atoms, the ultimate objects of chemical research.

\* The elasticity of the air is shown by placing a bladder full of it, under the receiver of an air-pump, and exhausting; as we withdraw the air, in other words, diminish the pressure, the bladder becomes distended from the enlargement of that within it: indeed, the whole operation of the pump itself depends on the elasticity of the air; for when the piston is drawn up, by which a vacuum is produced, that in the receiver, owing to its elasticity, expands, and part of it rushes into the syringe. When the piston is forced down, this is expelled through the valve; and on again raising it, more is drawn out, so that, by alternately raising and depressing it, almost the whole may be withdrawn. It is evident, however, that the whole cannot be taken out; for when the elasticity of what remains in becomes trifling, it ceases to move the valve, so that any further working of the pump does not withdraw more. The more easily, therefore, the valves are moved, the more nearly does the vacuum approach to a perfect one. See page 95.

Atmospheric air is *compressible*, that is, the particles may be made to occupy less space than it naturally does, but it cannot be condensed into a liquid. Mr. Perkins, however, says, that he has condensed it into a liquid by a pressure of 2000 atmospheres; but it is very generally thought he is mistaken.

It is remarkable that, in compressing air, caloric is evolved, and if the compression be sudden, the heat generated is sufficient to set fire to inflammables. By a particular contrivance tinder can be kindled, or even gun-powder exploded, merely by the condensation of air (no friction being concerned in the effect), and if the apparatus in which the compression is effected, be terminated by a glass tube, light is observed to be disengaged.



There are probably many provisions in nature by which the proportion of oxygen in the atmosphere, continually consumed in respiration and combustion, is again restored to that fluid: the principal sources of oxygen appear to be the growth of vegetables, and the decomposition of water.\*

WITH WHAT BODIES DOES NITROGEN COMBINE?

Its chief combinations are with oxygen and hydrogen. It likewise combines with chlorine and iodine, forming two very formidable compounds—the chloride and iodide of nitrogen.†

\* This is an interesting fact, which exhibits the wisdom and beneficence of OUR GOD in a most striking light. It is well ascertained that the vegetation of plants continually counteracts the noxious tendency of respiration, combustion, and putrefaction. By these processes, the vital air of the atmosphere is incessantly consumed, while a noxious gas (principally carbonic acid) is generated in its stead; but almost all plants, during their growth, absorb and feed upon the noxious vapours, and afford in its place pure oxygen gas, or vital air. Dr. Ingenhouz found by experiment, 1st. That most plants have the property of correcting bad air within a few hours, when they are exposed to the light of the sun; but that, on the contrary, during the night, they corrupt the common air of the atmosphere. 2nd. That the disengagement of pure or vital air does not commence until the sun has been some time above the horizon; that it ceases altogether with the termination of day-light; and that the disadvantage arising from the impure exhalation of plants, during the night, is far exceeded by the great advantage they afford during the day; insomuch, that the impure air generated by a plant during the whole night, scarcely amounts to a hundredth part of the pure oxygen gas exhaled from the same plant in two hours of a serene day.

† The *chloride of nitrogen* is formed by filling a perfectly clean glass basin with a solution of about one part of sal ammoniac in twelve of water, into which a tall jar of chlorine gas is to be inverted. As the saline solution gradually ascends by the condensation of the gas, oily-looking drops are seen floating on its surface, which collect together, and fall to the bottom in large globules. The chloride of azote thus obtained is an oily-looking liquid, of a yellow colour, and a very pungent intolerable odour, similar to that of chlorocarbonous acid. It is the most powerfully detonating com-



*What are the compounds of nitrogen and oxygen?*

Nitrogen unites with oxygen in five proportions, forming five important compounds, viz.—NITROUS OXIDE, NITRIC OXIDE, HYPONITROUS ACID, NITROUS ACID, and NITRIC ACID.\*

pound with which we are acquainted, and therefore requires to be examined with extreme caution, for when gently warmed, it explodes with so much violence, that it is not safe to employ a quantity larger than a grain of mustard seed. Its specific gravity is 1.653.

It evaporates pretty rapidly in the air; and *in vacuo*, it expands into a vapour, which still possesses the power of exploding by heat. It gradually disappears in water, producing azote; while the water becomes acid, acquiring the taste and smell of a weak solution of nitro-muriatic acid.

Sir H. Davy concludes, from various experiments, that it is constituted of one atom of nitrogen to four atoms of chlorine; its atomic weight is therefore 158.

Nitrogen does not combine directly with iodine, but when iodine is kept in a solution of ammonia in water, it is gradually converted into a brownish black substance, which is an *iodide of nitrogen*. It detonates from the smallest shock, and from heat, with a feeble violet vapour. From theoretical considerations, Gay Lussac believes it to consist of 3 atoms of iodine and 1 atom of nitrogen.

\* According to the proportions in which the oxygen and nitrogen exist in these compounds, their qualities undergo a remarkable variation, so that from two elementary bodies, variously united, we have several compounds, totally unlike each other in external qualities, as well as in their chemical relations. The composition of the above five compounds, as deduced from the remarks of Sir H. Davy, Gay Lussac, and Dr. Henry is as follows:—

	By Volume.		By Weight.	
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
Nitrous oxide.....	100	+ 50	14	+ 8
Nitric oxide .....	100	+ 100	14	+ 16
Hypo-nitrous acid....	100	+ 150	14	+ 24
Nitrous acid .....	100	+ 200	14	+ 32
Nitric acid .....	100	+ 250	14	+ 40

The first of these (the protoxide) as containing the smallest quantity of oxygen, is regarded as a compound of one atom of each element. The other four compounds are composed of one atom of nitrogen, united in the second with two, in the third with three, in the fourth with four, and in the fifth with five, atoms of oxygen.

It is obvious that as these five compounds of nitrogen and oxygen contain the same elements, and differ only in their proportion, they may be converted



*How is NITROUS OXIDE procured?*

The best mode of procuring it, is to expose the salt called nitrate of ammonia, to the flame of an Argand lamp, in a glass retort.\* When the temperature reaches 400° Fahr. a whitish cloud will begin to rise into the neck of the retort, accompanied by the copious evolution of gas, which continues till the whole of the salt disappears.†

*What are its properties?*

It has all the physical properties of common air, with a sweet taste, and a faint agreeable

into each other, by adding or subtracting a due proportion of oxygen. Thus nitric acid, by contact with some of the oxidizable metals, is converted into nitrous gas; and nitrous gas, by abstracting a further quantity of oxygen, is changed into nitrous oxide. Again, by adding oxygen to nitrous gas, it may be reconverted into hyponitrous, nitrous, or nitric acid, according to the proportion of oxygen which is added, and the circumstances under which the combination is effected.

\* Nitrous oxide may be obtained by several processes, but the above is by far the best method.

Nitrous oxide, or protoxide of nitrogen, was discovered by Dr. Priestley, in 1772, but was first accurately examined by Sir H. Davy in 1799. A full account of it may be seen in his *Researches, Chemical and Philosophical*. It was called by Priestley, *dephlogisticated nitrous air*; and by the associated Dutch chemists *gaseous oxide of azote*.

† This gas must be collected over mercury for accurate researches, but for common experiments may be received over water.

The changes that take place during the conversion of nitrate of ammonia into nitrous oxide, are the following:—nitric acid is composed of oxygen and nitric oxide; ammonia, of hydrogen and nitrogen. By the action of heat these elements arrange themselves in a new order. The nitric oxide combines with an additional dose of nitrogen, and forms nitrous oxide; while the oxygen of the decomposed nitric acid unites with the hydrogen of the ammonia, and forms water. Water and nitrous oxide are, therefore, the only results of the careful decomposition of nitrate of ammonia by heat.



odour.\* Its specific gravity is 1.5277, and its atomic weight 22.† It supports combustion,‡ and is respirable, but not fitted to support life.§

*How is NITRIC OXIDE, or DEUTOXIDE OF NITROGEN procured?*

By pouring nitric acid, diluted with six or eight times its quantity of water, on metallic copper, and applying a gentle heat. A gas comes over, which may be collected over water or mercury.||

\* Recently boiled water, which has cooled without exposure to the air, absorbs nearly its own bulk of it at 60° Fahr. This property enables us to determine the purity of nitrous oxide, since water removes it readily from all other gases, such as oxygen and nitrogen, which are sparingly absorbed by that fluid.

† 100 cubic inches weigh about 46.6 grains.

‡ A taper plunged into this gas burns with great brilliancy; the flame being surrounded with a bluish halo. Phosphorus, introduced into it in a state of inflammation, burns with increased splendour. It may, however, be melted and sublimed in this gas, without alteration. Sulphur, when burning feebly, is instantly extinguished by it; but when in a state of active inflammation, it burns with a vivid and beautiful rose-coloured flame. Iron wire burns in this gas with much the same appearance as in oxygen, but for a shorter period.

§ The action of this gas on the human system when inspired, is very remarkable. The sensations that are produced by it vary greatly, as we might expect, in persons of different constitutions; but, in general, they are highly pleasurable, and resemble those attendant on the early period of intoxication. Great exhilaration, an irresistible propensity to laughter, a rapid flow of vivid ideas, and an unusual disposition to muscular exertion, are the ordinary feelings it produces. These pleasant sensations are not usually succeeded by any subsequent depression. To administer the gas, it may be introduced into an oiled silk bag, or clean bladder, furnished with a stop-cock, and may be breathed repeatedly from the bag and back again, as long as it will last.

|| The copper gradually disappears during the process; the liquid acquires a beautiful blue colour, and yields on evaporation a salt which is composed of nitric acid and peroxide of copper. The chemical changes that



*What are its properties?*

It is a colourless gas; but when a jar of nitric oxide is opened in the atmosphere, dense, suffocating, red fumes appear in consequence of the absorption of oxygen, and formation of nitrous acid.\* It is irrespirable, and does not support combustion.† Its specific gravity is 1.0416. 100 cubic inches weigh 36.77 grains. Its atomic weight is 30.

*How is NITROUS ACID procured?*

By mixing two measures of the deutoxide of nitrogen and one of oxygen, free from moisture, in a dry glass vessel, previously exhausted by the air-pump, nitrous acid gas is formed. To form

occur are as follows. One portion of nitric acid suffers decomposition. Part of its oxygen unites with the copper, and converts it into the peroxide; while another part is retained by the nitrogen of the nitric acid, forming the deutoxide of nitrogen. The peroxide of copper attaches itself to some undecomposed nitric acid, and forms the blue nitrate of copper. Many other metals are oxidized by nitric acid, with the disengagement of a similar compound; but none, except mercury, yields so pure a gas as copper.

\* The deutoxide of nitrogen may be distinguished by this character from every other substance, and for the same reason affords a convenient test of the presence of free oxygen. On this property of its condensing oxygen, but no other gas, is founded the application of nitrous gas to the purpose of *eudiometry*, or of ascertaining the purity of air.

It is sparingly absorbed by water. 100 measures of that liquid, cold, and recently boiled, take up about 11 of the gas.

† When a burning taper is immersed in this gas, it is extinguished; as also the flame of sulphur. But inflamed phosphorus burns in it with great splendour. Homberg's pyrophorus spontaneously burns in it.

It is decomposable by several of the metals, when they are heated in it, such as arsenic, zinc, and potassium in excess. It oxidizes them, and affords half its volume of azote. Charcoal ignited in it by a burning glass, produces half a volume of azote, and half a volume of carbonic acid. All these analytical experiments concur to show, that nitric oxide consists of oxygen and azote, in equal volumes.



liquid-nitrous acid, nothing more is necessary than to saturate water with its vapour.\*

*By what is nitrous acid vapour characterized?*

By its orange-red colour.

*What are its properties?*

It is irrespirable, but supports combustion. Water absorbs it, and gives a tint of green. It

\* Dr. Thomson formed this acid, by introducing to 100 measures of common air, contained in a cylindrical glass tube, 18 inches long, and 0.9 inch diameter over water, 100 measures of nitrous gas. The diminution corrected for moisture, amounted to 60.917 volumes, and all the oxygen had disappeared. But from other experiments, he had ascertained the oxygen in 100 measures of air to be 20 measures, which in this case must be reduced, on account of its being saturated with moisture, to 19.65 volumes. The whole diminution, less the oxygen,  $(60.917 - 19.65) = 41.267$ , shows the nitrous gas condensed, which gives the proportion of 20 volumes of oxygen to 42 nitrous, the 2 volumes being probably absorbed by the air in the water through which the gas was passed. We have again, therefore, as in the experiment of Sir H. Davy, 2 volumes of nitrous gas ( $=$  1 volume of nitrogen and 1 volume of oxygen) uniting with 1 volume of oxygen to form nitrous acid vapour, which must be constituted of

1 volume of nitrogen gas	} condensed into 1 volume.
2 volumes of oxygen	

and as 1 volume of nitrogen, and half a volume of oxygen each represent an atom, nitrous acid must consist of 1 atom of nitrogen  $=$  14, and 4 atoms of oxygen  $=$  32, together 46.

Liquid nitrous acid is conveniently prepared by exposing crystallized nitrate of lead, carefully dried, to a low red-heat in a glass retort. The nitric acid of the salt is by this means resolved into pure *nitrous* acid and oxygen; and if the products are received in vessels kept moderately cool, the greater part of the former is condensed into a liquid. Gay Lussac regarded this substance as hyponitrous acid, but it is generally considered to be in reality anhydrous nitrous acid. It is so volatile as to boil at the temperature of  $82^{\circ}$ . Its specific gravity is 1.450. It is powerfully corrosive, has a strong acid taste and pungent odour, and is of a yellowish orange colour. When mixed with water, it is decomposed, and is instantly resolved into nitric acid and nitrous gas, which is disengaged, occasioning effervescence.

The various coloured acids of nitre are not *nitrous* acids, but nitric acid impregnated with nitrous gas.



reddens litmus paper, has a sour taste, a strong smell, and turns animal substances yellow.\*

*In what way do you obtain NITRIC ACID?*

It may be formed by passing a succession of electric sparks through a mixture of oxygen and nitrogen gases, confined in a glass tube over mercury; † but the nitric acid of commerce is usually procured by decomposing nitrate of potash by means of concentrated sulphuric acid. ‡

\* Nitrous acid is a powerful oxidizing agent, readily yielding oxygen to the more oxidable metals, and to most substances which have a strong affinity for it.

*Hyponitrous acid* is obtained by mixing together nitrous gas (400 measures) and oxygen (100 measures) over a solution of potassa confined by mercury: 100 measures of hyponitrous acid are the result.—See *Henry's Chemistry*, vol. i. p. 318.

† In this manner the nature of nitric acid is demonstrated synthetically, which was first accomplished by Mr. Cavendish in 1785. On admitting a little water to the mixture of gases, an acid solution is obtained, which affords crystals of nitre when saturated with potassa.

Pure nitric acid is therefore to be considered as a gaseous body, having the specific gravity, compared with that of common air, of 2.440.

The best proportion of the gases is seven of oxygen to three of nitrogen; but as some nitrous acid is always formed during the process, the exact composition of nitric acid cannot be determined in this way. It may be formed more conveniently by adding the deutoxide of nitrogen slowly over water to an excess of oxygen gas. Gay Lussac proved that the nitric acid may in this manner be obtained quite free from the nitrous or hyponitrous acids; and that it is composed of 100 measures of nitrogen, and 250 of oxygen. This result agrees with the proportions which Sir H. Davy has deduced from his observations; and it is confirmed by an analysis of the nitrate of baryta, recently made by Dr. Henry. Nitric acid is therefore composed of

	<i>By Volume.</i>		<i>By Weight.</i>		
Nitrogen.....	100	.....	14	.....	1 atom or equivalent.
Oxygen .....	250	.....	40	.....	5 atoms or equivalents.

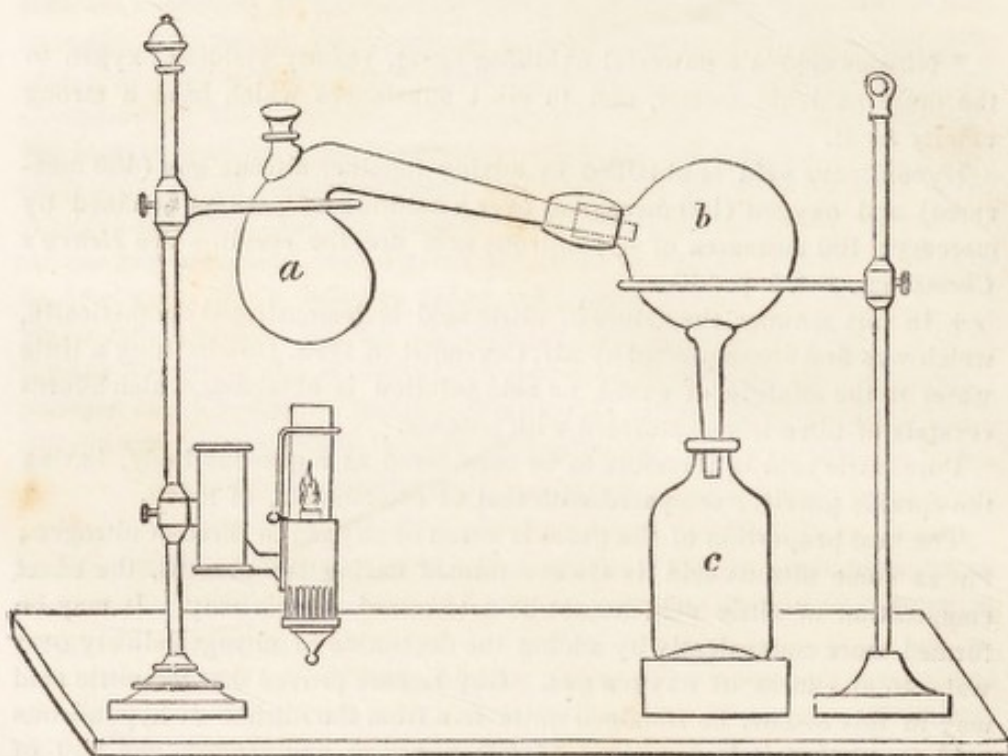
Its atomic weight is, consequently,  $(14 + 40) 54$ .

‡ The apparatus best adapted for preparing nitric acid is a glass retort, which may be either tubulated as *a*, or not; but, in the latter case, the sulphuric acid must be poured upon the nitre, coarsely powdered, through a



*There is a very remarkable fact dependent on the formation of nitric acid by the union of oxygen and nitrogen gases, as just noticed: do you know what it is?*

retort funnel, with care, to prevent any of it from adhering to the inner surface of the neck. A tubulated receiver *b*, of large capacity, is to be applied, between which, and the retort, an adapter may be interposed; these junctures being luted with a mixture of pipe-clay, sifted sand, and cut tow or flax. To the tubulure of the receiver, a glass tube may be fixed by means of the fat lute, and may terminate in another large receiver *c*, con-



taining a small quantity of water. If the operator wishes to collect the gaseous products, let a bent glass tube from this receiver communicate with a pneumatic trough.

Chemists differ as to the best proportions of nitrate of potash and sulphuric acid for forming nitric acid: 100 parts of good nitre, 60 of strong sulphuric acid, and 20 of water, form economical proportions. These substances are put into the retort, (the sulphuric acid being cautiously introduced, and the fumes that arise being avoided,) and heat applied by the lamp. The first product that passes into the receiver is generally red and fuming; but the appearances gradually diminish, till the acid comes over pale, and even colourless, if the materials used were clean. After this it



It is, that the same elements which constitute the air we breathe, and by which we live, when combined in different proportions, form this highly acrid, corrosive, and poisonous substance, called nitric acid.

*What is AQUA FORTIS?*

A dilute nitric acid.\*

again becomes more and more red and fuming, till the end of the operation; and the whole mingled together will be of a yellow or orange colour. What remains in the retort is a bisulphate of potassa.

The nitric acid which first passes over has the greatest specific gravity. In an experiment of Dr. Percival, of Dublin, the product was taken in three portions; the first of which had the specific gravity of 1.494, the second of 1.485, and the third of 1.442.

To form nitric acid, the London College recommends equal weights of nitre and sulphuric acid; and the Edinburgh and Dublin Colleges employ three parts of nitre to two of the acid. The proportions of the London College are so calculated, that the potassa of the nitre shall be entirely converted into a bisulphate; for one proportion of nitre (54 acid + 48 potassa) is 102, and 98 corresponds to two proportions of concentrated sulphuric acid. To comprehend the nature of this process, it should be observed, that the strong sulphuric acid of commerce consists of one equivalent of dry acid to one of water, and that the strongest nitric acid contains nearly one equivalent of dry or real acid, and two equivalents of water. Unless supplied with this proportion of water, the nitric acid is resolved, at the moment of quitting the potash, into oxygen and nitrous acid. Now, in the process of the London College, the water in the sulphuric acid is precisely sufficient for uniting with the nitric acid, and therefore the latter passes over almost entirely as such into the receiver.

\* Nitric acid is of considerable use in the arts. It is employed for etching on copper; as a solvent for tin, to form with that metal a mordant for some of the finest dyes; in metallurgy and assaying; in various chemical processes, on account of the facility with which it parts with oxygen and dissolves metals; in medicine as a tonic, as also in form of vapour to destroy contagion. For the purpose of the arts, it is commonly used in a diluted state, and contaminated with the sulphuric and muriatic acids, by the name of *aqua fortis*. Two kinds are found in the shops, one called *double aqua fortis*, which is about half the strength of nitric acid; the other simply *aqua fortis*, which is half the strength of the double.

The nitric acid of commerce, as obtained by the processes above described, is seldom perfectly pure. It usually contains both muriatic and sulphuric acids; the muriatic being derived from sea-salt, which is fre-



*Can nitric acid exist in an insulated state?*

No. The most simple form under which chemists have hitherto procured nitric acid is in solution with water. The deutoxide of nitrogen and oxygen gases never form nitric acid if mixed together when quite dry; and nitrous acid vapours may be kept in contact with oxygen gas without change, provided no water is present.

*What are the properties of liquid nitric acid?*

It is eminently corrosive, and hence its old name of *aqua fortis*. Its taste is sour and acrid. A few drops of it, diluted with a considerable quantity of water, form an acid solution, which reddens litmus paper permanently. It is heavier than water, and its specific gravity varies with the process employed in preparing it.\*

quently mixed with nitre, and the sulphuric from the acid used in the process. The former may be separated by *nitrate of silver*, and the latter by a very dilute solution of *nitrate of baryta*. Therefore, to obtain *pure nitric acid*, add to that of commerce a solution of nitrate of silver as long as it produces any white precipitate; and when this has subsided, pour off the clear liquor, and add, in the same way, the nitrate of baryta; then distil the acid, and it will pass over perfectly pure. For pharmaceutical purposes, the ordinary acid is generally sufficiently pure.

\* Proust obtained it of specific gravity as high as 1.62; and the specific gravity of real nitric acid, which cannot, however, be obtained separately, may be calculated at 1.75. In its heaviest form, it still contains a portion of water, which is essential to its existence in a liquid state, and without which its elements would probably separate from each other. In acid of the sp. gr. 1.50, the water amounts, calculating from the data furnished by Dr. Wollaston, to 25.11 grains in 100 grains of acid; or, according to Mr. R. Phillips, to 25.09. According to Sir H. Davy, the strongest acid (sp. gr. 1.55) contains 14.4 parts of water in 100; and acid of sp. gr. 1.42 contains 25.2 of water in 100.



It gives a yellow stain to the skin; boils at 248° Fahrenheit, and may be distilled over, without

*The following is Dr. Ure's Table of the quantity of Real or Anhydrous Nitric Acid in 100 parts of Liquid Acid, at different densities.*

Specific Gravity.	Real acid in 100 parts of the liq.	Specific Gravity.	Real acid in 100 parts of the liq.	Specific Gravity.	Real acid in 100 parts of the Liq.
1.5000	79.700	1.3783	52.602	1.1895	26.301
1.4980	78.903	1.3732	51.805	1.1833	25.504
1.4960	78.106	1.3681	51.068	1.1770	24.707
1.4940	77.309	1.3630	50.211	1.1709	23.910
1.4910	76.512	1.3579	49.414	1.1648	23.113
1.4880	75.715	1.3529	48.617	1.1587	22.316
1.4850	74.918	1.3477	47.820	1.1526	21.519
1.4820	74.121	1.3427	47.023	1.1465	20.722
1.4790	73.324	1.3376	46.226	1.1403	19.925
1.4760	72.527	1.3323	45.429	1.1345	19.128
1.4730	71.730	1.3270	44.632	1.1286	18.331
1.4700	70.933	1.3216	43.835	1.1227	17.534
1.4670	70.136	1.3163	43.038	1.1168	16.737
1.4640	69.339	1.3110	42.241	1.1109	15.940
1.4600	68.542	1.3056	41.444	1.1051	15.143
1.4570	67.745	1.3001	40.647	1.0993	14.346
1.4530	66.948	1.2947	39.850	1.0935	13.549
1.4500	66.155	1.2887	39.053	1.0878	12.752
1.4460	65.354	1.2826	38.256	1.0821	11.955
1.4424	64.557	1.2765	37.459	1.0764	11.158
1.4385	63.760	1.2705	36.662	1.0708	10.361
1.4346	62.963	1.2644	35.865	1.0651	9.564
1.4306	62.166	1.2583	35.068	1.0595	8.767
1.4269	61.369	1.2523	34.271	1.0540	7.970
1.4228	60.572	1.2462	33.474	1.0485	7.173
1.4189	59.775	1.2402	32.677	1.0430	6.376
1.4147	58.978	1.2341	31.880	1.0375	5.579
1.4107	58.181	1.2277	31.083	1.0320	4.782
1.4065	57.384	1.2212	30.286	1.0267	3.985
1.4023	56.587	1.2148	29.489	1.0212	3.188
1.3978	55.790	1.2084	28.692	1.0159	2.391
1.3945	54.993	1.2019	27.895	1.0106	1.594
1.3882	54.196	1.1958	27.098	1.0053	0.797
1.3833	53.399				



any essential change; and may be frozen by cold.\*

*What is the most remarkable chemical character of this acid?*

The readiness with which it yields a portion of the oxygen which enters into its composition.†

*It unites with and neutralizes alkaline substances, forming with them certain salts: what are they called?*

\* The temperature at which congelation takes place, varies with the strength of the acid. The strongest acid freezes at about 50 degrees below zero. When diluted with half its weight of water, it becomes solid at  $1\frac{1}{2}^{\circ}$  Fahr. By the addition of a little more water its freezing point is lowered to  $45^{\circ}$  F.

When very concentrated, this acid becomes coloured by exposure to the sun's rays, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of that principle to the nitrogen is diminished. Therefore, by exposing it to the light of the sun in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured.

+ Hence it is rapidly acted upon by all combustible bodies: sugar, alcohol, charcoal, &c. excite the most violent action, accompanied with the evolution of copious red fumes. If certain essential oils, as those of turpentine and cloves, be suddenly poured on this acid, the mixture will instantly take fire.

From this property, as I have already remarked, it is much employed by chemists for bringing bodies to their maximum of oxidation. Nearly all the metals are oxidized by it; and some of them, such as tin, copper, and mercury, are attacked with great violence. Sulphur and phosphorus are converted into acids by its action. All vegetable substances are decomposed by it. In general the oxygen of the nitric acid enters into direct combination with the hydrogen and carbon of these compounds, forming water with the first, and carbonic acid with the second. This happens remarkably in those compounds in which hydrogen and carbon are predominant, as in alcohol and the oils. It effects the decomposition of animal matters also.

When oxidation is effected through the medium of nitric acid, the acid itself is commonly converted into the deutoxide of nitrogen.



## NITRATES.\*

We must now advert to the UNION OF NITROGEN WITH HYDROGEN: *what is the result of their combination?*

## AMMONIA.†

*Do these gases unite directly, and form ammonia?*

No. Chemists therefore cannot prove the constitution of ammonia synthetically, that is, by forming it from the direct union of the elements of which it is composed.‡

*Then how do they show that this substance is really composed of nitrogen and hydrogen?*

\* All the salts of nitric acid are soluble in water, and therefore it is impossible to precipitate that acid by any re-agent. The presence of nitric acid, when uncombined, is readily detected by its strong action on copper and mercury, and by its forming with potassa a neutral salt, which crystallizes in prisms, and which has all the properties of nitre. Gold leaf is a still more delicate test.—See Dr. Turner's *Elem. of Chem.* p. 282.

A new test of the presence of nitric acid has been recently proposed by Dr. Liebig (*Quarterly Journal of Science for July 1827*, p. 204.) The liquid to be examined must be mixed with a sufficient quantity of a solution of indigo in sulphuric acid for acquiring a distinct blue colour, a few drops of sulphuric acid be then added, and the mixture boiled. If a nitrate is present, the liquid will be bleached, or, if the quantity is very small, rendered yellow. By this process nitric acid may be detected, though diluted with 400 times its weight of water; or by adding a little muriate of soda to the liquid before applying heat, 1-500th part of nitric acid may be discovered.

† It is sometimes called the *Volatile Alkali*, or *Spirit of Hartshorn*. Dr. Priestley first procured ammonia in its pure form, and gave it the name of *alkaline air*; and his experiments, with those of Scheele, repeated and illustrated in an elaborate manner by Berthollet, led to the knowledge of its elements; indeed the last chemist must be considered as the true discoverer of the composition of ammonia.

‡ Yet, says Sir H. Davy, when nitrogen is exposed to moist substances giving off hydrogen, a little ammonia is found after some time in the water; for instance, when nitrogen is placed in contact with moist iron filings above mercury.



By analysis; for when a succession of electric sparks is passed through ammoniacal gas, it is resolved into hydrogen and nitrogen, thus proving them to be its elements.\* The same effect is produced by conducting ammonia through porcelain tubes heated to redness.

*How is ammonia usually procured?*

From the decomposition of muriate of ammonia by quick lime. We mix together equal parts of muriate of ammonia and dry quick lime, each in fine powder, and introduce them into a small gas bottle or retort; then apply the heat of a lamp, and receive the gas that is disengaged, over mercury.†

\* Ammoniacal gas (perfectly dry), when mixed with oxygen, explodes with the electric spark, and is converted into water and nitrogen. This has been shown by Dr. Henry, in an ingenious paper, published in the *Philosophical Transactions for 1809*; or the reader may refer to his *Elem. of Chem.* vol. i. p. 411. But the simplest, and perhaps most accurate mode of resolving ammonia into its elementary constituents, is that first practised by M. Berthollet. This consists in making the pure gas traverse very slowly an ignited porcelain tube of a small diameter. Berthollet in analyzing ammoniacal gas in this way, ascertained that 200 measures of that gas, on being decomposed, occupy the space of 400 measures, 300 of which are hydrogen, and 100 nitrogen.

† A convenient method of preparing ammoniacal gas for the purpose of experiment, is by applying a gentle heat to the concentrated solution of ammonia (usually called *liquid ammonia*, or *aqua ammonia pura*,) contained in a gas bottle. It soon enters into ebullition, and a large quantity of pure ammonia is disengaged, which must be collected over mercury.

To obtain the gas pure from the decomposition of sal ammoniac by quick lime, join to the beak of the retort, by a collar of caoutchouc, (a neck of an indian rubber bottle answers well,) a glass tube about 18 inches long, containing pieces of ignited muriate of lime. This tube should lie in a horizontal position, and its free end, previously bent obliquely by the blow-pipe, should dip into dry mercury in a pneumatic trough. A slip of porous paper, as an additional precaution, may be tied round the tube, and kept



*How would you detect the presence of free ammoniacal gas?*

By its odour, by its temporary action on yellow turmeric paper, and by forming dense white fumes (muriate of ammonia,) when a glass rod moistened with muriatic acid is brought near it.

*What are the properties of ammonia?*

At common temperatures it is a permanent gas, and colourless.\* It has a strong and very pungent smell; is irrespirable, and does not support combustion.† It is lighter than atmospheric air, and has a strong affinity for water.‡ It has a

moist with ether. If a gentle heat from a charcoal chauffer or lamp be now applied to the bottom of the retort, a gaseous body will bubble up through the mercury. Fill a little glass tube, sealed at one end, with the gas, and transfer it, closely stopped at the other end, into a basin containing water. If the water rise instantly and fill the whole tube, the gas is pure, and may be received for examination.

\* According to Guyton de Morveau, it becomes a liquid at about 70 degrees below zero of Fahrenheit's scale: but his experiments were made in glass balloons, and the conclusions drawn from the appearance of fluid; so that the evidence, though strong, cannot be regarded as perfectly satisfactory, as ammonia contains vapour which must be condensed to a great extent by so intense a cold.

† Ammoniacal gas extinguishes combustion, but being itself to a certain degree combustible, the flame of a taper immersed in it, is enlarged before going out.

‡ Owing to this attraction, when a drop or two of water is admitted into a jar of this gas, confined over mercury, the gas will be immediately absorbed, and the mercury will rise, so as to fill the whole of the jar, provided the gas be sufficiently pure. Ice produces the same effect, in a still more remarkable manner. From Sir H. Davy's early experiments, it appeared that 100 grains of water absorb 34 grains of ammoniacal gas, or 190 cubic inches. Therefore a cubic inch of water takes up 475 cubic inches of the gas. More recently he has stated, that at 50° Fahrenheit, water absorbs 670 times its bulk, and acquires the specific gravity .875. Even this is much below the proportion absorbed in Dr. Thomson's experiments, viz. 780 volumes of ammoniacal gas by 1 volume of water.



very acrid taste, and possesses all the properties of an alkali.\*

Dr. Ure says (*Dict. of Chem.* p. 142,) Water is capable of dissolving easily about one-third of its weight of ammoniacal gas, or 460 times its bulk. The following is Sir H. Davy's valuable Table:—

*Table of the Quantities of Ammoniacal Gas in Solutions of different Densities (Temp. 50° Fahrenheit, Barometer, 29.8.)*

100 parts of Specific Gravity.		Of Ammonia.	100 parts of Specific Gravity.		Of Ammonia.
.8750	contain	32.5	.9435	contain	14.53
.8875		29.25	.9476		13.46
.9000		26.	.9513		12.40
.9054		25.37	.9545		11.56
.9166		22.07	.9573		10.82
.9255		19.54	.9597		10.17
.9326		17.52	.9619		9.60
.9385		15.88	.9692		9.50

“ The remarkable expansiveness which ammonia carries into its first condensation with water, continues in the subsequent dilutions of its aqueous combinations. This curious property is not peculiar to pure ammonia, but belongs, as I have found, to some of its salts. Thus sal ammoniac, by its union with water, causes an enlargement of the total volume of the compound, beyond the volume of the constituents of the solution. Or the specific gravity of the saturated solution is less than the mean specific gravity of the salt and water. I know of no salts with which this phenomenon occurs, except the ammoniacal.”—*Dr. Ure.*

\* It gives a brown stain to turmeric paper; though the yellow colour soon reappears on exposure to the air, owing to the volatility of the alkali. It combines also with acids, and neutralizes their properties completely.

The alkaline nature of ammonia is demonstrated, not only by its neutralizing acidity, and changing the vegetable reds to purple or green, but also by its being attracted to the negative pole of a voltaic arrangement. When a pretty strong electric power is applied to ammonia in its liquid or solid combinations, simple decomposition is effected: but in contact with mercury, very mysterious phenomena occur. If a globule of mercury be surrounded with a little water of ammonia, or placed in a little cavity in a piece of sal ammoniac, and then subjected to the voltaic power by two wires, the negative touching the mercury, and the positive the ammoniacal compound, the globule is instantly covered with a circulating film, a white smoke rises from it, and its volume enlarges, whilst it shoots out ramifications of a semi-



*What is its specific gravity, and its atomic weight?*

Its specific gravity is to that of common air as 0.5902 to 1.\* It is composed of 3 atoms of hydrogen and 1 of nitrogen; its atomic weight will therefore be  $(3 + 14)$  17.†

solid consistence over the salt. The amalgam has the consistence of soft butter, and may be cut with a knife. Whenever the electrization is suspended, the crab-like fibres retract towards the central mass, which soon, by the constant formation of white saline films, resumes its pristine globular shape and size. The enlargement of volume seems to amount occasionally to ten times that of the mercury, when a small globule is employed. Sir H. Davy, Berzelius, and MM. Gay Lussac and Thenard, have studied this singular phenomenon with great care. They produced the very same substance by putting an amalgam of mercury and potassium into the moistened cupel of sal ammoniac. It becomes five or six times larger, assumes the consistence of butter, whilst it retains its metallic lustre.

What takes place in these experiments? In the second case, the substance of metallic aspect which we obtain is an ammoniacal hydruret of mercury and potassium. There is formed, besides, muriate of potash. Consequently a portion of the potassium of the amalgam decomposes the water, becomes potash, which itself decomposes the muriate of ammonia. Thence result hydrogen and ammonia, which, in the nascent state, unite to the undecomposed amalgam. In the first experiment, the substance which, as in the second, presents the metallic aspect, is only an ammoniacal hydruret of mercury; its formation is accompanied by the perceptible evolution of a certain quantity of chlorine at the positive pole. It is obvious, therefore, that the salt is decomposed by the electricity. The hydrogen of the muriatic acid, and the ammonia, both combine with the mercury.—See *Dr. Ure's Dict. of Chem.* p. 144.

\* Its specific gravity is an important *datum* in chemical researches, and has been rather differently stated. MM. Biot and Arago make it  $\pm 0.59669$  by experiment, and by calculation from its elementary gases, they make it  $\pm 0.59438$ . Kirwan says, that 100 cubic inches weigh 18.16 gr. at 30 inches of barom. and  $61^{\circ}$  Fahr. which compared to air reckoned 30.519, gives 0.59540. Sir H. Davy determines its density to be  $\pm 0.5902$ , with which estimate the theoretic calculations of Dr. Prout, in the 6th vol. of the *Annals of Philosophy*, agree.

† To ascertain the precise amount of the gases evolved from ammonia, by the agency of electricity, great care and nicety are necessary; for if either the gas itself, or the mercury which confines it, contain any moisture, the product of gas, resulting from its decomposition, will exceed what it ought to be. "The problem," as Dr. Henry observes, (*Elem. of Chem.* vol. i. p. 410.) "is one of importance, because from the proportion of the elements



*How is LIQUID AMMONIA obtained?*

It is made by passing a current of ammoniacal gas, as long as it continues to be absorbed, into distilled water, which is kept cool by means of ice or moist cloths.\*

*Ammonia unites with acids, forming certain salts: What are the principal salts it thus forms?*

MURIATE OF AMMONIA, NITRATE OF AMMONIA, CHLORATE OF AMMONIA, and HYDRIODATE OF AMMONIA.†

of ammonia, is deduced the weight of the atom of nitrogen. This will differ considerably, according to the statement which we may adopt, of the amount of gases obtained by decomposing ammonia; their proportion to each other; and the exact specific gravities of hydrogen and nitrogen gases. I have therefore, again analyzed ammonia with every possible precaution to avoid sources of inaccuracy, and have obtained results strictly agreeing with the proportions above stated. (*Annals of Phil.* N. S. vol. viii. p. 341.) If then hydrogen be made the decimal unit, and it be admitted that the three volumes of hydrogen in ammonia represent 3 atoms, and the one volume of nitrogen 1 atom, the weights of the atoms of hydrogen and nitrogen will be as their specific gravities, viz. as .0694 to .9722, or as 1 to 14. Ammonia, according to this view, will be constituted of three atoms of hydrogen = 3 + 1 atom of nitrogen = 14, and its representative number will be 17."

\* Or liquid ammonia may be formed by the following process, which is recommended by Mr. R. Phillips, as preferable to that of the London Pharmacopœia. On 9 oz. of well-burnt lime, pour half a pint of water, and when it has remained in a well closed vessel for nearly an hour, add 12 oz. of muriate of ammonia, and about 3½ pints of boiling water. When the mixture has cooled, filter the solution; and having put it into a retort, distil off 20 fluid ounces. The solution will have the specific gravity 0.954, which is quite as strong as it can be conveniently kept.

This concentrated solution of ammonia should be preserved in well-stopped bottles, both on account of its great volatility, and its tendency to absorb carbonic acid from the atmosphere.

† This alkali also combines with *iodic acid*, forming *iodate of ammonia*; with *carbonic acid*, forming *carbonate of ammonia*; and with *phosphoric* and *sulphuric acids*, forming *phosphate* and *sulphate of ammonia*: but these salts we shall notice in the subsequent pages.

Chlorine and ammonia exercise so powerful an action on each other, that when mixed suddenly, a sheet of white flame pervades them. No com-



*How is muriate of ammonia procured?*

It may be formed by mixing over mercury equal measures of ammoniacal gas and muriatic acid gas, when they are entirely condensed into a white solid, which is *muriate of ammonia*, or *sal ammoniac*.\*

*What are the properties of sal ammoniac?*

Its taste is cool, acrid, and bitterish, and it slightly attracts moisture from the air. Its

pound of chlorine and ammonia can exist, for as soon as ammonia is brought into contact with chlorine, it is decomposed: the nitrogen gas is disengaged, and muriatic acid is formed. In this case the hydrogen of the ammonia unites with the chlorine, and the nitrogen is liberated.

\* Muriate of ammonia was formerly imported from Egypt, where it was obtained by burning the dung of camels; it is now abundantly prepared on the Continent and in this country. The dung of camels and other animals constitutes the chief fuel used in Egypt, and in the fabrication of sal ammoniac, the soot is carefully collected. Globular glass vessels, about a foot in diameter, are filled within a few inches of their mouth with it, and are then arranged in an oblong furnace, where they are exposed to a heat gradually increased. The upper part of the glass balloon stands out of the furnace, and is kept relatively cool by the air. On the third day the operation is completed, at which time they plunge an iron rod occasionally into the mouths of the globes, to prevent them from closing up, and thus endanger the bursting of the glass. The fire is allowed to go out; and on breaking the cooled globes, their upper part is found to be lined with sal ammoniac, in hemispherical lumps, about  $2\frac{1}{2}$  inches thick, of a greyish-white colour, semi-transparent, and possessed of a degree of elasticity: 26 pounds of soot yield 6 of sal ammoniac.

In Europe it is manufactured by several processes. The most usual method is to decompose sulphate of ammonia by the muriate either of soda or magnesia. Double decomposition ensues, giving rise in both cases to muriate of ammonia, and to sulphate of soda, when the muriate of that base is used, or to sulphate of magnesia when the muriate of magnesia is employed. The sal ammoniac is afterwards obtained in a pure state by sublimation. Sulphate of ammonia may be conveniently procured for this purpose, either by lixiviating the soot of coal, which contains that salt in considerable quantity, or by digesting the impure carbonate of ammonia, procured by exposing bones and other animal matters to a red heat, with gypsum or sulphate of lime, so as to form an insoluble carbonate of lime, and a soluble sulphate of ammonia.



specific gravity is 1.42. It is readily soluble in water, three parts and a half of which, at  $60^{\circ}$ , take up one of the salt. It is remarkable for possessing a certain degree of ductility, so that it is not easily pulverable.\*

*How do you procure nitrate of ammonia?*

The most easy mode of procuring it is by adding carbonate of ammonia to dilute nitric acid, till saturation has taken place.†

*What are its properties?*

Its taste is acrid and bitter; it is deliquescent, and soluble in twice its weight of water at  $60^{\circ}$ , and in its own weight at  $212^{\circ}$ . The dry salt is constituted of 1 atom of acid, and 1 atom of base, and its equivalent is consequently  $54 + 17 = 71$ .‡ When heated it is entirely resolved into nitrous oxide gas (see page 193) and water. This is its most important property.§

\* It may be sublimed. On the addition of a solution of pure potassa, or pure soda, the ammonia is disengaged, as is evinced by the pungent smell that arises on the mixture of these two bodies, though perfectly inodorous when separate. It consists of 1 atom of muriatic acid = 37, and 1 of ammonia = 17; its atomic weight is therefore 54.

Sal ammoniac is used in the arts for a variety of purposes, especially in certain metallurgic operations. It is used in tinning, to prevent the oxidation of the surface of copper; and small quantities are consumed by dyers.

† It may also be procured by the direct union of ammonia with nitric acid.

‡ Its composition varies according to the mode of its preparation; and it contains different proportions of water of crystallization. The prismatic variety is stated by Berzelius to consist of

		Atom.
Acid .....	67.625	1 = 54
Base .....	21.143	1 = 17
Water .....	11.232	1 = 9
	100.	80

§ One pound of the compact kind gives, by careful decomposition, nearly



*What is CARBON?*

It is the pure inflammable principle, which is the characteristic ingredient of all kinds of charcoal.\*

*How is charcoal procured?*

It is obtained from many sources.† Most ani-

five cubic feet of gas, or rather more than 34 doses of nitrous oxide; so that the expense, estimating the salt at 5s. 10d. the pound, is about 2d. for each dose.

At a temperature of 600° nitrate of ammonia explodes, and is entirely decomposed. Hence it was formerly called *Nitrum flammans*.

*Chlorate of Ammonia*, referred to at page 208, is formed by saturating chloric acid with carbonate of ammonia. It forms very soluble acicular crystals, of a sharp taste, which detonate with a red flame when thrown upon hot coals. The proportion of its components is not known.

*Hydriodate of Ammonia* is constituted of equal volumes of hydriodic acid gas and ammoniacal gas. It may be formed by mixing the watery solutions of the acid and base. It crystallizes in cubes which are more soluble than sal ammoniac, and nearly as volatile, subliming in close vessels without decomposition.

*Iodate of Ammonia* is best formed by saturating iodic acid with ammonia. It is deposited in small crystals of an indeterminate form. Its composition is not known.

\* Charcoal, in the form under which it ordinarily occurs, contains several ingredients that are not essential to it; and it is to the pure carbonaceous principle, divested of these impurities, that the term *Carbon* is alone properly applied. Wood-charcoal contains from 1-50th to 1-200th of its weight of alkaline and earthy salts, which constitute the ashes when this species of charcoal is burned.

† To obtain charcoal free from contamination, pieces of oak, willow, hazel, or other woods, deprived of the bark, may be buried in sand in a crucible, which is to be exposed, covered, to the strongest heat of a wind-furnace. For purposes of accuracy, charcoal must be used when recently prepared, and before it has had time to become cold; or if it cannot be had fresh made, it must be heated again to redness under sand in a crucible.

When the volatile matters are driven off from coal, as in the process for making coal gas, a peculiar kind of charcoal, called *coke*, remains in the retort. This is an impure sort of charcoal, generally containing sulphur, and other substances. Again, when bones are made red-hot in a covered crucible, a black mass remains, which consists of charcoal mixed with the earthy matters of the bone. It is called *ivory-black*, or *animal charcoal*. The purest carbon for chemical purposes is obtained by strongly igniting



mal and vegetable substances yield it when ignited in close vessels. Thus, a very pure charcoal may be procured from starch or sugar; and from oil of turpentine, or spirit of wine, by passing their vapour through a red-hot tube. In the large way, charcoal is now most commonly prepared in this country by the distillation of wood in cast iron cylinders.\* By this means the volatile parts are driven off, and leave behind a black porous substance, which is charcoal.

*What are the properties of charcoal?*

It is perfectly insipid, and free from smell; insoluble in water,† brittle, and easily pulverized. It is a bad conductor of heat,‡ but a good conductor of electricity. It undergoes little change from exposure to air and moisture, being less injured under these circumstances than wood. If excluded from the air, it supports the most

lamp-black in a covered crucible. This yields, like the diamond, unmixed carbonic acid by combustion in oxygen. Lamp-black is the condensed soot collected from the refuse resin of turpentine makers.

\* The loppings of young trees, commonly called crop-wood, are generally employed; and, besides the charcoal, liquid products of value are collected, especially an impure vinegar called *pyroligneous acid*.

† From its insolubility in water arises the utility of charring the surface of wood exposed to that liquid, in order to preserve it. This preparation of timber has been proposed as an effectual preventive of what is commonly called the dry-rot. It has an attraction, however, for a certain portion of water, which it retains very forcibly. Thus, the charcoal obtained from light wood, rapidly attracts moisture from the atmosphere, so as to increase in weight from 12 to 14 per cent.

‡ It appears from experiment, that caloric is conveyed through charcoal more slowly than through sand, in the proportion of three to two. Hence, powdered charcoal may be advantageously employed to surround substances which are to be kept cool in a warm atmosphere; and also to confine the caloric of heated bodies.



intense heat of our furnaces without change.\* It is highly combustible in the open air, or in oxygen gas. It is more than twice as heavy as water. Its atomic weight is 6.

*There are two other remarkable properties it possesses: what are they?*

That of absorbing gases without alteration;†

\* Sir H. Davy says, (*Elem. Chem. Philosophy*, p. 300,) "Carbon, whether coherent in charcoal, or in powder, is infusible by any heat that has hitherto been applied. I have exposed it to the powers of intense ignition of different Voltaic batteries; that of Mr. Children, one of 40 double plates of 18 inches square, and the battery of 2000 double plates of 4 inches, both in vacuo, and in compressed gases, on which it had no power of chemical action. A little hydrogen was given off from it, and it slowly volatilized in these experiments, and the part remaining was much harder than before, so as in one case to scratch glass, and the lustre was greater; but its other properties were unaltered, and there was no appearance of fusion."

Professor Silliman, of Yale College, America, appears, however, to have observed, on subjecting cylindrical pieces of charcoal, tapered to a point, to the *Galvanic* deflagrator of Dr. Hare, when in powerful action, that the charcoal point of the positive pole instantly shot out  $\frac{1}{10}$ th,  $\frac{1}{8}$ th, or even  $\frac{1}{4}$ th of an inch. The charcoal of the negative point underwent, in the mean time, a change precisely the reverse, its point disappearing, and a crater-shaped cavity being substituted in its stead. By placing a piece of metal at the negative pole in lieu of charcoal, it was ascertained by the absence of the usual phenomena, that the increase, before observed in the charcoal at the positive pole, was occasioned by an actual transference of charcoal from the former to the latter. On examining with a magnifier the projecting point of the charcoal at the positive pole, it was found to have undergone distinct fusion into small spheres collected into botryoidal or mamillary concretions.—*See Annals of Philos.* N. S. vol. iv. p. 119.

† It absorbs different gases, condensing them in its pores without any alteration of their properties or its own. This was first observed by Priestley, but it was afterwards more fully investigated by Morozzo, Rouppe, and Saussure, the last of whom has performed the latest and greatest number of experiments on it. His experiments were performed by plunging a piece of red-hot charcoal under mercury, and introducing it when cool into the gas to be observed. He found that charcoal prepared from box-wood, absorbs, during the space of 24 or 36 hours, of



and that of resisting the putrefaction of animal substances. Thus, tainted flesh may be rendered perfectly sweet and eatable by rubbing it daily with powdered charcoal. It produces, also, a remarkable effect in destroying the taste, odour, and colour of many vegetable and animal substances. Foul water may be purified by filtering through charcoal, and common vinegar, by being boiled in it, is rendered perfectly limpid.\*

Ammoniacal gas .....	90	Times its Volume.	Olefiant gas .....	35	Times its Volume.
Muriatic acid .....	85		Carbonic oxide.....	9.42	
Sulphurous acid .....	65		Oxygen .....	9.25	
Sulphuretted hydrogen	55		Nitrogen .....	7.5	
Nitrous oxide .....	40		Hydrogen .....	1.75	
Carbonic acid .....	35				

This power of absorbing different gases appears to be entirely a mechanical effect, in reality owing to the peculiar porous texture of charcoal, which enables it, in common with most spongy bodies, to absorb more or less of all gases, vapours, and liquids, with which it is in contact. The densest and heaviest kinds of charcoal are most remarkable for this property, which is much diminished by reducing them to powder. In plumbago, which has not the requisite degree of porosity, it is altogether wanting. That this absorbing power cannot be attributed to chemical action is evident, since the quantity of each gas, which is absorbed, bears no relation whatever to its affinity for charcoal.

The porous texture of charcoal accounts for the general fact of absorption only; its power of absorbing more of one gas than of another, must be explained on a different principle. This effect seems to depend chiefly on the natural elasticity of the gases. Those which possess such a degree of elasticity as to have hitherto resisted all attempts to condense them into liquids, are absorbed in the smallest proportion; while those that admit of being converted into liquids by compression, are absorbed more freely.

\* From this property charcoal is certainly the best dentifrice. Malt spirit also is freed from its disagreeable flavour by distillation from charcoal; but if too much be used, part of the spirit is decomposed. Simple maceration, for eight or ten days, in the proportion of about 1-150th of the weight of the spirit, improves the flavour much. It is necessary that the charcoal be well burned, brought to a red heat before it is used, and used as soon as may be, or at least be carefully excluded from the air. The



*Has it a strong affinity for oxygen?*

It has; whence its use in disoxygenating metallic oxides, and restoring their base to its original metallic state, or reviving the metal. Thus too it decomposes several of the acids, as the phosphoric and sulphuric, from which it abstracts their oxygen, and leaves the phosphorus and sulphur free.

*Is there any natural substance formed of pure carbon?*

Yes; the diamond, the most valued of all minerals, is carbon in a state of absolute purity.\*

charcoal may be used repeatedly, by exposing it for some time to a red heat before it is again employed.

\* Diamonds were first discovered in Asia, in the provinces of Golconda and Visapour in Bengal, and in the island of Borneo. About the year 1720 diamonds were first found in Brazil. They always occur in detached crystals in alluvial soil. The diamond has been found nearly of all colours; those which are colourless are most esteemed; then those of a decided red, blue, or green tint. Blue and black diamonds are extremely rare. The diamond is the hardest substance known. Its texture is crystalline in a high degree, and its cleavage very perfect. Its primary form is the octahedron. It has a specific gravity of from 3.4 to 3.6. When rubbed, whether in the rough or polished state, it shows positive electricity. It becomes phosphorescent when exposed to the sun or the electric spark, and shines with a fiery light.

It was formerly considered an incombustible body, but Sir George Mackenzie ascertained that when heated to 14° Wedgewood, (equal to 2897° of Fahrenheit's thermometer,) in the open air, it is entirely consumed. Newton first suspected it to be combustible from its great refracting power (see page 98), a conjecture which was rendered probable by the experiments of the Florentine Academicians in 1694, who exposed diamonds to the focus of a powerful burning lens. The fact has been subsequently fully established by several philosophers. In oxygen gas the diamond takes fire, when the focus of a powerful lens is thrown upon it; and continues to burn, though removed out of the focus, with a steady brilliant light, visible in the strongest sunshine. Carbonic acid is the product.

From the results of Sir H. Davy's different experiments, conducted with



*Then diamond and charcoal, though so widely remote from each other in external character, are, as to their chemical nature, identically the same. To what is the great difference in their external or physical characters owing?*

In all probability merely to the respective states of aggregation or condensation of their particles.\*

the most unexceptionable precision, it is demonstrated, that diamond affords no other substance by its combustion than pure carbonic acid gas; and that the process is merely a solution of diamond in oxygen, without any change in the volume of the gas. It likewise appears, that in the combustion of the different kinds of charcoal, water is produced; and that from the diminution of the volume of the oxygen, there is every reason to believe that the water is formed by the combustion of hydrogen existing in strongly ignited charcoal. The quantity of water formed is, however, so small, that hydrogen cannot exist in charcoal as an essential ingredient, or in any definite proportion. The diamond appears to be absolutely free both from water and hydrogen; and it is in this respect only, and in the mechanical arrangement of its particles, that we have any evidence of its differing from charcoal.

\* If proof were wanted of the identity of the two substances, it is furnished by the fact that the diamond converts iron into steel (see *Iron*), under circumstances quite free from all sources of fallacy.—*Philos. Transactions*, 1815, p. 371.

The weight, and consequently the value of diamonds, is estimated in carats, one of which is equal to four grains; and the price of one diamond, compared to that of another of equal colour, transparency, purity, form, &c. is as the squares of the respective weights: thus, the value of three diamonds, of one, two, and three carats weight respectively, is as one, four, and nine. The average price of rough diamonds that are worth working, is about £2. for the first carat. The value of a cut diamond being equal to that of a rough diamond of double weight, exclusive of the price of workmanship, the cost of a wrought diamond of

1 Carat is . . . . .	£.8
2 ditto . . . . .	32
3 ditto . . . . .	72
4 ditto . . . . .	128
5 ditto . . . . .	200
10 ditto . . . . .	800
20 ditto . . . . .	3.200



*What are the uses to which charcoal is applied?*

It is used on particular occasions as fuel, on account of its giving a strong and steady heat without smoke. It is employed to convert iron into steel by cementation, and it enters into the composition of gunpowder. In its finer states, as in ivory black, lamp black, &c. it forms the basis of black paints, indian ink, and printer's ink.

*With what substances does carbon unite?*

It combines with almost all the bodies already noticed, forming a series of most important compounds. It unites with oxygen in two definite proportions, forming CARBONIC ACID and CARBONIC OXIDE; and with hydrogen in a similar manner, constituting CARBURETTED and SUB-

This rule, however, is not extended to diamonds of more than 20 carats, in consequence of the difficulty of finding purchasers for the larger ones. It is said the price of diamonds is so great, the smallest difference in weight making a difference in price, that diamond merchants consult the barometer in their dealings; and like to sell only when the pressure is diminished, and buy when it is increased.

The largest diamond known is one mentioned by Tavernier, who saw it in the possession of the Great Mogul. It was about as big as a hen's egg, and weighed 900 carats in the rough. It was cut in the rose form, and was found in Golconda, about 1550. The largest diamond ever brought to Europe is one among the crown jewels of Russia. It weighs 195 carats, and was long employed as the eye of a Braminical idol, whence it was purloined by a French soldier. He, however, had some difficulty in disposing of his plunder, and at length got for it only an inconsiderable sum. After passing through several hands, the Empress Catherine bought it for the sum of £90,000, and an annuity of 4,000 rubles (upwards of £600). It is cut in the rose form, and is of the size of a pigeon's egg.

Perhaps the most perfect and beautiful diamond hitherto found, is a brilliant brought from India by an English gentleman of the name of Pitt, who sold it to the Duke of Orleans, then Regent of France, who placed it among the crown jewels of that kingdom. It weighs rather more than 136 carats, and was bought for £100,000.



CARBURETTED HYDROGEN gases. With chlorine it forms CHLORIDES OF CARBON, and with nitrogen and hydrogen PRUSSIC ACID--the most energetic of all known poisons.\*

*How is CARBONIC ACID procured?*

It is most conveniently obtained by pouring muriatic acid, diluted with five or six times its weight of water, on common chalk, or fragments of marble, which are compounds of carbonic acid and lime. The muriatic acid unites with the lime, forming a muriate of lime, and carbonic acid gas escapes with effervescence.†

*What are the properties of this acid?*

In a gaseous state, it is colourless, inodorous, and possesses all the physical characters of the gases. It extinguishes flame,‡ and is fatal to

\* It combines, also, with sulphur, forming a curious limpid liquid, called *carburet of sulphur*; and with phosphorus. Steel and plumbago are two different compounds of carbon with iron. These combinations will be described under the articles on *sulphur*, *phosphorus*, and *iron*.

† This acid, being a compound of carbon and oxygen, may be formed by burning charcoal; but as it exists in great abundance in nature ready formed, it is not necessary to have recourse to this expedient. It not only abounds in great quantities in nature, but appears to be produced in a variety of circumstances. It composes about 44 parts in the hundred of the weight of limestone, marble, calcareous spar, and other natural specimens of calcareous earth, from which it may be extricated either by the simple application of heat, or by the superior affinity of some other acid; most acids having a stronger action on bodies than this.

Carbonic acid was discovered by Dr. Black in 1757, and described by him in his inaugural dissertation *de Magnesia Alba*, under the name of *fixed air*. He not only observed the existence of this gas in calcareous earths, but remarked that it is also formed during respiration, fermentation, and combustion.

‡ To show its effect on burning bodies, set a vessel, filled with this gas, with its mouth upwards, and let down a lighted candle. The candle will instantly be extinguished.



animals.\* It is absorbed by water,† and is much

\* Small animals die in the course of a minute or two when put into a vessel containing this gas. In this way, butterflies and other insects, the colours of which it is desirable to preserve, for the purpose of cabinet specimens, may be suffocated better than by the common mode of killing them with the fumes of sulphur. It is this gas which has often proved destructive to persons sleeping in a confined room with a pan of burning charcoal. Indeed, this gas is peculiarly noxious to animals, for when inspired freely, it not only destroys life, but the heart and muscles of animals killed by it, lose all their irritability, so as to be insensible to the stimulus of galvanism.

† Water absorbs about its own volume of this acid gas, and thereby acquires a specific gravity of 1.0015. By artificial pressure with forcing pumps, it may be made to absorb two or three times its bulk of carbonic acid. Indeed, it appears that the quantity of gas, forced into water, is directly as the pressure. Thus, if water under common circumstances takes up an equal bulk of carbonic acid, under the pressure of two atmospheres it will absorb twice its bulk; under three atmospheres three times its bulk, and so on. In this operation, if a little potash or soda is added to the water, it becomes aerated or carbonated alkaline water, often called *soda water*, which some find a pleasant beverage, and a useful remedy in indigestion and other complaints.

The impregnation of water with carbonic acid gas is most commodiously effected on a small scale, by an apparatus, sold in the glass shops, under the name of Nouth's machine, of which a figure is here given. It consists of three vessels, the lowest, *a*, flat and broad, so as to form a steady support; it contains the materials for evolving the gas, such as fragments of marble and dilute muriatic acid, or common chalk and dilute sulphuric acid, of which fresh supplies may occasionally be introduced through the stopped aperture *f*. The gas passes through the tube *g*, in which is a glass valve opening upwards, into the vessel *c*, containing the water or solution intended to be saturated with the gas, and which may occasionally be drawn off by the glass stop-cock *b*. Into this vessel *c*, dips the tube of the uppermost vessel *d*, which occasions some pressure on the gas in *c*, and also produces a circulation and agitation of the water. At the top of *d* is a heavy conical stopper, which acts as an occasional valve for the escape of gas, and keeps up a degree of pressure in the vessels.



Water and other liquids which have been charged with carbonic acid under great pressure, lose the greater part of the gas when the pressure is



heavier than common air.\* When combined with water it reddens vegetable and blue colours.

*There are other characters of carbonic acid gas: What are they?*

It precipitates lime water,† and is generated during combustion, respiration, and fermentation.

removed. The effervescence which takes place on opening a bottle of ginger beer, cyder, or brisk champagne, is owing to the escape of this gas. Water and wine, which is fully saturated with carbonic acid gas, sparkles when it is poured from one vessel into another; and the solution has an agreeably acidulous taste, and gives to litmus paper a red stain, which is lost on exposure to the air. The agreeable pungency of beer, porter, and ale, is in a great measure owing to the presence of carbonic acid, by the loss of which, on exposure to the air, they become vapid and stale. All kinds of spring and well water contain carbonic acid absorbed from the atmosphere, and to which they are partly indebted for their pleasant flavour.

\* From carbonic acid gas being much denser than common air, it occupies the lower parts of such mines or caverns as contain materials which afford it by decomposition. The miners call it choke-damp. The Grotto del Cano, in the kingdom of Naples, has been famous for ages on account of the effects of a stratum of fixed air which covers its bottom. It is a cave or hole in the side of a mountain, near the lake Averno, measuring not more than eighteen feet from its entrance to the inner extremity; where if a dog or any other small animal be thrust, it is immediately killed by inhaling this noxious fluid.

In consequence of the superior weight of carbonic acid gas, it may be conveyed into any bottle, as it displaces the common air contained in the bottle, which, if well corked, may be used to convey it to great distances, or it may be drawn out of a vessel by a cock like a liquid. The effects produced by pouring this invisible fluid from one vessel to another, have a very singular appearance: if a candle or small animal be placed in a deep vessel, the former becomes extinct, and the latter expires in a few seconds, after the carbonic acid gas is poured upon them, though the eye is incapable of distinguishing any thing that is poured.

According to Sir H. Davy, 100 cubic inches, at 55° Fahrenheit, and 30 inches of the barometer, weigh 47.5 grains; and at 60°, with the same pressure, would weigh 47.11. Messrs. Allen and Pepys determined that 100 cubic inches, at 60° Fahrenheit, and 30 inches barometer, weigh 47.26 grains. Dr. Thompson and Dr. Ure state its specific gravity to be 1.5277, and Berzelius and Dulong 1.5240.

† The precipitation of lime water by carbonic acid gas, affords a ready test of the presence of this acid whenever it is suspected. For if we pass



It also retards the putrefaction of animal substances, and exerts powerful effects on living vegetables.\*

*What is the proportion of the constituents of carbonic acid?*

the gas, as it proceeds from the materials, through a portion of lime water, it will instantly become milky, though perfectly transparent before. Or if we mix equal measures of water saturated with carbonic acid and lime water, the same precipitation will ensue.

The application of this test proves, that carbonic acid is generated in several cases of combustion. Thus, if we fill the pneumatic trough with lime water, and burn a candle, in a jar filled with atmospherical air, over the lime water till the flame is extinguished, on agitating the jar the lime water will become milky. The same appearances will take place, more speedily and remarkably, if oxygen gas be substituted for common air. The carbonic acid, thus formed during combustion, by its admixture with the residuary air, renders it more unfit for supporting flame, than it otherwise would be from the mere loss of oxygen. Hence, if a candle be burnt in oxygen gas, it is extinguished long before the oxygen is totally absorbed, because the admixture of carbonic acid with oxygen gas, in considerable proportion, unfits it for supporting combustion. Whenever any substance, by combustion in oxygen gas or common air over lime water, gives a precipitate, soluble with effervescence in muriatic acid, we may confidently infer that it contains carbon.

By the same test we ascertain that the respiration of animals is another source of carbonic acid gas. This is shown by simply blowing the air from the lungs, with the aid of a quill, through lime water, which will immediately become milky. The carbonic acid, thus added to the air, unfits it for supporting life, not merely by diminishing the proportion of oxygen gas, but apparently by exerting a positively noxious effect. Hence it has been found, that an atmosphere consisting of oxygen gas and carbonic acid is fatal to animals, though it should contain a larger proportion of oxygen than the air we commonly breathe.

\* Water saturated with this gas, proves highly nutritious to plants, when applied to their roots. The carbonic acid is decomposed, its carbon forming a component part of the vegetable, while the oxygen is liberated in a gaseous state. A certain quantity of this gas, applied as an atmosphere, is likewise favourable to vegetation; but it must not exceed the proportion of  $\frac{1}{8}$ th, to  $\frac{7}{8}$ ths of atmospherical air. It is this process of nature that appears to be the principal means of preventing an excess of carbonic acid in the general mass of the atmosphere.



It consists of one proportion or atom of carbon, united to two proportions or atoms of oxygen. Its atomic weight is therefore 22.

*What are the salts called which it forms by uniting with alkaline substances: and is its affinity for the earths and alkalies strong or weak?*

Its salts are called CARBONATES. Its affinity for the earths and alkalies is very inconsiderable; hence the carbonates are decomposed by almost all the acids, even the acetic, the carbonic acid escaping in the form of gas, with effervescence.\*

*May carbonic acid gas be rendered liquid?*

Yes, by great pressure. This was first effected by Mr. Faraday. In this state it is a limpid, colourless body, extremely fluid, and possessing a refractive power much less than that of water. Its vapour exerts a pressure of 36 atmospheres at a temperature of 32°.

*How is CARBONIC OXIDE procured?†*

By mixing together two parts of well-dried chalk and one of pure iron filings, and exposing them to a red heat in a gun barrel. By this means a large quantity of gaseous matter is evolved, which, on examination, is found to contain two compounds of carbon and oxygen, one of which is carbonic acid, and the other *carbonic oxide*. By washing the mixed gases with lime

\* Many of the carbonates are of great importance in the arts, and in medicine. The most valuable of these salts are the *carbonates of lime, potassa, soda, magnesia, ammonia, and baryta*.

† The composition of carbonic oxide was first pointed out by Mr. Cruickshank, of Woolwich, but it was originally discovered by Dr. Priestley.



or potash water, the carbonic acid is absorbed, and the carbonic oxide gas is left in a state of purity.\*

*What are its properties?*

It has an offensive smell, and is lighter than common air.† It is inflammable,‡ but does not support respiration.§ It is very sparingly absorbed by water. It does not combine with the pure alkalies, nor does it precipitate lime water.

*What is its composition?*

It is considered as a combination of one proportion of carbon, and one of oxygen; its atomic weight is therefore  $(6 + 8) 14$ . ||

\* It may also be procured by various other methods. When carbonic acid gas is transmitted over charcoal ignited in a porcelain tube, the acid gas combines with an additional dose of charcoal, loses its acid properties, and is converted into a double volume of carbonic oxide.

By whatever process this gas may be obtained, it is mixed with much carbonic acid, which must be separated in the way recommended above in the text.

† Its specific gravity is 0.9722 according to Dr. Thomson, but Berzelius and Dulong state it to be 0.9727. One hundred cubical inches weigh 30 grains, the temperature being  $55^{\circ}$  Fahrenheit, and pressure 29.5; or at temperature  $60^{\circ}$ , and barometer 30, 100 cubic inches weigh 30.19 grains.

‡ When set fire to, as it issues from the orifice of a small pipe, it burns with a blue flame. The temperature of an iron wire, heated to dull redness, is sufficient to kindle it. (The sole product of its combustion, when the gas is quite pure, is carbonic acid, a fact which proves that it does not contain any hydrogen.) When mixed with common air, it does not explode like other inflammable gases, unless in very few proportions, (*See Dalton's System*, p. 373), but burns silently with a lambent blue flame. A mixture of two measures with one measure of common air, may, however, be exploded by a lighted taper, or even by red-hot iron or charcoal.

§ It acts very injuriously on the system, even when diluted with air.

|| According to Gay Lussac, it contains per cent. 43 charcoal and 57 oxygen by weight. Berzelius, however, makes it consist of 44.28 charcoal, and 55.72 oxygen, proportions which agree, within a small fraction, with those of Clement and Desormes.



CARBON *likewise* COMBINES WITH CHLORINE.  
*What is the result of this union?*

Carbon and chlorine unite in three proportions, forming *perchloride of carbon*, *protochloride of carbon*, and *subchloride of carbon*.\*

*How is PERCHLORIDE OF CARBON procured?*

When chlorine and olefiant gases are mixed in equal volumes, they are condensed into an oily looking liquid, sometimes called chloric ether; and on exposing this liquid in a vessel full of chlorine gas to the direct solar rays, the chlorine acts upon and decomposes the liquid, muriatic acid is set free, and the carbon, at the moment of separation, unites with chlorine.†

\* For the knowledge of these compounds we are indebted to Mr. Faraday, of the Royal Institution.

Their composition may be exhibited at one view, thus—

<i>Perchloride of carbon</i> consists of ..		3 atoms of chlorine =	108
		2 ditto of carbon =	12
		Weight of its atom	120
<i>Protochloride of carbon</i> consists of ..		1 atom of chlorine =	36
		1 ditto of carbon =	6
		Weight of its atom	42
<i>Subchloride of carbon</i> consists of ..		1 atom of chlorine =	36
		2 atoms of carbon =	12
		Weight of its atom	48

It should be observed, that olefiant gas is a compound of 1 atom of carbon and 1 atom of hydrogen; when mixed with an equal volume of chlorine, the three elements all unite and form a ternary liquid composed of chlorine, carbon, and hydrogen, which is the chloric ether; and by subjecting this triple compound to the repeated action of fresh quantities of chlorine, the hydrogen may be entirely abstracted, and a compound of chlorine and carbon produced. The details of this process may be read in *Henry's Chem.* vol. i. p. 357, or *Dr. Ure's Dictionary*, p. 294, or in the *Philosophical Transactions* for 1821.



*What are its properties?*

It is solid at common temperatures, and has an aromatic odour, approaching that of camphor, but scarcely any taste. It is very friable, and when scratched, has much of the feel and appearance of white sugar. Its specific gravity is 2, being exactly double that of water. It fuses at 320° Fahr. and immediately after fusion is a transparent colourless substance. It boils at 360°, and may be distilled without change, assuming a crystalline arrangement as it condenses. It is not readily combustible,\* and is insoluble in water.† It is not changed by chlorine, nor by concentrated acids, nor solutions of pure alkalies.‡ Most of the metals decompose it at elevated temperatures. Both sulphur and phosphorus unite with it.§

*How is PROTOCHLORIDE OF CARBON obtained?*

By passing the vapour of perchloride of carbon

\* When held in the flame of a spirit lamp, it burns with a red flame, emitting much smoke and acid fumes; but on removal from the lamp, its combustion ceases. In an atmosphere of pure oxygen, it burns with a brilliant light.

† It dissolves readily in alcohol, and especially in ether. It is soluble also in the volatile oils; from which it may be obtained in crystals by evaporation. Fixed oils likewise dissolve it.

‡ At moderate temperatures iodine unites with it, but at high temperatures takes away a portion of chlorine, reducing the perchloride to the fluid protochloride of carbon, while chloriodine is formed.

Hydrogen gas, when transmitted along with it through red-hot tubes, decomposes it, and muriatic acid and charcoal are produced.

§ Sulphur and phosphorus unite with it at moderate temperatures, but at higher ones, remove one portion of chlorine.

The metals in decomposing it, form chlorides, and charcoal is liberated. Peroxides produce with it, at a high temperature, chlorides and carbonic acid; protoxides afford chlorides and carbonic oxide.



through a red-hot glass or porcelain tube,\* containing fragments of rock crystal; a partial decomposition is effected; one portion of chlorine is separated and escapes; and the remainder, continuing united to the carbon, forms a fluid substance, which may be collected and purified by repeated distillations. This is the protochloride of carbon.

*What are its properties?*

It is a highly limpid fluid, and perfectly colourless. Its specific gravity is 1.5526. It is a non-conductor of electricity, and is not combustible, except when held in the flame of a spirit lamp. It does not become solid at the zero of Fahrenheit's scale. At  $160^{\circ}$  or  $170^{\circ}$  of Fahr. it is converted into vapour. It is insoluble in water, but readily dissolves in alcohol and ether, the fixed and volatile oils. In its chemical relations it is very analogous to the perchloride of carbon.†

*Does not carbon also combine with chlorine and oxygen, forming a peculiar acid?*

Yes, the CHLORO-CARBONIC ACID. It was

\* The upper part of the tube must be bent up and down two or three times, so that the angles may form receivers for the new compound.

† The *subchloride of carbon* was brought over from Sweden by M. Julin, of Abo, where it had been accidentally formed during the distillation of nitric acid from crude nitre and sulphate of iron. M. Julin describes it to be white, and consisting of small soft adhesive fibres. He says, that it sinks slowly in water; is insoluble in it whether hot or cold; is tasteless; has a peculiar smell, somewhat resembling spermaceti; is insoluble in strong acids or alkalies, but is dissolved in hot oil of turpentine and in alcohol, forming acicular crystals on cooling. It fuses on the application of heat, and boils at a temperature between  $350^{\circ}$  and  $450^{\circ}$  Fahr.



discovered by Dr. John Davy in 1812, by whom it was called *phosgene gas*. It is formed by exposing a mixture of equal measures of dry chlorine and carbonic oxide gases to sunshine, when rapid but silent combination ensues, and they contract to one half their volume.\*

*What are the properties of chlorocarbonic acid gas?*

It is colourless, has an intolerably pungent odour, and reddens litmus paper. It combines with four times its volume of ammoniacal gas, and the product is a white neutral salt; so that it possesses the characteristic property of acids. It is decomposed by contact with water, and is changed into muriatic and carbonic acid gases.†

*It is now necessary to speak of the COMBINATIONS OF CARBON WITH HYDROGEN. How many compounds of carbon and hydrogen are there?*

There are two distinct and well known compounds of these gases, namely, SUB-CARBURETTED and CARBURETTED HYDROGEN GASES.‡

\* Diffused day-light also effects their union slowly; but they do not combine at all when the mixture is wholly excluded from light.

† In contact with water, one proportion of each compound undergoes decomposition; the hydrogen of the water unites with chlorine, to form muriatic acid, and its oxygen with carbonic oxide to form carbonic acid. Several of the metals decompose it, and unite with the chlorine, evolving carbonic oxide equivalent in volume to the original gas.

Since chlorocarbonic acid gas contains its own volume of both its constituents, its specific gravity must be equal to that of chlorine (2.5) added to that of carbonic oxide (0.9722): it is therefore 3.4722, and 100 cubic inches weigh 105.9 grains; namely, 76.25 of chlorine added to 29.65 of carbonic oxide.

‡ These compounds are sometimes termed *carburetted* and *bi-carburetted hydrogen gases*, but the names given in the text are, in my opinion, more



*How do you procure SUB-CARBURETTED HYDROGEN GAS?*

This gas was formerly called *heavy inflammable air, gas of marshes, hydro-carburet*, and being found abundantly in stagnant pools during the decomposition of dead vegetable matter, it may be readily procured by stirring the mud at the bottom of them, and collecting the gas, as it escapes, in an inverted wide-mouthed goblet or other vessel.\*

*What are its properties?*

Sub-carburetted hydrogen is destitute of colour, taste, and smell.† It is highly inflammable, burning with a yellow flame, like that of a candle, but is unable to support respiration. Water absorbs about  $\frac{1}{60}$ th of its volume. Its specific gravity is 0.555, and hence 100 cubic inches, at a mean of the barometer and thermometer, weigh 16.95 grains. It is composed of 1 proportion of

correct, because in both the proportion of carbon is the same, and therefore neither of them can with propriety be called a *bi-carburet*; while in the former, the carbon exists in the proportion of 1 atom to 2 atoms of hydrogen, and therefore may correctly be designated a *sub-carburet*, the other compound being termed a *carburet*, since, as that name expresses, neither of its constituents are in excess or deficient, the proportions being 1 atom of carbon to 1 of hydrogen,

\* In this state it contains a small proportion of carbonic acid gas, which must be removed by washing it with lime water, or liquid potassa.

It may, also, be procured by the purification of gas from coal, by means of chlorine and solution of potassa.

This gas is sometimes called *light carburetted hydrogen*. It is the same gas as is obtained from coal for the purpose of illumination, and which is found in mines, forming the *fire-damp* of the miners.

† The strong and disagreeable smell of coal gas is dependent on foreign admixtures, and principally on sulphuretted hydrogen.



carbon united to 2 proportions of hydrogen; \* its atomic weight is, therefore, 8.†

*Is it not this gas which is now so extensively employed for lighting streets, houses, &c.?*

Yes. Sub-carburetted hydrogen is abundantly produced during the destructive distillation of common pit-coal, and it is in this way that the common gas-lights are obtained. The coal is placed in oblong cast-iron cylinders, or *retorts*, which are ranged in furnaces, to keep them at a red heat, and all the volatile products are conveyed by a common tube into a *condensing vessel*, kept cold by immersion in water; and in which the water, tar, ammoniacal, and other condensible vapours, are retained. The gaseous products (not condensible) are chiefly sub-carburetted hydrogen, sulphuretted hydrogen, and carbonic oxide and acid; these are passed through a mixture of quick lime and water, ‡ in vessels

\* From this view of its constitution, Dr. Thomson has proposed to call it *bi-hydrouret of carbon*.

† When mixed with atmospheric air, it may be kindled by a lighted taper, and it explodes with violence, provided it forms no less than  $\frac{1}{12}$ th of the mixture, and does not exceed  $\frac{1}{6}$ th. With oxygen gas, the detonation is louder and more violent; but it is necessary that the oxygen should rather exceed the inflammable gas in volume, and yet should not be more than  $2\frac{1}{4}$  times its bulk.

When sub-carburetted hydrogen and chlorine gases are mixed together, no change happens either immediately or on standing, provided light be carefully excluded; but if exposed to the ordinary light of day, and still more rapidly in sunshine, a mutual action ensues. If 4 volumes of chlorine and 1 of carburetted hydrogen, be thus kept, during a few hours, in a bottle filled entirely with the mixture, and furnished with a well-ground stopper, on removing this under water, a sudden absorption of muriatic acid gas takes place, and 1 volume of carbonic acid remains.

‡ It is said that passing the gas through successive layers of dry hydrate of lime, is still better, as it not only deprives the gas completely of sulphu-



called *purifiers*, by which the sulphuretted hydrogen and carbonic gases are absorbed, and the subcarburetted hydrogen and hydrogen gases, transmitted sufficiently pure for use into gasometers, whence the pipes issue for the supply of streets, &c.\*

*This, then, is COAL GAS, but OIL GAS is likewise sometimes used for the same purposes. Are these gases the same in chemical constitution?*

They do not differ essentially from one another, both being composed principally of carburetted hydrogen gases.†

retted hydrogen, but there is no loss from absorption of olefiant gas, or the heavy hydro-carburets, as invariably ensues when quick lime and water are employed.

\* Coal gas is extremely variable in composition and properties, not only when prepared from different coals, but from the same kind of coal under different circumstances. Within certain limits, the more quickly the heat is applied, the greater is the quantity, and the better the quality of the gas obtained from coal; for too slow a heat expels the inflammable matter in the form of tar. The earthy products of gas are, also, the heaviest and most combustible, and there is a gradual decline in quality towards the close of the distillation, insomuch that the last products are inferior, by more than one half, to the first.

The best kind of coal for distillation is that which contains most bitumen and least sulphur. The best gas has the specific gravity .650 or upwards; and each volume consumes about  $2\frac{1}{4}$  volumes of oxygen, and gives  $1\frac{1}{4}$  volume of carbonic acid; the last portions have a specific gravity as low as .340, and each volume consumes about 8-10ths of a volume of oxygen, and gives about 3-10ths of a volume of carbonic acid.

It is scarcely possible to assign the quantity of gas, which ought to be obtained from a given weight of coal, but Dr. Henry says, it may be considered as an approach to a general average to state that 112lb. of good coal are capable of giving from 450 to 500 cubic feet of gas of such quality, that half a cubic foot per hour is equivalent to a mould candle of six to the pound, burning during the same space of time. Mr. Brande says a chaldron of coals should yield about 12,000 cubical feet of purified gas, of which each Argand's burner, equal to six wax candles, may be considered as consuming from four to five cubical feet every hour.

† As Dr. Henry observes, (*Elem. of Chem.* vol. i. p. 428,) it is of mixtures of two or more of the three following gases, viz. *sub-carburetted*,



*And in what way is the process of procuring gas from oil conducted?*

It consists in letting whale oil fall\* by drops into an iron cylinder, placed horizontally in a furnace, and ignited to a cherry redness. In this manner the oil is decomposed, and converted

*carburetted*, and *super-carburetted hydrogen gases*, with occasionally a proportion of carbonic oxide, and a few other gases, that the almost infinite variety of aëriform products are constituted, which are obtainable by the exposure of alcohol or ether, of oil, tallow, wax, or coal, to a heat a little above ignition.

Among these different ingredients of coal and oil gas, the carburetted hydrogen gases are the real illuminating agents, and the degree of light emitted by these is dependent on the quantity of carbon they contain. The density of a common flame is always proportional to the quantity of solid carbon first deposited, and afterwards burned; and hence olefiant gas, that is carburetted hydrogen gas, gives the most brilliant white light of all combustible gases, because at a very high temperature it deposits a very large quantity of solid carbon. "The above principle (says Dr. Ure, *Dict. of Chem.* p. 351,) readily explains the appearances of the different parts of the flames of burning bodies, and of flame urged by the blow-pipe. The point of the inner blue flame, where the heat is greatest, is the point where the whole of the charcoal is burned in its gaseous combinations, without previous deposition."

"The fitness of the gas obtained from coal for the purposes of illumination, is, *ceteris paribus*, dependent upon the quantity of carburetted hydrogen, or olefiant gas, which it contains; and, consequently, the fitness of the purified mixed gas for illumination, will be directly as its specific gravity; or the relative proportion of olefiant gas, may be judged of by mixing the purified coal gas with twice its volume of chlorine over water, by which the olefiant gas will be absorbed, and its quantity shown by the amount of the absorption which takes place." *Brande's Manual of Chem.* vol. i. p. 442. There is another method of estimating the comparative illuminating power of different kinds of coal and oil gas, which is by the relative quantities of oxygen required for their complete combustion. This method is decidedly preferred by Dr. Henry, of Manchester, and his reasons for the preference may be read in his *Elem. of Chem.* vol. i. p. 432.

\* The commonest whale oil, or even pilchard dregs, quite unfit for burning in the usual way, afford abundance of excellent gas, requiring no other purification than passing through a refrigerator, to free it of a quantity of empyreumatic vapour.



almost entirely into charcoal, which is deposited in the tube, and into a mixture of carburetted hydrogen and hydrogen gases.\*

*What is the gas called FIRE-DAMP by the miners, the explosion of which was formerly so frequently destructive of the lives of those employed in coal mines?*

It is sub-carburetted hydrogen gas. It is emitted from the coal in the mines, through the chinks of which it issues, sometimes in great abundance, and as it is lighter than atmospheric air, it ascends, mixing with it as it rises.† As it

\* From each wine gallon of oil, about 100 cubic feet of gas may with care be obtained, of the specific gravity of more than .900, containing upwards of 40 per cent. of gas condensable by chlorine, and of which 100 volumes consume 260 volumes of oxygen, and yield 158 of carbonic acid. But of gas from Wigan canal, when the whole product is mingled together, 100 measures do not saturate more than 155 of oxygen, and give 88 measures of carbonic acid. Oil gas may, therefore, be inferred to contain, in a given volume, twice the quantity of combustible matter that is present in the average of gas from canal coal; and its illuminating power will be as 2 to 1.

The advantages of oil gas over gas from coal are, that smaller distilling vessels are required; that gasometers and conduit pipes of half the capacity are sufficient; that no washing apparatus is necessary; that the trouble and expense of removing waste materials is avoided; and that the gas affords a much brighter light, with a smaller production of heat, and also of water. When only a moderate quantity of light is required; when it is an object to save room or labour; and in countries where coal is dear, oil gas is entitled to a decided preference; but it cannot be brought into competition with coal gas, where coal is cheap, or where the establishments to be lighted are of very considerable magnitude, and of such a nature as to allow of their being freely ventilated.

† The mixture of fire-damp with common air which explodes most readily is one measure of the former to about seven or eight of the latter. When the inflammable gas is mixed with three or four times its volume of air, it does not explode at all; it detonates feebly when mixed with five or six times its bulk of air; and when a larger quantity of air than fourteen times its volume be admitted, a taper burns in it only with an enlarged flame.



increases in quantity, it gradually occupies more and more of the mine, till it reaches the lights used by the miners, by which it is inflamed, and from the immense quantity of it, it explodes with tremendous violence, and produces the most dreadful consequences.

*By what means are these dangerous explosions now prevented?*

By the SAFETY LAMP of Sir Humphry Davy, which consists of a cage of fine wire gauze surrounding a common oil lamp.\*

*On what fact or observation is this safety-lamp constructed?*

On the fact that flame cannot pass through a narrow tube.† The observation of this circum-

\* Some attempts have been made to invalidate Sir H. Davy's title to this most valuable invention, but they have altogether failed, and it is now very generally considered to have originated solely with him, and, as has been correctly remarked, to be not "the offspring of chance, but the fruit of elaborate experiment and close induction." The annexed figure represents the *safety-lamp*. A is a cylinder of wire gauze, with a double top, securely and carefully fastened by doubling over, to the brass rim B, which screws on to the lamp C. The whole is protected and rendered convenient for carrying, by the frame and ring D.

† It is readily proved by experiment that an explosive mixture cannot be kindled in a glass tube so narrow as  $\frac{1}{4}$ th of an inch diameter; and when two separate reservoirs of an explosive mixture are connected by a metallic tube  $\frac{1}{5}$ th of an inch in diameter, and  $1\frac{1}{2}$  inch in length, and one of the portions of gas is set on fire, the explosion does not extend to the other. Again, if we set fire to a jet of gas, and hold a piece of gauze over it, the flame is seen only below, provided we do not keep the same part always over the pipe, for, in this case, the wire becomes red-hot, and kindles the gas above. If a jet of gas be allowed to pass through the gauze, and be kindled above, the flame does not communicate to that below.





stance led Sir H. Davy to discover, that the power of tubes to prevent the transmission of flame is not necessarily connected with any particular length, and that a very short one will have the effect, provided its diameter is proportionally reduced. Now, a piece of fine wire gauze may be regarded as an assemblage of short narrow tubes, and it is quite impermeable to flame; consequently, if a common lamp be completely surrounded with a case of such gauze, it may be introduced into an explosive mixture of fire-damp and air without kindling it.

*To what is this effect of wire gauze owing?*

It is considered to be dependent on its cooling agency, exerted on the portion of gas burning within the cylinder. Flame is gaseous matter heated so highly as to be luminous, in which state it is kept by the elevated temperature generated during the combustion, which is above that of the incondescence of solids,\* consequently, when the gaseous matter passes through the meshes of gauze, it is instantly cooled by the wire below the temperature at which it is luminous, and therefore has no power of kindling the mixture of fire-damp and air surrounding the lamp.†

\* It should be observed, that sub-carburetted hydrogen gas is the least combustible of all the inflammable gases known; and it is found that the strongest explosive mixture of this gas and atmospheric air may come in contact with iron, or any other solid body, heated to redness, or even to whiteness, without exploding, if they are not in a state of actual combustion; whereas the smallest point of flame, owing to its higher temperature, instantly causes an explosion.

† The following remarks of Dr. Ure will assist in rendering this subject



*Is Sir Humphry Davy's safety-lamp considered quite effectual?*

Perfectly so, even in the most dangerous atmospheres of coal mines. It has been employed most extensively in the mines of Newcastle,

more clearly understood. Since flame is gaseous matter, heated so intensely as to be luminous, and that to a degree of temperature beyond the white heat of solid bodies, (for air not luminous will communicate this degree of heat,) "When an attempt (says this author, *Dict. of Chem.* p. 357) is made to pass flame through a very fine mesh of wire-gauze of the common temperature, the gauze cools each portion of the elastic matter that passes through it, so as to reduce its temperature below that degree at which it is luminous. This diminution of temperature is proportional to the smallness of the mesh, and to the mass of the metal. The power of metallic or other tissue to prevent explosion, will depend upon the heat required to produce the combustion, as compared with that acquired by the tissue. Hence, the flame of the most inflammable substances, and of those that produce most heat in combustion, will pass through a metallic tissue that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion. Or, the tissue being the same, and impermeable to all flames at common temperatures, the flames of the most combustible substances, and of those which produce most heat, will most readily pass through it when it is heated, and each will pass through it at a different degree of temperature. In short, all the circumstances which apply to the effect of cooling mixtures upon flame will apply to cooling perforated surfaces. Thus, the flame of phosphuretted hydrogen, at common temperatures, will pass through a tissue sufficiently large, not to be immediately choked up by the phosphorous acid formed, and the phosphorus deposited. If a tissue, containing above 700 apertures to the square inch, be held over the flame of phosphorus or phosphuretted hydrogen, it does not transmit the flame till it is sufficiently heated to enable the phosphorus to pass through it in vapour. Phosphuretted hydrogen is decomposed by flame, and acts exactly like phosphorus. In like manner, a tissue of 100 apertures to the square inch, made of a wire of one-sixtieth, will, at common temperatures, intercept the flame of a spirit-lamp, but not that of hydrogen. But when strongly heated, it no longer arrests the flame of alcohol. A tissue which will not interrupt the flame of hydrogen when red-hot will still intercept that of olefiant gas; and a heated tissue, which would communicate explosion from a mixture of olefiant gas and air will stop an explosion from a mixture of fire-damp, or sub-carburetted hydrogen. The latter gas requires a considerable mass of heated metal to inflame it, or contact with an extensive heated surface."



Whitehaven, and other places, without the occurrence of a single failure or accident.\*

*How is CARBURETTED HYDROGEN GAS† procured?*

By mixing in a glass retort three measures of concentrated sulphuric acid, and one measure of alcohol, and exposing the retort to a moderate heat. The mixture soon assumes a black colour, and thick consistence, and carburetted hydrogen gas is disengaged, which may be collected over water, and freed from carbonic acid by washing it with a solution of potassa.

*How is carburetted hydrogen gas procured by this process?*

It is derived solely from the alcohol, and its production is owing to the strong affinity of sulphuric acid for water. Alcohol, or spirit of wine, is composed of carbon, hydrogen, and oxygen; and from the proportion of its elements

\* If the genius of this illustrious philosopher had made no other discovery than that of the *safe-lamp*, it would have been sufficient to have elevated him very high in the scale of public benefactors, and to lay mankind under deep and lasting obligations. Prior to this invention, attempts used to be made to ventilate mines thoroughly, with the hope that by keeping up a constant change of air, the inflammable gas might in a great measure be carried away, or so diluted as not to be explosive. When this could not be done, the miners would occasionally set fire to the gas, before much of it was collected, which was done by one person, who stood up to his neck or shoulders in water, and the instant he thrust the taper into the inflammable gas, plunged under the fluid. These means were in some degree effectual, but occasionally tremendous explosions would, nevertheless, take place, destroying the lives of a great number of miners, and entailing unspeakable distress on their surviving families. By a single explosion in one of the Newcastle collieries, no less than one hundred and one persons perished in an instant. This gigantic power has now been happily subdued by the genius and application of Sir H. Davy,

† Or bi-carburetted hydrogen, sometimes also called *olefiant gas*.



it is inferred to be a compound of 14 parts,\* or one proportion of carburetted hydrogen gas, united with 9 parts or one proportion of water. Therefore, in order to obtain carburetted hydrogen gas, it is only necessary to deprive alcohol of the water which is essential to its constitution, and this is effected by sulphuric acid.

*What are the* PROPERTIES OF CARBURETTED HYDROGEN GAS?

It is invisible, and void of taste and smell when pure. Water absorbs about one-eighth of its volume. It is destructive of animal life, and extinguishes flame. Its specific gravity is about 0.978,† 100 cubic inches weighs 28.80 grains. When set on fire as it issues from the orifice of a small pipe, it burns with a splendid white flame, very superior to that of sub-carburetted hydrogen.‡ When passed through a red-hot porcelain

\* That is, 2 proportions of carbon = 12, added to 2 proportions of hydrogen = 2 + 12 = 14. Water, it will be recollected, is composed of 1 proportion of oxygen = 8, and one of hydrogen = 1, making together 9. 14 + 9 makes 23, which is the atomic weight of alcohol. See page 36.

† Its specific gravity is stated by the associated Dutch chemists, who discovered this gas, to be 0.909, by Dr. Henry 0.967, and by Dr. Thomson, from his latest trials, 0.9709.

‡ Its greater combustibility depends on its containing, in a given volume, twice the quantity of carbonaceous matter that is present in sub-carburetted hydrogen.

When mixed with three times its bulk of oxygen, and kindled by a taper or the electric spark, it explodes with great violence, and the four volumes are converted into two volumes of carbonic acid. Dr. Henry says, that in order to insure the perfect combustion of the inflammable gas, it should be mixed with 5 times its bulk of oxygen, of at least 90 per cent. purity. If too little oxygen be used, charcoal is apt to be precipitated unburnt; and the excess of oxygen does no harm, but remains in the mixture. "Calculating," observes Dr. Henry, (*Elem. of Chem.* vol. i. p. 425,)



tube it is decomposed, and lets fall a portion of charcoal, and nearly doubles its volume.\* Its atomic weight is 14.

*Why is carburetted hydrogen sometimes called OLEFIANT GAS?*

Because, when it is mixed with its own bulk of chlorine, the gaseous mixture is condensed over water into a peculiar oily-looking compound.† It was at first mistaken for oil, but it possesses very different properties from those of oil. It approaches more nearly in character to

“the constitution of this gas, from the oxygen spent in its combustion and the carbonic acid formed, precisely as was done with respect to sub-carburetted hydrogen, we have the following results, the first column including the composition of 100 cubical inches.

	Grains.		Grains.		Grains.
Charcoal .....	25.38	.....	85.63	.....	100.
Hydrogen .....	4.26	.....	14.37	.....	16.71
	<hr/>		<hr/>		<hr/>
	29.64		100.		116.71

“In this gas, therefore, 100 grains of charcoal are united with 16.71 hydrogen, and in the last (sub-carburetted hydrogen) with 33.41; or, as nearly as possible, carburetted hydrogen contains only one half the hydrogen.”

\* At a higher temperature it deposits more charcoal, and augments in bulk; till finally, at the greatest heat to which we can expose it, it lets fall almost the whole of its carbon, and assumes a volume  $3\frac{1}{2}$  times greater than it had at first. These remarkable results, have induced Berthollet to conclude, that hydrogen and carbon combine in many successive proportions.

The transmission of a series of electric sparks through this gas produces a similar effect with that of simple heat.

† Dr. Thomson first ascertained that it is a compound of olefiant gas and chlorine, (*Memoirs of the Wernerian Society*, vol. i. p. 516.) MM. Robiquet and Colin formed this liquid in considerable quantities, by making two currents of its constituent gases meet in a glass globe. The olefiant gas should be in rather larger quantity than the chlorine, otherwise the liquid becomes of a green colour, and acquires acid properties. When it is washed with water, and distilled off dry muriate of lime, it may be regarded as pure.



ether, and is therefore sometimes called *chloric ether*.\*

*What are the properties of CHLORIC ETHER?*

When pure it is a limpid colourless essence, of a pleasant ethereal flavour, and a sharp, sweet, but not disagreeable taste. At 45° its specific gravity is 1.2201. It boils at 152°. At 49° its vapour is capable of supporting a column of mercury 24.66 inches in length, and the specific gravity of its vapour is to that of air as 3.4434 to 1. It is constituted of 2 atoms of olefiant gas and 1 atom of chlorine.†

*Are there not some new carburets of hydrogen lately discovered?*

Yes; Mr. Faraday has discovered two new compounds of this description, which have been named *bi-carburet of hydrogen*, and *quadro-carburetted hydrogen*. The constituents of the former are 6 atoms of carbon and 3 atoms of hydrogen; its atomic weight is therefore 39. It is a colour-

\* Some authors call it *hydro-carburet of chlorine*, others *hydro-chloride of carbon*.

† Olefiant gas unites also with iodine. When iodine and olefiant gas are exposed to the sun's rays, the two substances unite, and form colourless crystals. When the redundant iodine has been removed by solution of potassa, and the residue collected and dried, it is a solid white crystalline body, heavier than sulphuric acid; having a sweet taste and an aromatic odour; being friable, and a non-conductor of electricity. It is fusible, and capable of being sublimed at a moderate heat without change; but is decomposed by a strong heat. It is not readily combustible, but it burns, if held in the flame of a spirit-lamp, giving off abundance of iodine and some hydriodic acid. It is insoluble both in water and in acid or alkaline solutions; but dissolves in alcohol and in ether. From Mr. Faraday's analysis, (*Quarterly Journal*, vol. xiii. p. 429,) it appears to consist of 1 atom of iodine, and 2 atoms of olefiant gas. It may be called *hydro-carburet of iodine*, or *hydriodide of carbon*.



less transparent liquid, which smells like oil gas, and when exposed to the air at the ordinary temperature, evaporates, and boils at  $186^{\circ}$ . The quadro-carburet of hydrogen is a highly combustible vapour. At  $54^{\circ}$  its specific gravity is 0.627, so that among solids and liquids it is the lightest body we are acquainted with. Its constituents are 4 atoms of carbon united to 4 atoms of hydrogen; its atomic weight is consequently 28.\*

CARBON has the property of combining also WITH NITROGEN: what is the result?

A singular compound called by M. Gay Lussac, its discoverer, CYANOGEN.†

*How is CYANOGEN obtained?*

By decomposing the cyanide of mercury (formerly called *prussiate of mercury*) by heat. Some of this salt, carefully dried, is put into a small glass retort, and heated by means of a spirit-lamp. The cyanide of mercury is composed of

\* The reader will find a detailed account of these substances in the *Philos. Trans. for 1825, Part 2*; and in the *Annals of Philos.* vol. xxvii. p. 44.

According to Dr. Thomson, *naphtha* and *naphthaline* are also pure carburets of hydrogen. These substances are obtained by the distillation of coal tar. The first is called *naphtha* because of its similarity to mineral *naphtha*. See Dr. Kid's paper in *Philos. Trans. for 1821*, p. 216, and a paper by Mr. Brande in *Quar. Journal*, vol. viii. p. 289. Also Mr. Faraday's Observations in *Philos. Trans. for 1826*.

† It is sometimes called *carburet of nitrogen* or *carburetted nitrogen*. It was discovered by Gay Lussac in 1815. His memoir may be read in the *Annal. de Chimie.* vol. xcv. The term *cyanogen* signifies the *producer of blue*; but as Dr. Ure correctly remarks, the same reason which leads to the term *cyanogen* would warrant us in calling it *leucogen*, *erythrogen*, or *chlorogen*; for it produces white, red, or green, with other metals, if it produce blue with iron.



cyanogen and metallic mercury, and when decomposed in this way, the cyanogen passes over in the form of gas, and the metallic mercury is sublimed. In the retort there remains a small portion of charry matter, of the colour of soot, which is charcoal, derived from the cyanogen itself, a portion of which is decomposed by the temperature applied.\*

*What are its PROPERTIES?*

It is a permanently elastic fluid, having a strong, penetrating, and very peculiar smell. It burns with a bluish flame mixed with purple; and its specific gravity, compared to that of common air, is 1.8064. 100 cubic inches weigh about 55 grains. Water at 60° Fahr. absorbs about  $4\frac{1}{2}$  times its volume, and pure alcohol 23 times its volume. The watery solution reddens litmus.† Sulphuric ether and oil of turpentine dissolve at least as much as water. Its constituents are 2 atoms of carbon = 12, and 1 atom of nitrogen = 14. Its atomic weight is therefore 26.‡

\* It must be collected over mercury.

† This effect is not to be ascribed to the gas itself, but to the acid products to which it gives rise by the decomposition of water. On this point, the reader may peruse with advantage Vauquelin's paper in *Annals of Philos.* vol. xiii. p. 436.

‡ The composition of cyanogen may be determined by detonating (by the electric spark) 100 measures of that gas, in a Volta's eudiometer, with 250 measures of oxygen, when 200 measures of carbonic acid result, and 100 measures of nitrogen. There remain likewise 50 measures of oxygen gas uncondensed. From these data, Gay Lussac inferred, that cyanogen is composed of two volumes of vapour of carbon, and one volume of nitrogen, condensed into 1 volume.

Dr. Henry says, analysis by more complicated methods affords the same result, coinciding with that in which cyanogen yields, by a decomposition



*Has cyanogen any tendency to combine with elementary substances?*

It has a remarkable tendency to do so. It has a strong attraction for metals, and is capable of uniting with the simple non-metallic bodies. All its compounds, which are not acid, are called *cyanides* or *cyanurets*.\*

*Cyanogen forms the base of a very remarkable acid. What is it?*

PRUSSIC OR HYDROCYANIC ACID.† It is formed of equal proportions of cyanogen and hydrogen.‡

effected by means of oxygen, twice its volume of carbonic acid and an equal volume of nitrogen. No water whatsoever is formed during its combustion, if the gas be perfectly free from prussic acid vapour, a sufficient proof of the absence of hydrogen from the composition of cyanogen.

Phosphorus, sulphur, and iodine, may be sublimed by the heat of a spirit-lamp in cyanogen, without occasioning any change on it. But when heated in contact with cyanide of mercury, compounds of those bodies with cyanogen are formed.

\* It has been remarked, that "it enters into direct combination with a few alkaline bases only, and these compounds are by no means permanent. From these remarks it is apparent that cyanogen has no claim to be regarded as an acid." But Dr. Ure properly observes (*Dict. of Chemistry*, p. 382,) "We must admit that cyanogen forms particular combinations with the alkalies, which are permanent till some circumstance determines the formation of new products. These combinations are true salts, which may be regarded as analogous to those formed by acids. In fact, cyanogen possesses acid characters. It contains two elements, nitrogen and carbon, the first of which is strongly acidifying, according to M. Gay Lussac. (Is it not as strongly alkalifying, with hydrogen, in ammonia?) Cyanogen reddens the tincture of litmus, and neutralizes the bases. On the other hand, it acts as a simple body when it combines with hydrogen; and it is this double function of a simple and compound body which renders its nomenclature so embarrassing."

† This acid is found in many vegetable productions; especially in the bark of the *Prunus Padus*, or bird-cherry; the leaves of the peach and nectarine trees, bitter-almonds, and the kernels of many fruits.

‡ The student will perceive that hydrogen (not oxygen) is here the acidifying principle.



*How is prussic acid obtained?*

By heating cyanide of mercury in a glass retort with two-thirds of its weight of concentrated muriatic acid. By an interchange of elements the cyanogen of the cyanide unites with the hydrogen either of water or muriatic acid, forming hydrocyanic acid. A solution of corrosive sublimate (*deuto-chloride of mercury*) remains in the retort.\*

\* The mode of conducting the process is as follows:—The cyanide of mercury is put into a tubulated glass retort, to the beak of which is adapted a horizontal glass tube, about two feet long, and full half an inch bore. The first third part of the tube next the retort is filled with small pieces of white marble, the other two thirds with fused muriate of lime. To the end of this tube is adapted a small receiver, which should be artificially refrigerated. Muriatic acid is then poured on the cyanide of mercury in rather less quantity than is sufficient to saturate the metallic base of the salt. A very gentle heat is applied to the retort, when hydrocyanic acid will be evolved in vapour, and will condense in the tube. As it rises, the acid is mixed with muriatic acid and water, the former of which will be abstracted by the marble, and the latter by the muriate of lime. By successively heating the different parts of the tube, the prussic acid may be driven onwards to the receiver.

By this process the product of hydrocyanic acid is very small, and Vauquelin has recommended the following as affording a much more abundant product. It consists in passing a current of sulphuretted hydrogen gas, (disengaged from sulphuret of iron and sulphuric acid,) very slowly, through a glass tube slightly heated and filled with cyanide of mercury, its extremity ending in a receiver which was kept cool by a mixture of snow and salt. The process is carried on till the smell of sulphuretted hydrogen, which for a long time cannot be perceived, is discovered in the receiver. The prussic acid amounts in weight to  $\frac{1}{5}$ th of the cyanide of mercury used.

Dr. Ure says, “the simplest, and perhaps most economical, process which I know for obtaining hydrocyanic acid of moderate strength, for most chemical, and all medical purposes, is to dissolve ferroproussiate of potash in water, and to add to the solution, contained in a retort, as much sulphuric acid as there was salt employed. Distilling with a gentle heat, hydrocyanic acid is obtained. If it be tinged blue with a little iron, this may be separated either by filtration or redistillation.”



*What are the PROPERTIES OF HYDROCYANIC ACID?*

It is a limpid and colourless fluid, possessing a strong odour, similar to that of peach-blossoms. Its taste is at first cool, but soon becomes hot and acrid: when diluted it has the flavour of bitter almonds. Its specific gravity at 45° Fahr. is 0.7058; at 64° it is 0.6969.\* Though repeatedly rectified in chalk, it still reddens litmus paper. It is highly volatile, and boils at 79° Fahr., and congeals at zero.† It liquefies at 50° Fahr. A drop of it let fall on paper becomes solid instantly, because the cold, produced by the evaporation of one portion, reduces the temperature of the remainder below its freezing point. It unites with water and alcohol in every proportion, and is very inflammable, burning with a blue flame.‡

*Has it not some other remarkable properties?*

Yes. It has a great tendency to decompose by keeping, and the strong acid can rarely be preserved for more than a fortnight.§ And it is the

\* The specific gravity of its vapour is, experimentally compared to that of air, 0.9476. This small density of prussic acid, as Dr. Ure observes, compared with its great volatility, furnishes a new proof that the density of vapour does not depend upon the boiling point of the liquids that furnish them, but upon their peculiar constitution.

† Dr. Ure says it boils at 81½°, and congeals at about 3°.

‡ It is decomposed by a high temperature and by light; being resolved into carbonic acid, ammonia and carburetted hydrogen gas, which are dissipated, and leave behind a carbonaceous deposit. It should therefore be kept in opaque stoppered bottles.

§ The commencement of decomposition is marked by the liquid acquiring a reddish-brown tinge. The colour then gradually deepens,



most violent of all poisons, producing its fatal effects with an inconceivable rapidity. When a rod dipped into it is brought in contact with the tongue of an animal, death ensues before the rod can be withdrawn.\*

*It unites with most alkaline bases, forming salts: what are they called?*

PRUSSIATES OR HYDROCYANATES.†

*You have said that prussic acid is composed of cyanogen and hydrogen:‡ what are the proportions by weight?*

carbonaceous matter being deposited, which emits a strong smell of ammonia. This acid may be preserved for a longer period if diluted with water, but even then it undergoes gradual decomposition.

\* The following notice appears in the *Annales de Chimie* for 1814: M. B. professor of chemistry, left by accident on a table a flask containing alcohol impregnated with prussic acid; the servant, enticed by the agreeable flavour of the liquid, swallowed a small glass of it. In two minutes she dropped down dead, as if struck with apoplexy.

A professor at Vienna, named Scharinger, prepared a pure and concentrated prussic acid; he spread a certain quantity of it on his naked arm, and died a little time after.

It is said that this acid destroys vegetables as well as animals. Seeds steeped in it either die or lose the power of germinating; and the more delicate the vegetable the more rapidly it perishes.

† These salts are not permanent, and have no useful properties. They are poisonous. They are decomposed by the weakest acids, and have the peculiar odour of hydrocyanic acid, a character by which the hydrocyanates may easily be recognised.

‡ On subjecting prussic acid to the action of galvanism, it is resolved into hydrogen and cyanogen, the former of which is disengaged at the negative pole, and the latter at the positive.

When a quantity of potassium, precisely sufficient for absorbing 50 measures of pure cyanogen gas, is heated in 100 measures of prussic acid vapour, the cyanide of potassium is generated, a diminution of 50 measures takes place, and the residue is pure hydrogen. From this it appears, that prussic or hydrocyanic acid vapour is composed of equal volumes of cyanogen and hydrogen, united without any condensation. For this decisive experiment we are indebted to M. Gay Lussac.



They are . . . . .	Carbon . . . . .	44.39
	Nitrogen . . . . .	51.71
	Hydrogen . . . . .	3.90
		<hr/>
		100.00 *

*Notwithstanding the poisonous qualities of this acid, it is used in its diluted state in medicine,† and it is therefore highly desirable to know at all times the strength of the diluted acid in use. How is this ascertained?*

The red oxide of mercury (the common red precipitate of the shops) is used as the test in the following manner.—To 100 grains, or any other convenient quantity of the acid, contained in a small phial, add in succession small quantities of the red oxide of mercury in fine powder, till it ceases to be dissolved on agitation. The weight of the red precipitate taken up being divided by four, gives a quotient representing the quantity of real prussic acid present.‡

\* These being the constituents of this acid, it is evidently distinguished, when compared with the other animal products, by the great quantity of nitrogen it contains, by its small quantity of hydrogen, and especially by the absence of oxygen.

† It is much used by some medical men as a remedy for cough and consumption, and has likewise been strongly recommended in dyspepsia. But it is not in my opinion of any service except in spasmodic coughs, and that variety of consumption which is dependent on a disease of the trachea or bronchiæ. It appears to me quite uncalled for in dyspepsia. Its extraordinary activity seems to form, as in the case of arsenic, an insuperable objection to its frequent employment.

‡ By weighing out beforehand, on a piece of paper, or a watch-glass, forty or fifty grains of the red oxide of mercury, the residual weight of it shows at once the quantity expended. This operation may always be completed in five minutes, and it therefore affords the chemist and medical practitioner an easy mode of readily ascertaining the strength and purity of the hydrocyanic acid before him. Sometimes this acid is adulterated with muriatic acid, and then the specific gravity of the liquid being compared



*In what way do you detect the presence of free hydrocyanic acid?*

with the numbers in the table below, and with the weight of oxide of mercury dissolved, will detect it. For if 100 grains of hydrocyanic acid, specific gravity 0.996, dissolve more than 12 grains of the red precipitate, we may be sure that the liquid has been contaminated with muriatic acid. Dr. Ure observes, nitrate of silver, in common cases so valuable a re-agent for muriatic acid, is unfortunately of little use here; for it gives with prussic acid a flocculent white precipitate, soluble in water of ammonia, and insoluble in nitric acid, which may be easily mistaken by common observers for the chloride of that metal. But the difference in the volatility of prussiate and muriate of ammonia may be had recourse to with advantage; the former exhaling at a very gentle heat, the latter requiring a subliming temperature of about 300° Fahr. After adding ammonia in slight excess to the prussic acid, if we evaporate to dryness at a heat of 212°, we may infer from the residuary sal ammoniac the quantity of muriatic acid present.

For the method above given for ascertaining the real strength of prussic acid, we are indebted to Dr. Ure, of Glasgow, and it is one amongst many practical uses to which the doctrine of atomic proportions may be applied. For since the atomic weight of hydrocyanic acid is exactly one-eighth of that of the red oxide of mercury, and as this acid combines in the proportion of two of the former to one of the latter, we have, at once, the relation of one to four in the formation of this compound. Hence it is evident, that if to 100 grains of diluted hydrocyanic acid, there are added in succession small quantities of the red oxide of mercury until it ceases to be dissolved on agitation, the weight of the oxide so dissolved, being divided by four, will give a quotient representing the quantity of real hydrocyanic acid present.

The following table comprehends the results of a series of experiments instituted by Dr. Ure to determine the relation between the specific gravity of the dilute prussic acid and the quantity of real acid.

Quantity of above Liquid Acid.	Specific Gravity.	Real Acid per cent.	Quantity of above Liquid Acid.	Specific Gravity.	Real Acid per cent.
100.0	0.9570	16	22.2	0.9945	3.6
66.6	0.9768	10.6	20.0	0.9952	3.2
57.0	0.9815	9.1	18.2	0.9958	3.0
50.0	0.9840	8.0	16.6	0.9964	2.7
44.4	0.9870	7.3	15.4	0.9967	2.5
40.0	0.9890	6.4	14.3	0.9970	2.3
36.4	0.9900	5.8	13.3	0.9973	2.1
33.3	0.9914	5.3	12.5	0.9974	2.0
30.8	0.9923	5.0	11.8	0.9975	1.77
28.6	0.9930	4.6	10.5	0.9978	1.68
25.0	0.9940	4.0	10.0	0.9979	1.60



By means of sulphate of copper. The liquid containing the acid, must be rendered slightly alkaline with potash, and then a few drops of sulphate of copper should be added, and afterwards sufficient muriatic acid to redissolve the excess of oxide of copper; when the liquid will appear more or less milky, according to the quantity of hydrocyanic acid present. This test will detect  $\frac{1}{20,000}$ th part of this acid in water.\*

*There are other acids, besides the hydrocyanic acid, which have cyanogen for their base: do you know what they are?*

With oxygen it forms an acid called CYANIC ACID; with chlorine an acid termed CHLOROCYANIC; with sulphur and hydrogen one called SULPHOCYANIC; and with iron and hydrogen an acid called FERROCYNIC.†

\* One ten-thousandth part of prussic acid may be detected in water, by the addition of a few drops of solution of sulphate of iron.

† The composition of these acids may be seen at one view thus:—

Cyanic Acid is composed of .... Cyanogen 1 atom = 26  
Oxygen 1 atom = 8

Weight of its atom ..... 34

Chlorocyanic Acid ..... Cyanogen 1 atom = 26  
Chlorine 1 atom = 36

Weight of its atom ..... 62

Sulphocyanic Acid ..... Cyanogen 1 atom = 26  
Sulphur 2 atoms = 32  
Hydrogen 1 atom = 1

Weight of its atom ..... 59

Ferrocyanic Acid ..... Cyanogen 3 atoms = 78  
Iron 1 atom = 28  
Hydrogen 2 atoms = 2

Weight of its atom ..... 108

Cyanogen also unites with iodine forming a *cyanide of iodine*. It is composed of 1 atom of cyanogen and 1 of iodine.



*How is CYANIC ACID obtained?*

It has never yet been exhibited in an insulated state, but it may be obtained in combination with potassa, forming cyanate of potassa, by heating to dull redness a very finely pulverized mixture of about equal parts of ferrocyanate of potassa (well dried), and peroxide of manganese. The mass is to be boiled with alcohol of moderate strength, (0.840 sp. gr.) and, on cooling, the salt separates in small plates, resembling the chlorate of potassa.\*

*In what way is CHLOROCYANIC ACID procured?*

By passing a current of chlorine gas through a solution of hydrocyanic acid till the liquid acquires bleaching properties, when the excess of chlorine must be removed by agitating the liquid with mercury, and by distilling with a gentle heat the chlorocyanic acid is expelled.† It was discovered by Berthollet.

\* The cyanates acted on by aqueous acids are decomposed, and give out their carbon of composition in the form of carbonic acid. It is remarkable that the constitution of cyanic acid above given, is precisely the same as Liebig and Gay Lussac have assigned to cyanic acid as it exists in a class of salts, called by them *fulminates*. In all salts of this kind, the elements of cyanic acid exist, constituting, with a metallic oxide, which may differ in different cases, the acid that gives to each salt its peculiar properties. For further information on the subject of cyanic and chlorocyanic acids, see *Dr. Ure's Dict.* p. 76; or *Henry's Chemistry*, vol. i. p. 456.

† This, however, is not pure chlorocyanic acid, but a mixture of this and carbonic acid gas, in proportions not yet determined. This mixture has the following properties. It is colourless; has a very penetrating smell, and excites a flow of tears; reddens litmus; is not inflammable; and does not detonate when mixed with twice its bulk of oxygen or hydrogen. Its density, determined by calculation, is 2.123 (some say 2.111,) air being 1. It is very soluble in water, and this solution does not precipitate nitrate of silver, not barytes water.

A characteristic property of this acid is, that with the intervention of



*How is SULPHOCYANIC ACID obtained?*

By mixing as much sulphuric acid with a concentrated solution of the sulphocyanate of potassa as is sufficient to neutralize the alkali, and then distilling the mixture; when sulphocyanic acid is obtained mixed with water. It is a transparent liquid, either colourless, or having a slight pink hue, and possessing an odour somewhat similar to vinegar. It boils at  $216^{\circ}.5$  F. and at  $54^{\circ}.5$  crystallizes in six-sided prisms.\*

*And in what way is FERROCYANIC ACID procured?*

By mixing the ferrocyanate of baryta, dissolved in water, with a quantity of sulphuric acid precisely sufficient for combining with the baryta. The insoluble sulphate of baryta is precipitated, and the ferrocyanic acid remains in solution, and may be decanted for use. It is of a pale lemon-yellow colour; has no smell; and is decomposed by heat and light.† It combines directly with alkalies, earths, and metallic

potassa, it forms green precipitates from solutions in which the iron is oxidized to a minimum. The experiment only succeeds when we first add the chlorocyanic acid to the metallic solution, then a little alkali, and finally a small portion of acid.

\* It was discovered by Mr. Porrett in 1808. It reddens litmus paper, and is capable of uniting with alkalies, forming a genus of salts called *sulpho-cyanates*.

† In its decomposition, hydrocyanic acid and ferro-prussiate of iron (Prussian blue) are formed; but it is much less liable to spontaneous decomposition than hydrocyanic acid. It differs also from this acid in possessing the properties of acidity in a much greater degree. Thus, it reddens litmus permanently, and separates the carbonic and acetic acids from their combinations. Mr. Porrett calls it *ferruretted chyazic acid*.



oxides, forming the salts called *ferro-cyanates*, formerly *triple prussiates*.\*

*What is the nature of ferrocyanic acid?*

Chemists have differed in opinion on this subject, but certainly there is something peculiar in the nature of this acid. It was formerly supposed that the iron, which is always present in the salts called ferrocyanates, acted the part of a base, with which (as well as with an alkali or earth) the hydrocyanic acid was considered to be united in the triple compounds. It is now believed not to act the part of a base, but to enter into the constitution of the acid itself, that is, to be really an element of the acid.†

*What is BORON?*

It is the combustible basis of boracic acid. It was discovered by Sir H. Davy, in 1807.‡

*In what way is it procured?*

According to Berzelius§ and Dr. Ure, the

\* The most useful of these triple prussiates, are the *ferrocyanate of potassa* and *ferrocyanate of iron*. The last is the beautiful pigment called Prussian blue.

† The experiments of Mr. Porrett render this opinion exceedingly probable. He found that when triple prussiate of soda in solution is exposed to galvanic electricity, the oxide of iron is carried, along with the elements of the Prussic acid, to the positive pole, whereas, if it had existed as a base, it would have been determined to the negative pole. From late researches Mr. Porrett concludes, that ferrocyanic acid contains no oxygen, its sole elements being carbon, hydrogen, nitrogen, and metallic iron; the iron not being in the state of an oxide as has been generally supposed.

The above view explains why the iron in ferrocyanates is not discoverable by the most delicate tests, for it can no more be affected by them, than sulphur can be indicated by its appropriate tests when existing in sulphuric acid.

‡ It is a fixed and infusible solid similar to carbon.

§ The process may be found in *Annals of Philos.* vol. xxvi. p. 128, and in Dr. Ure's Dict. p. 228.



easiest and most economical method of preparing boron, is to decompose an alkaline borofluate by potassium. Sir H. Davy first obtained it by the decomposition of boracic acid by Voltaic electricity,\* and afterwards by the action of potassium.†

*What are ITS PROPERTIES?*

It is an opaque, dark olive-coloured powder, infusible, and not volatile at any temperature to which it has as yet been exposed. It is a non-conductor of electricity; has no taste; is insoluble in water, and does not affect vegetable blue colours. Its specific gravity is about twice as great as that of water. When heated strongly in contact with air, it burns, and forms dry boracic acid. In oxygen gas it throws off bright scintillations, becomes coated with boracic acid, and the portion not converted into acid, is found darker coloured than before. Its atomic weight is 8.‡

*With what substances does it combine?*

With oxygen, forming BORACIC ACID, with chlorine, constituting a CHLORIDE OF BORON, and with fluorine, forming FLUOBORIC ACID.

*How is BORACIC ACID obtained?*

\* When boracic acid, slightly moistened with water, was exposed between two surfaces of platina to a battery of 500 pairs of plates, an olive brown matter began immediately to appear on the negative surface, and gradually increased in quantity. This substance was found not to be acted on by water, but to dissolve with effervescence in warm nitric acid. When heated to redness on platina, it burned slowly, and boracic acid was regenerated.

† By this means, the boracic acid is deprived of its oxygen, and boron is set free.

‡ It is more analogous to carbon than to any other substance.



It is found native in volcanic districts; \* but for the purposes of experiment, it may be procured artificially from borax.† To a solution of borax, in boiling water, half its weight of sulphuric acid is added, previously diluted with an equal quantity of water; the solution is then evaporated a little, and on cooling, shining scaly crystals will appear, which consist of boracic acid. These must be well washed with distilled water, and dried on filtering paper.‡

*What are the properties of this acid?*

In its common form it exists in combination with water, and then appears as a series of thin hexagonal scales, of a pearly whiteness, without smell, with a slightly acid taste, which is succeeded by a sweetness. Boiling water does not take up above  $\frac{1}{50}$ th of its weight, and cold water much less, but it is soluble in alcohol, and gives it the power of burning with a green flame. It reddens vegetable blues, and effervesces with alkaline carbonates; and, what is remarkable, it renders turmeric paper brown like the alkalies. Its specific gravity in the form of scales (that is, the hydrate of boracic acid,) is 1.479; in the form of dry acid 1.803.§

\* It is found native on the edges of hot springs, near Sasso, in the Florentine territory; also in the Lipari Islands.

† Borax is a native compound of boracic acid and soda. It is found in the East Indies and South America. In the above process, the sulphuric acid unites with the soda, and the boracic acid is deposited.

‡ It is not obtained perfectly pure in this way, as it contains a minute portion both of alkali and sulphuric acid.

§ By a long continued white heat the water is driven off from this acid, a part of which sublimes, and the remaining acid is a transparent fixed glass,



*What are the proportions of the constituents of boracic acid?*

It is considered to be composed of 1 atom of boron and 2 atoms of oxygen; its equivalent will therefore be  $(8 + 16) 24$ .\*

*How is FLUOBORIC ACID procured?*

By distilling perfectly dry boracic acid with fluuate of lime (fluor spar).†

*What are its properties?*

It is colourless; it has a pungent smell; it extinguishes combustion, and is fatal to animal life. It reddens strongly the tincture of turnsole, and has a strong affinity for water.‡ It has no effect in corroding glass, but acts very ener-

which rapidly attracts moisture from the air. The compound of boracic acid and water appears to contain about 57 parts of acid to 43 of water.

\* The atomic weight of this acid, however, has not yet been fully determined.

*Crystallized boracic acid*, according to Sir H. Davy, is composed of

Boracic acid, 1 atom = 24

Water, 2 atoms = 18

---

Weight of its atom 42

In union with alkaline bases, it forms salts called *borates*.

From the weakness of the acid properties of boracic acid, all the borates, when in solution, are decomposed by the stronger acids.

Boron undergoes brilliant combustion in chlorine gas, and the product of the combustion is a new gas, which is colourless, when collected over mercury, and has a strong suffocating odour. This is the *chloride of boron*, a compound which has not been fully investigated.

† The proportions are one part of boracic acid, two parts of fluor spar, and twelve of sulphuric acid, which, when distilled in a glass vessel, give rise to a great quantity of a peculiar gaseous substance called fluoboric acid.

‡ Water takes up about 700 times its bulk, and acquires the specific gravity 1.77. It has so strong an affinity for water as to take it from other gases which hold it in combination, when it becomes in consequence a liquid which emits extremely dense vapours. It may hence be employed with advantage to show whether or not a gas contains moisture.



getically on vegetable and animal matter.\* It is not decomposed by a high temperature. Its specific gravity is about 2.3622.

*What is SULPHUR?*

A well known substance, distinguished also by the name of brimstone, and which has been in use from the earliest ages.† It is a simple combustible solid, which is both fusible and volatile at a high temperature.‡

*What are its PROPERTIES?*

It is brittle, moderately hard, of a greenish

Water saturated with this gas is limpid, foaming, and very caustic. By heat about one-fifth of the absorbed gas may be expelled, but not more. It then resembles concentrated sulphuric acid, and boils at a temperature considerably above  $212^{\circ}$ . It unites with the bases, forming salts, called *fluoborates*, none of which has been applied to any useful purpose.

\* It attacks animal and vegetable substances with as much force as concentrated sulphuric acid. It blackens paper, and affords a true ether with alcohol.

It is believed to consist of 1 atom of fluoric acid = 10, and 1 of boracic acid = 24. Its atomic weight is therefore 34.

† It was used by the ancients in medicine, and its fumes were employed in bleaching wool.

‡ Considerable quantities of it are found native, especially in the neighbourhood of volcanoes. Native sulphur is of two species, the common and volcanic. The common sulphur, occurs in great abundance in primitive mountains, in a state of combination with metals, forming the different genera of pyrites, glauce, and blonde. In secondary mountains, it is more abundant in the pure uncombined state. It is found in the island of Iceland, and abundantly in Sicily, at Urbino in the Papal States, and in Arragon in Spain. Volcanic sulphur is found in considerable abundance at Solfaterra, in the neighbourhood of Vesuvius, and in Iceland.

The sulphur, which occurs as an article of commerce, is brought to this country chiefly from Sicily. That which is procured in our own island, is generally of very inferior quality, and contains a portion of the metal, from combination with which it has been separated. In the shops it is met with under two different forms; one that of a compact solid, which has generally the shape of long rolls or sticks, the other in the form of a light powder called *flowers of sulphur*. The latter may be considered as most pure.



yellow colour, and has a peculiar smell, but little taste. It is a non-conductor of electricity,\* and is excited negatively by friction. Its specific gravity is 1.990, and its fusing point about 220° Fahr., before which temperature it begins to volatilize.† At the temperature of 560° it becomes an elastic fluid, and in this state inflames if in contact with air, and burns with a pale blue flame.‡ It is insoluble in water, but in small quantity in alcohol § and ether. It is perfectly soluble in boiling oil of turpentine, which may be employed as a means of determining its purity. Its atomic weight is 16.

*How is sulphur purified?*

It is partly purified by sublimation, and its purification is completed by boiling it repeatedly

\* When a roll of sulphur is suddenly seized in a warm hand, it crackles, and sometimes falls in pieces. This is owing to the unequal action of heat on a body which conducts that power slowly, and which has little cohesion.

† At about 290° Fahr. it is completely converted into vapour; and if the operation be conducted in close vessels, the volatilized sulphur is again collected in a solid form. This affords an example of the process of *sublimation*, which differs from distillation (see page 94), in affording a solid product, while the latter yields a condensed liquid.

‡ If it be heated above 300° Fahr. it gradually becomes thick and viscid, when if it be poured into a basin of water it will be found of a red colour, and ductile like wax. In this state it is used for receiving impressions of seals or medals; and its specific gravity is increased to 2.325. It has been supposed that this change was owing to its combining with oxygen, but this appears to be incorrect, since it takes place in close vessels.

Fused sulphur has a tendency to crystallize, but so confusedly, that we cannot define the shape of the crystals, further than that they are slender interlaced fibres.

§ When flowers of sulphur are digested in alcohol, no union takes place; but if the two substances be brought into contact, when both are in a state of vapour, they enter into chemical union.



in distilled water; then in twice or thrice its weight of nitro-muriatic acid, diluted with one part of distilled water; and, finally, by washing it with distilled water, till this comes off tasteless, and incapable of changing the blue colour of vegetables.\*

*With what substances does sulphur combine?*

It COMBINES WITH OXYGEN, forming SULPHURIC AND SULPHUROUS ACIDS; † with CHLORINE, producing a CHLORIDE OF SULPHUR; with HYDROGEN, forming SULPHURETTED HYDROGEN; and also with CARBON, when a CARBURET OF SULPHUR is formed.‡

*How is SULPHURIC ACID procured?*

It was originally prepared by the distillation of sulphate of iron, or, as it was sometimes called, *green vitriol*; § but that now made in Great

\* Sulphur contains a minute portion of hydrogen, which was first discovered by Sir H. Davy by exposing sulphur to the powerful agency of galvanism, when some sulphuretted hydrogen was disengaged.

† Oxygen unites with sulphur in four proportions, forming four definite compounds, all of which have acid properties; but the sulphuric and sulphurous acids are the most important, and best known. These four compounds, with their constituents, are as follows:—

	Sulphur.	Oxygen.	Atomic Weight.
Sulphuric acid, consisting of	1 atom	+ 3 atoms....	= 40.
Sulphurous acid.....	1 atom	+ 2 atoms....	= 33.
Hyposulphuric acid .....	2 atoms	+ 5 atoms....	= 72.
Hyposulphurous acid ....	2 atoms	+ 1 atom ....	= 40.

‡ It likewise unites with iodine, forming an *iodide of sulphur*, which is procured by mixing the two ingredients in a glass tube, and exposing them to such a heat as melts the sulphur. It is a greyish black substance.

§ Hence the acid was called *vitriolic acid*. From its oily appearance, it is likewise sometimes termed *oil of vitriol*.

Sulphuric acid has been known since the 15th century, and the first mention of it occurs in the writings of Basil Valentine.



Britain is produced by the combustion of sulphur. A mixture of about eight parts of sulphur with one of nitre is placed in a proper vessel, enclosed within a chamber of considerable size, lined on all sides with lead, and covered at bottom with a stratum of water. The mixture being set on fire, will burn for a considerable time, and the products of the combustion are sulphurous acid and nitric oxide gas. The nitric oxide absorbs oxygen from the atmosphere, and is converted into nitrous acid. Both the acids are absorbed by water. The nitrous acid gives out part of its oxygen to the sulphurous acid, and converts it into sulphuric acid, and being reduced to the state of nitric oxide gas again flies off, unites to oxygen, is converted into nitrous acid, and absorbed by the water. This process goes on till the whole of the sulphurous acid is converted into sulphuric acid. The water thus acidulated, is evaporated first in leaden vessels, and then in glass retorts, till the acid acquires the requisite degree of strength.\*

It is still prepared in Germany, in large quantities, by the distillation of copperas, or green vitriol. Dr. Roebuck was the person who first made it by the combustion of sulphur in leaden chambers, and he established the original manufactory at Prestonpans, in Scotland. He afterwards removed to Birmingham.

\* This explanation of the process was first given by Clement and Desormes, in *Annal. de Chem.* tom. lix. p. 329; and the following observations will assist the student fully to comprehend the changes that take place, and will point out a modification of the theory of Clement and Desormes, worthy of notice. The sulphur by burning, forms sulphurous acid gas, and the acid in the nitre is decomposed, giving off nitric oxide or nitrous gas (see p. 192); this coming in contact with the oxygen of the atmosphere, produces nitrous acid gas, which has no action on sulphurous acid, to con-



*What are the PROPERTIES OF SULPHURIC ACID?*

As obtained by the above process it is a colourless liquid, of a thick and oily consistence. It is one of the strongest acids with which we are acquainted, and in its concentrated state is powerfully corrosive.\* It decomposes all animal and vegetable substances by the aid of heat, causing a deposition of charcoal and formation of water.† Its action on litmus is so strong, that a single drop of acid will give to an immense quantity of water the power of reddening that substance. It has a very strong affinity for water, and unites with it in every proportion, producing,

convert it to sulphuric acid, unless water be present, and if this substance be only in a certain proportion, the water, the nitrous acid gas, and the sulphurous acid gas combine, and form a white crystalline solid. By the large quantity of water usually employed, this compound is instantly decomposed, oil of vitriol formed, and nitrous gas given off, which in the air again becomes nitrous acid gas, and the process continues according to the same principle of combination and decomposition, till the water at the bottom of the chamber is become strongly acid. It is easy to prove the truth of these reasonings. Let dry sulphurous acid gas, and nitrous acid gas, be mixed together, by suffering the sulphurous acid gas to pass into a glass globe partially exhausted, and containing nitrous acid gas. There will be no action between the gases. But if a drop of water be introduced, there will be an immediate condensation, and a beautiful white crystalline solid will line the interior of the vessel. Whereas, if the globe contain plenty of water, nitrous gas will be given off with great violence, and the water will be found to be a solution of oil of vitriol.—See *Sir H. Davy's Elements*, p. 276,

\* It has sometimes been taken or administered as a poison. The person who unfortunately swallows it, generally speedily dies in dreadful agonies and convulsions; but recoveries have been witnessed after swallowing a considerable quantity of it. Chalk, calcined magnesia, or common carbonate of magnesia, is the best antidote. See, for full directions, my *Modern Domestic Medicine*, page 183.

† Wood, and other vegetable substances, when immersed in this acid, without heat, are disorganized, softened, and blackened, a certain portion of carbonaceous matter being separated from them.



by the combination, an intense degree of heat.\* It unites with alkaline bases, forming salts called *sulphates*; and it separates all other acids more or less completely from their combinations with the alkalies.

*What is its density?*

It is nearly twice as heavy as water. The specific gravity of the strongest pure acid that can be obtained, is 1.850; but even this contains 19 per cent of water, which appears essential to its constitution, and can only be separated by combining the acid with a base.†

\* If four parts by weight be mixed with one of water at 50°, they produce an instantaneous heat of 300° Fahr.; and four parts raise one of ice to 212°. When an ounce of water has been suddenly mixed with three of sulphuric acid, and the mixture been suffered to cool to the temperature of the atmosphere (say 60°,) an additional half ounce of water raises it to 86°, a second to 96°, and a third to 104°. This elevation of temperature takes place, because the affinity or capacity of the compound of sulphuric acid and water for caloric, is less than that of the acid and water separately; a diminution of bulk also ensues; that is, one measure of acid and one of water do not occupy the space of two measures, but about  $\frac{1}{75}$ th less; and the greatest condensation results, when those proportions are used (73 parts sulph. ac. + 27 of water,) which give the greatest increase of temperature. From the heat produced by its admixture with water, it is evident the dilution, for ordinary purposes, should be conducted very gradually.

It absorbs water with avidity from the air, imbibing, when suffered to remain in an open vessel, one third of its weight in 24 hours, and more than six times its weight in a twelve-month.

† Dr. Ure states, that genuine commercial acid should not exceed 1.8485. When denser, its purity may be suspected.

It is sometimes of importance to the chemist to know the proportion of oil of vitriol, of the ordinary specific gravity (1.8485,) that is, of the common *sulphuric acid of commerce*, in diluted sulphuric acid of different specific gravities; and I have therefore here inserted Dr. Ure's table by which that point may be readily ascertained. This table was originally published in the 4th vol. of the *Journal of Science*, which contains much valuable information, from the pen of Dr. Ure, respecting sulphuric acid.



*What is its prime equivalent or atomic weight?*

Its constituents are 3 atoms of oxygen = 24, and 1 atom of sulphur = 16, its equivalent is therefore 40.\*

*What is meant by absolute sulphuric acid?*

*Dr. Ure's Table of the quantity of Oil of Vitriol, of sp. gr. 1.8485, and of Anhydrous Acid, in 100 parts of dilute Sulphuric Acid, at different densities.*

Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.
100	1.8485	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8475	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8460	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8439	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8410	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8376	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8336	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8290	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8233	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8179	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8115	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.8043	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7962	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7870	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7774	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7673	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7570	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7465	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7360	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7245	66.05	47	1.3612	38.32	13	1.0887	10.60
80	1.7120	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6993	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6870	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6750	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6630	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6520	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

\* 40 is the atomic weight of the *dry* acid, but that of the strongest *liquid* acid is 49, since it contains one atom of water = 9.



When the fuming sulphuric acid, obtained by the distillation of *green vitriol*, is put into a glass retort, and distilled by a moderate heat into a receiver cooled with ice, the fuming portion comes over first, and may be obtained in a solid state by stopping the distillation in time. This is *absolute sulphuric acid*, that is, the acid entirely void of water. It is in silky filaments, tough, difficult to cut, and somewhat like asbestos.\*

*What are the USES OF SULPHURIC ACID?*

It is a substance of great utility, and is abundantly employed in the arts and manufactures. It is used in medicine, when largely diluted, as a refrigerant and tonic. It is used in pharmacy in the preparation of many medicines. It is employed by bleachers for scouring the cloth; by dyers, for dissolving their indigo; by calico printers, for forming the *sours* in which they soak the cloth, previously to its immersion in the dye-stuff; by brass-founders, button makers, gilders, and japanners, for cleaning the surface of the metals with which they work; and by hatters, tanners, paper-makers, and many others.†

\* Exposed to the air, it fumes strongly, and gradually evaporates. Up to 66° it continues solid, but at temperatures above this it becomes a colourless vapour, which whitens on contact with air. Such is its attraction for water, that when dropped into it in small quantities, it excites a hissing noise, as if it were red-hot iron; in larger quantities it produces a species of explosion. It is convertible into ordinary sulphuric acid, by the addition of water.

† It is likewise employed in the preparation of nitric and muriatic acids, by the decomposition of nitre and sea salt.



*There is a capital test of the presence of sulphuric acid: what is it?*

A solution of muriate of baryta. If a small quantity only of this solution is dropped into a liquid containing sulphuric acid, it immediately causes a white precipitate which is insoluble in acids and alkalies. This is the sulphate of baryta.

*What are the principal SULPHATES, which this acid forms by combination with the various bases?*

The sulphates are a class of salts which have long been known, and several of them are of great use both in chemistry and medicine. The most valuable are the SULPHATE OF MAGNESIA, SULPHATE OF SODA, SULPHATE OF POTASSA, SULPHATE OF IRON, SULPHATE OF BARYTA, and SULPHATE OF LIME.\*

*In what way is SULPHUROUS ACID obtained?*

\* *Sulphate of magnesia* is generally known by the name of *Epsom salt*, and the *sulphate of soda* by that of *Glauber's salt*. The *sulphate of potash* is the *vitriolated tartar* and *sal polychrest* of the old dispensatories. All these are very valuable purgatives. The latter acts in a particularly mild, yet effectual, manner, and proves in many instances, as its old name expresses, a *salt of many virtues*; but it is not now so frequently employed as formerly, perhaps because professional men think, notwithstanding the visible increase of luxurious and sedentary living, and the consequent augmentation of the number of diseases of debility, (usually called *chronic diseases*,) that patients in the present day can bear the more active purgatives much better than our robuster and more vigorous forefathers. If this be the reason of the rejection of the mild aperients now so common, and the use of the more active, and therefore more debilitating, purgatives, it appears to the present author a very bad one.

The *sulphate of baryta* is commonly called *heavy spar*, and is found native in great abundance in many places. *Sulphate of lime*, called also *selenite*, *gypsum*, *plaster of Paris*, and sometimes *alabaster*, is found in abundance in Derbyshire, and other places. It is this salt chiefly which imparts the property of *hardness* to water.



It may be formed by the combustion of sulphur in the open air;\* but it is most conveniently obtained by digesting mercury in sulphuric acid, with heat, in a retort. By boiling one part by weight of mercury, with six or seven of sulphuric acid, to dryness, in a glass retort, and then raising the heat, sulphurous acid gas is formed, and may be collected and preserved over mercury.†

*What are the properties of sulphurous acid?*

It has a pungent suffocating smell, and is more than twice as heavy as atmospherical air. Its specific gravity is about 2.222.‡ In a gaseous state, it is colourless, and extinguishes burning bodies. It is fatal to animal life. It is absorbed by water,§ and the watery solution does not redden infusion of litmus, as acids in general do, but totally destroys its colour.|| In a gaseous

\* The formation of sulphurous acid is the cause of the peculiar odour emitted by sulphur during its combustion.

† In this case, the metal becomes oxidized by abstracting an atom or proportion of oxygen from the sulphuric acid, which is thereby converted into sulphurous acid.

M. Berthier has recently shown that sulphurous acid gas may be procured very pure and in abundance, by heating a mixture of twelve or fourteen parts of sublimed sulphur and a hundred parts of peroxide of manganese in a glass retort. The residue in the retort is not a sulphuret of manganese but a protoxide of that metal, mixed with a little sulphate, and sometimes a little sulphur.—*Ann. de Chem.* tom. xxiv. p. 275.

‡ Sir H. Davy states that 100 cubic inches weigh 68 grains, which would give the specific gravity of 2.23, agreeing almost exactly with the statement of Thenard. According to a calculation of Dr. Thomson, founded on the proportion of its elements, its specific gravity should be 2.222, as above stated. Berzelius (*Annal. de Chem. et Phys.* tom. v. p. 178,) finds it by experiment to be 2.247.

§ Recently boiled water absorbs 33 times its bulk, or nearly one eleventh of its weight, caloric is evolved, and the solution at 68° has the specific gravity 1.0513.

|| It is probably more correct to say, that it destroys most colours, but the



state, also, it possesses bleaching properties. It is of all the gases most readily liquefied by compression.\* In combination with the salifiable bases, it forms a class of salts called *Sulphites*.†

*What is its atomic proportion?*

It consists of 1 atom of sulphur = 16 added to 2 atoms of oxygen = 16, and its equivalent is therefore 32. It contains per cent. about equal weights of each constituent.

*How is HYPOSULPHURIC ACID procured?*

This acid is a combination of sulphur and

blues are first reddened by it, and then wholly discharged. Hence sulphurous acid is used in bleaching, particularly for silks, and straw bonnets. It not only bleaches silk, but gives it lustre. It likewise discharges vegetable stains, and iron-moulds from linen. "A pleasing instance," says Dr. Ure, "of its effect on colours may be exhibited by holding a red rose over the blue flame of a common match, by which the colour will be discharged wherever the sulphurous acid comes into contact with it, so as to render it beautifully variegated, or entirely white."

It is remarkable that the colouring principle is not destroyed by the sulphurous acid. Thus, in the case of the bleached rose, if it be dipped into water, the redness after a time will be restored.

\* According to Mr. Faraday, it is condensed by a force equal to the pressure of two atmospheres. He describes it as a very limpid fluid, and quite colourless. Its refractive power appeared to be nearly equal to that of water. M. Bussy has obtained it in a liquid form under the usual atmospheric pressure, by passing it through tubes surrounded by a freezing mixture of snow and salt. The liquid anhydrous acid thus procured is colourless, transparent, of specific gravity about 1.45, and boils at a temperature of 14° Fahr. It is exceedingly volatile, insomuch that mercury may be readily frozen in a thermometer tube by surrounding the ball with cotton wetted by the liquid acid.

† The sulphites differ in their properties from the sulphates. The alkaline sulphites are more soluble than the sulphates, the earthy less. They are converted into sulphates by an addition of oxygen, which they acquire even by exposure to the air. A strong heat either expels their acid entirely, or converts them into sulphates. They have all a sharp, disagreeable, sulphurous taste. None of them has yet been applied to any use.



oxygen, intermediate between sulphuric and sulphurous acids, and was discovered by Welter and Gay Lussac in 1819.\* It is obtained by passing a current of sulphurous acid through water, in which peroxide of manganese, in fine powder, is suspended. A combination takes place, and a perfectly neutral solution is produced, consisting of hypo-sulphate and common sulphate of manganese. Pure baryta being added, precipitates the manganese, and sulphate of baryta being insoluble, the filtered liquor contains only the hypo-sulphate, and also the redundant portion of baryta. It is separated from the latter by a current of carbonic acid. Hypo-sulphate of baryta being thus obtained, sulphuric acid is cautiously added to the solution, which throws down the baryta, and leaves the hypo-sulphuric acid in solution.†

*What are its properties?*

It is decomposed by heat into sulphuric and sulphurous acids. It saturates the salifiable

\* *Annal. de. Chim. et de Phys.* tom. x. p. 312.

† *Hyposulphurous acid* remains to be described. Like the hyponitrous acid, this acid exists permanently only in combination with salifiable bases, forming compounds which were first examined by Gay Lussac, in 1813, and were called by him *sulphuretted sulphites*. Besides other methods of preparing these salts, he found that they might be obtained by digesting the solution of a sulphite with sulphur, an additional quantity of which might thus be made to combine with the sulphurous acid. Mr. Herschel succeeded in obtaining free hyposulphurous acid, by adding a slight excess of sulphuric acid to a dilute solution of the hyposulphite of strontia; but its decomposition very soon took place, even at common temperatures, and was instantly effected by heat. *Edinburgh Philos. Journal*, vol. i. Further information respecting this acid may be obtained by consulting *Dr. Ure's Dictionary*, p. 97, or Mr. Herschel's papers in *Edinburgh Philos. Journal*.



bases, and affords soluble compounds with baryta, strontia, lime, and lead;\* indeed all the hyposulphates are soluble. At common temperatures these salts are permanent, but when heated, sulphurous acid escapes, and they pass to the state of sulphates.†

SULPHUR COMBINES WITH HYDROGEN, *forming a very peculiarly offensive gas called* SULPHURETTED HYDROGEN GAS.‡ *How is it procured?*

There are several ways of obtaining it, but one of the best is by pouring diluted sulphuric or muriatic acid on the black sulphuret of iron or antimony in a retort.§ It must be collected over mercury.

\* Sulphuric acid, on the contrary, yields insoluble compounds with all those bases.

† We have remarked that sulphur unites with chlorine, forming a *chloride of sulphur*. This substance was first described by Dr. Thomson, in 1804, (*Nicholson's Journal*, vol. iv. p. 104,) and it has since been examined by Berthollet, Junior, and M. Bucholz. Dr. Thomson obtained it by passing a current of chlorine gas through flowers of sulphur. It may be made more expeditiously by heating sulphur in a retort or dry glass vessel filled with chlorine gas. The sulphur and chlorine unite, and form a fluid substance, which is volatile below 200° Fahr. This substance seen by reflected light is of a red colour, but is yellowish-green when seen by transmitted light. Its smell is strong, and similar to that of sea-weed, and the eyes when exposed to it are filled with tears, and effected in a manner resembling the feeling produced by exposure to peat smoke. The taste is acid, hot, and bitter. Its specific gravity is 1.7. It does not change the colour of dry litmus paper, but if the paper be moist it immediately becomes red.

According to Sir H. Davy's experiments, 10 grains of pure sulphur absorb nearly 30 cubic inches of chlorine, so that the compound contains about 2 sulphur and 4.5 chlorine, or one atom of each. Its equivalent is therefore 52.

‡ The gaseous compound of sulphur and hydrogen was discovered by Scheele in 1777.

§ Sulphuret of iron may always be bought at a chemist's shop, but it is better to prepare the compound when wanted, than to keep it ready made, because, unless very carefully preserved from contact with the air, it becomes less fit for the purpose of affording this gas.



*What are its properties?*

It has an extremely offensive smell, resembling that of rotten eggs, \* and a sour taste. It is absorbed by water, which takes up more than an equal volume of the gas.† Its specific gravity has been variously stated, but it would appear that its true density is 1.1805.‡ It is inflammable, and burns with a pale blue flame, depo-

To obtain it from the sulphuret of antimony, (crude antimony of the shops,) mix this compound with 5 or 6 times its weight of muriatic acid, (specific gr. 1.160 or thereabouts) in a retort or gas bottle, and apply the heat of a lamp. Sulphuretted hydrogen will be disengaged in great abundance.

There are two modes in which the changes that take place in this process may be explained, and as it is doubtful which explanation is correct, some chemists adopt one opinion, and others the other. In the first, an interchange of elements is supposed to take place between water and the sulphuret of antimony, in consequence of which, sulphuretted hydrogen and the protoxide of antimony are generated. The former escapes with effervescence, while the latter unites with muriatic acid, forming a muriate antimony. The affinities which determine these changes are the attraction of hydrogen for sulphur, of oxygen for antimony, and of muriatic acid for protoxide of antimony. In the second method of explanation, instead of water, muriatic acid is considered to undergo decomposition, and yielding its hydrogen to the sulphur, and its chlorine to the metal, give rise to sulphuretted hydrogen and chloride of antimony.

\* The smell of rotten eggs, and the washings of a gun-barrel, are owing to the extrication of sulphuretted hydrogen gas. It is the common gas of privies, and is the cause of the accidents which so frequently befall nightmen.

† Water saturated with this gas acquires its peculiar smell, and it gives to the Harrowgate waters their very offensive odour.

‡ Sir H. Davy states the weight of 100 cubic inches at 36.5 grains, and its specific gravity, therefore, is 1.196. According to Gay Lussac and Thenard, its specific gravity is to that of air as 1.1912 to 1. Dr. Thomson makes it 1.1805, and hence 100 cubic inches (bar. 30. therm. 60°) would weigh 35.89 grains

Its constituents are 1 atom of the vapour of sulphur (1.111) + 1 atom of hydrogen gas (0.069). The numbers 0.069 and 1.111 being in the pro-



siting sulphur; but is highly deleterious when respired.\* It is decomposed by electricity, by mixture with chlorine, and when passed over ignited charcoal.† It tarnishes silver, mercury, and other polished metals,‡ forming with them metallic sulphurets.

*It has another property, which you have omitted to notice, although a very remarkable one. What is it?*

That of reddening vegetable blues, and possessing all the characters of an acid. For it combines with an equal volume of ammonia, and

portion very nearly of 1 to 16, gives exactly the same relative weight for the ultimate particle of sulphur, as that deduced from the composition of sulphuric acid.

\* During its combustion, water results from the union of the hydrogen with the oxygen, and sulphurous acid, with a little sulphuric acid, from that of the oxygen and sulphur.

It is peculiarly deleterious to animal life, perhaps the most so of all the gases. It appears, from the experiments of Thenard, that a dog of middle size is destroyed in air that contains  $\frac{1}{800}$ , and that a horse cannot live in an atmosphere containing  $\frac{1}{250}$ . Indeed, Dr. Chaussier says, that to kill an animal it is sufficient to make the sulphuretted hydrogen gas act on the surface of its body, when it is absorbed by the inhalants.

† When decomposed by chlorine, the chlorine seizes the hydrogen, and sulphur is precipitated. If passed over ignited charcoal, it is converted into carburetted hydrogen gas.

The composition of sulphuretted hydrogen is demonstrated by the change produced in it by electricity. If platina wires be ignited in it by the voltaic apparatus, it is rapidly decomposed; sulphur is deposited, and an equal volume of hydrogen remains. The same change is effected more slowly by electrical sparks.

‡ Its affinity for metallic substances renders it a chemical agent of great importance. This affinity causes it instantly to blacken solution of acetate of lead, and white paint, owing to the lead which it contains. The salts of nearly all the common metals are decomposed by its action. For the most part, the hydrogen of the sulphuretted hydrogen combines with the oxygen of the oxide, and the metal unites with the sulphur.



unites to alkalies and oxides. Its salts are termed **HYDROSULPHURETS**.\*

*What is the most delicate chemical test of the presence of sulphuretted hydrogen?*

Carbonate of lead, that is, white lead (white paint). If this is mixed with water, and spread upon a piece of white card or paper, and exposed to the action of sulphuretted hydrogen gas, it will exhibit a sensible discolouration (a dark stain), although the gas be mixed with 20,000 times its volume of common air, hydrogen, or carburetted hydrogen.

*There is another compound of sulphur and hydrogen, which consists of one atom of hydrogen to two atoms of sulphur. It is therefore called BISULPHURETTED HYDROGEN.† How is it obtained?*

By pouring hydrosulphuret of potassa, little by little, into muriatic acid. The greater part of the sulphur separates, one portion of it combines with the sulphuretted hydrogen, assumes the appearance of an oil, and is deposited at the

\* All the *hydrosulphurets*, soluble in water, have an acid and bitter taste, and, when in the liquid state, the odour of rotten eggs. All those which are insoluble are, on the contrary, insipid, and without smell. There are only two coloured hydrosulphurets, that of iron, which is black, and of antimony, which is chesnut-brown.

All the hydrosulphurets are decomposed by muriatic or sulphuric acid. Indeed, the acids in general combine with the base of the hydrosulphurets, and disengage sulphuretted hydrogen with a lively effervescence, without any deprivation of sulphur, unless the acid be in excess, and be capable, like the nitric and nitrous acids, of yielding a portion of its oxygen to the hydrogen of the sulphuretted hydrogen.

† Scheele was its discoverer. It has subsequently been particularly examined by Berthollet (*Annal. de Chem.* tom. 25.)



bottom of the vessel. This is bisulphuretted hydrogen.

*What are its properties?*

They are in some respects obscure. Its taste and smell resemble those of rotten eggs. It is inflammable, burning with great facility, with a smell of sulphurous acid. It appears to possess the properties of an acid; for it combines with alkalies and earths, and forms with them a class of salts called *hydroguretted sulphurets*,\* or by some authors *sulphuretted hydrosulphurets*.

SULPHUR COMBINES WITH CARBON, *forming an interesting liquid: what is it called, and what are its properties?*

It is termed CARBURET OF SULPHUR.† It is sometimes called *sulphuret of carbon*, and *alcohol of sulphur*. When pure it is a liquid as trans-

\* The most interesting of the hydroguretted sulphurets is that of ammonia, which was discovered by Mr. Boyle, and called his fuming liquor. The method of preparing it may be seen in Dr. Ure's *Dictionary of Chem.* p. 756.

† It was discovered by Lampadius, in 1796, while distilling a mixture of barytes and charcoal. He considered it a compound of sulphur and hydrogen. Clement and Desormes first ascertained its true constituents to be carbon and sulphur; and they invented an easy process for at once preparing it. Calcined charcoal is to be put into a porcelain tube, that traverses a furnace so that one end shall be considerably elevated above the other. To the higher end of the tube, a retort of glass, containing sulphur, is luted; and to the lower end is attached an adapter tube, which enters into a bottle with two tubulures, half full of water, and surrounded with very cold water or ice. From the other aperture of the bottle, a bent tube proceeds into the pneumatic trough. When the porcelain tube is brought into a state of ignition, heat is applied to the sulphur, which subliming into the tube, combines with the charcoal, forming the liquid carburet.

Thus obtained, the carburet of sulphur has a yellow colour, owing to a small excess of sulphur, which may be removed by distillation from a glass retort, plunged in water, at a temperature of  $115^{\circ}$ .



parent and colourless as water, of a penetrating, fetid smell, and an acrid burning taste. Its specific gravity, according to Berzelius and Marcet, is 1.272, according to Cluzel, 1.263. It boils briskly at a temperature between  $105^{\circ}$  and  $110^{\circ}$ . It does not congeal when cooled down to  $60^{\circ}$ . It is scarcely soluble in water, but alcohol and ether dissolve it readily. It dissolves camphor. The waters of potassa, baryta, and lime, slowly decompose it, with the evolution of carbonic acid gas.\* When passed through red-hot copper, it combines with that metal, forming a carbosulphuret of metal. By this method, Berthollet, Thenard, and Vauquelin, succeeded in ascertaining its composition, which is 1 atom of carbon + 2 atoms of sulphur; or 15.79 carbon and 84.21 sulphur, in 100 parts.

*What is PHOSPHORUS?*

It is a simple inflammable solid, of a yellowish semi-transparent appearance, and somewhat like wax.†

\* It is one of the most volatile liquids known, and produces a greater degree of cold, by its evaporation, than any other substance. The bulk of a thermometer being enveloped in fine lint, dipped in this liquid, and suspended in the air, sinks from  $60^{\circ}$  to about zero. Dr. Marcet found that if it be introduced under the receiver of an air-pump, and the receiver rapidly exhausted, the thermometer will sink to  $82^{\circ}$  in less than two minutes.

Carburet of sulphur takes fire in the open air, at a temperature scarcely exceeding that at which mercury boils. It burns with a blue flame, giving out the smell of sulphurous acid. Its vapour detonates when mixed with oxygen gas, and an electric spark is passed through it. The products are sulphurous and carbonic acids, and carbonic oxide, if the oxygen be in small proportion; but if six or seven times the bulk of the vapour, the whole of the carbon is converted into carbonic acid.

† It was discovered by Brandt, an alchemist of Hamburg, in 1669,



*How is it procured?*

It was originally obtained from human urine, but has since been generally procured from bones.\* 100 parts of calcined bones, in powder, are to be mixed with 40 parts of sulphuric acid, and suffered to remain in contact for 48 hours, the mixture being frequently stirred. The whole is then to be poured upon a filter of cloth, and the liquor that passes through is to be added to a solution of nitrate of lead; a white powder will be formed; this must be mixed with about  $\frac{1}{5}$ th of its weight of charcoal powder, and exposed to a strong red heat in a porcelain retort, the beak of which is plunged in water;† drops of a waxy-looking substance will pass over, and, falling into the water, will concrete into the solid called phosphorus.‡

while engaged in a vain search after the *philosopher's stone*, which was to transmute the baser metals into gold. Afterwards Mr. Boyle discovered it, and revealed the process to his assistant, Godfrey Hankwitz, a London apothecary, who continued for many years to supply all Europe with phosphorus. Hence it was known to chemists by the name of *English phosphorus*. Other chemists, indeed, had attempted to produce it, but without success, till in 1737 a stranger appeared in Paris, and offered to make phosphorus. The French Government granted him a reward for communicating his process, which was successful.

\* In these animal substances the phosphorus exists in combination with oxygen and lime, forming a *phosphate of lime*; and the art of preparing phosphorus consists in decomposing these compounds, for which purpose we have first to separate the phosphoric acid from the lime, and then the oxygen from the phosphoric acid, leaving the phosphorus free. Phosphate of lime constitutes four-fifths of the weight of calcined bones.

† In this process, the phosphoric acid of the phosphate of lime is disengaged by the sulphuric acid added, and the oxygen of the phosphoric acid subsequently separated by the charcoal, when phosphorus itself is thrown down.

‡ It must be purified by straining it through chamois leather, under warm water.



*What are ITS PROPERTIES?*

It is usually of a light amber colour and semi-transparent; though when carefully prepared it is nearly colourless and transparent. It is as soft as wax, and fully more cohesive and ductile. Its specific gravity is 1.77. It melts at 90° Fahr. and boils at 550°.\* It is so exceedingly inflammable, as to require being kept under water in well closed bottles. In the atmosphere, at common temperatures, it emits a white smoke, which, in the dark, appears luminous. This smoke is acidulous, and results from the slow oxygenation of the phosphorus.† It is dissolved in a small proportion by alcohol, ether, and oils.‡ When taken internally, it is poisonous.§ It combines with earthy and metallic bases, forming a series of compounds termed *Phosphurets*.

*Does phosphorus combine with oxygen?*

It COMBINES WITH OXYGEN in three definite proportions, FORMING PHOSPHORIC ACID, PHOS-

\* Care must be taken to keep phosphorus under water when melted; because it is so combustible, that it cannot easily be melted in the open air without taking fire.

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

† It does not smoke in air perfectly dry, and in this case the acid adheres to it, and in a short time prevents it from being luminous.

‡ When the oily solution of phosphorus is poured upon paper and carried into a dark room, it shines vividly, provided the temperature be above 60°. At lower temperatures the light is scarcely perceptible.

§ It has, however, been employed in medicine, in minute doses, in cases of debility, and putrid fevers, and is said to have been of great service; but it is not now used in England.



PHORUS ACID, and HYPOPHOSPHORUS ACID. IT UNITES ALSO WITH CHLORINE in two proportions, producing a CHLORIDE and BI-CHLORIDE OF PHOSPHORUS; and WITH IODINE, forming an IODIDE OF PHOSPHORUS; likewise WITH HYDROGEN, in two proportions, producing PROTOPHOSPHURETTED HYDROGEN, and PERPHOSPHURETTED HYDROGEN.\*

*How is PHOSPHORIC ACID procured?*

By burning phosphorus in common air or oxygen gas.† Copious white vapours are produced, which fall to the bottom of the vessel in flakes. This is the solid anhydrous phosphoric acid; which, from its powerful affinity for water, soon attracts moisture from the atmosphere, and in a very few minutes appears in the form of minute drops of liquid, which is a solution of phosphoric acid in water.‡ It may likewise be

\* It combines also with sulphur, forming a *phosphuret of sulphur*, and with carbon, producing a *phosphuret of carbon*.

† When phosphorus is burnt in highly rarefied air, three products are formed from it; one is phosphoric acid; one is easily volatile, and appearing as a white powder; and the other is a red solid, comparatively fixed, and requiring a heat above that of boiling water for its fusion. The volatile substance is soluble in water, giving it acid properties. It contains less oxygen than phosphoric acid, and appears to be *phosphorous acid*. The red substance is probably an *oxide of phosphorus*, since for its conversion into phosphoric acid it requires less oxygen than phosphorus does.

Phosphorus, when heated in air to  $148^{\circ}$ , takes fire, and burns with a splendid white light. In oxygen gas, it burns with intense brilliancy.

‡ "The only unequivocal method of obtaining a pure acid," says Dr. Ure, (*Dict. of Chem.* p. 68,) "appears to consist in first converting it into phosphorus by distillation of the materials with charcoal, and then converting this again into acid by rapid combustion, at a high temperature, either in oxygen or atmospheric air, or some other equivalent process."

Dr. Henry recommends, as the most economical process, procuring it from calcined bones by the action of sulphuric acid. In this way, it is



obtained by the oxygenation of phosphorus by nitric acid.\*

*What are its PROPERTIES?*

It is soluble in water in all proportions;† its taste is sour, but not corrosive; it reddens litmus paper strongly, and neutralizes the alkalies.‡ It has no smell when pure. When perfectly dry it sublimes in close vessels, but loses this property by the addition of water.§ With char-

obtained as a transparent glass, which is called *glacial phosphoric acid*.—See *Henry's Chem.* vol. i. p. 374.

\* This is an eligible mode of procuring phosphoric acid in quantity, and perfectly pure.

† Hereby producing a specific gravity, which increases as the quantity of acid is greater, but does not exceed 2.687, which is that of the *glacial acid*.

‡ Its salts are called *Phosphates*. The principal of these salts are the *phosphates of barytes, lime, potash, ammonia, and magnesia*. Phosphate of lime is very abundant in the native state, and likewise constitutes the chief part of the bones of all animals. It has in consequence been strongly recommended by a few writers as a remedy for *rickets*, but this recommendation originated in unscientific and erroneous views. Rickets are not owing to a deficiency of phosphate of lime in the system of persons suffering under that malady, but to a peculiar state of debility in the secreting vessels of the bones, which renders them incapable of separating it from the blood, and depositing it according to the wants of the constitution. Phosphate of lime is therefore found to be useless here, and the only availing remedies are free exposure to a pure bracing air, constant exercise, friction, generous food, and a careful regulation of the bowels. These means properly combined will often effect great and surprising changes in this disease.—See my *Modern Domestic Medicine*, article *Rickets*.

§ In this circumstance it greatly differs from the boracic acid, which is fixed when dry, but rises by the aid of water.

Phosphoric acid may be distinguished from all other acids by these circumstances;—that when carefully neutralized by pure carbonate of soda or potassa, it forms a solution in which no precipitate or change of colour is produced when a stream of sulphuretted hydrogen gas is passed through it; but which is precipitated white by a solution of the acetate of lead, and yellow by the nitrate of silver. The first precipitate, the phosphate of lead, dissolves completely on the addition of nitric or phosphoric acid; the second, the phosphate of silver, is dissolved by both these acids, and likewise by ammonia.



coal or inflammable matter, in a strong heat, it loses its oxygen, and becomes converted into phosphorus. It is generally considered to consist of 1 atom of phosphorus = 12, and 2 atoms of oxygen = 16: its atomic weight is therefore 28.\*

*In what way is PHOSPHOROUS ACID obtained?*

Phosphorus is sublimed through corrosive sublimate in powder in a glass tube; a limpid fluid comes over which must be mixed with water, and the solution heated till it is of the thickness of syrup. This is a combination of water and pure phosphorous acid.†

\* The composition of phosphoric acid is a subject of difficulty, and is variously stated by different chemists. The constituents given above are those adopted by Sir H. Davy and Dr. Thomson. Berzelius considers this acid as a compound of 2 atoms of phosphorus and 5 atoms of oxygen. According to

Rose.....	100 phosphorus combines with 114.6 oxygen.
Dulong....	100 ..... 124.8   ,,
Berzelius ..	100 ..... 127.5   ,,
Davy.....	100 ..... 135.   ,,

The three acids with base of phosphorus are usually stated to be constituted thus:—

	Atoms of Phosphorus.		Atoms of Oxygen.		Atomic Weight.
Phosphoric Acid .....	1	+	2	=	28
Phosphorous Acid .....	1	+	1	=	20
Hypophosphorous Acid....	2	+	1	=	32

† Phosphorous Acid was discovered by Sir H. Davy in 1812. The substance produced by passing phosphorus through corrosive sublimate, is a compound of phosphorus and chlorine; and when it acts upon water hydrogen is afforded to the chlorine, and oxygen to the phosphorus, thereby forming muriatic and phosphorous acids. A moderate heat suffices to expel the former, and the latter remains associated with water. That this acid is a compound of phosphorus, oxygen, and water, is shown by heating it in contact with ammonia over mercury; the ammonia unites to the pure acid, and water is expelled.



*What are its properties?*

It has a very sour taste, reddens vegetable blues, and neutralizes bases, forming salts called *Phosphites*. When formed in the above manner, it forms a white crystalline solid on cooling.\* It exhales a disagreeable fetid odour, and yields, when strongly heated, penetrating white vapours.† It is generally considered to be constituted of 1 atom of phosphorus and 1 of oxygen, which makes its atomic weight 20.‡

*Have you not said that PHOSPHORUS COMBINES ALSO WITH CHLORINE?*

\* *Phosphoric acid* is difficult of crystallizing.

† When exposed to air, it absorbs oxygen slowly, and becomes phosphoric acid. When it is gently heated, it takes fire and burns with great brilliancy, emitting globules of gas (phosphuretted hydrogen) that inflame in contact with air; a red oxide of phosphorus is deposited in the bottom of the vessel, and solid phosphoric acid is formed.

‡ Sir H. Davy after a careful investigation of the constitution of phosphorous acid, considers that 100 grains must consist of—

Phosphorus . . . . .	59.7.
Oxygen . . . . .	40.3.

*Hypophosphorous acid* is an acid which contains one proportion more of phosphorus than the phosphorous acid. It is procured in the following manner:—Pour water on the phosphuret of barytes, and wait till all the phosphuretted hydrogen which arises, be disengaged. Then add cautiously to the filtered liquid dilute sulphuric acid, till the barytes be all precipitated in the state of sulphate. The supernatant liquid is hypophosphorous acid, which should be passed through a filter. This liquid when concentrated by evaporation, yields a viscous fluid, strongly acid and uncrystallizable. It reddens vegetable blues, and forms with alkaline and earthy bases a class of salts called *hypophosphites*. It is supposed to consist of 1 atom of oxygen, and 2 atoms of phosphorus.

The *hypophosphites* have the remarkable property of being all soluble in water; while many of the phosphates and phosphites are insoluble. The hypophosphite of potassa is even more deliquescent than muriate of lime.



Yes, in two proportions, forming a CHLORIDE and BI-CHLORIDE OF PHOSPHORUS.\* When chlorine is introduced into a receiver exhausted of air, and containing phosphorus, the phosphorus takes fire and burns with a pale flame throwing off sparks, and a white substance rises and condenses on the sides of the retort. This is the *bi-chloride* of phosphorus.†

*What are the PROPERTIES of the BI-CHLORIDE of PHOSPHORUS?*

They are very peculiar. It is a snow-white substance, extremely volatile, rising in a gaseous form at a temperature much below that of boiling water. Under pressure it may be fused, and then it crystallizes in transparent prisms. It acts violently upon water, which it decomposes.‡ It produces flame when exposed to a lighted taper; and when passed through an ignited glass tube, along with oxygen, it is decomposed, and phosphoric acid and chlorine are obtained.§ Dry litmus paper exposed to its vapour in a vessel

\* Phosphorus and chlorine combine with great facility, when brought in contact with each other at common temperatures. These compounds were discovered in 1810, by Sir H. Davy.

† If the chlorine be in considerable quantity, as much as 12 cubical inches to a grain of phosphorus, the phosphorus will entirely disappear, and nothing but the white powder will be formed; and about 9 cubical inches of the chlorine will be found to be absorbed. No new gaseous matter will be produced.

‡ Its phosphorus combines with the oxygen of the water, producing phosphoric acid, and its chlorine with the hydrogen, forming muriatic acid.

§ Dr. Ure considers the superior fixity of the acid above the chloride to give that ascendancy of attraction to the oxygen here, which the chlorine possesses in most other cases.



exhausted of air is reddened.\* Its constituents are 2 atoms of chlorine and 1 atom of phosphorus.

*How is* PROTO-CHLORIDE OF PHOSPHORUS OBTAINED, *and what are its* PROPERTIES?

It is procured by passing the vapour of phosphorus over corrosive sublimate, heated in a glass tube.† A limpid fluid (proto-chloride of phosphorus) comes over as clear as water, and having a specific gravity of 1.45. This fluid itself does not redden litmus paper, though its fumes produce this effect, in consequence of being rendered acid by contact with the aqueous vapour of the air, which vapour it decomposes. Its vapour burns in the flame of a candle. When mixed with water and heated, muriatic acid flies off, and phosphorous acid remains. Its constituents are 1 atom of chlorine united to 1 of phosphorus.‡

*But* PHOSPHORUS COMBINES also WITH HYDROGEN; *what are the results of this union?*

\* When introduced into a vessel containing ammonia, they combine together, with much heat; and they form together a compound insoluble in water, undecomposable by acid or alkaline solutions, and having characters analogous to earths.

† *Corrosive sublimate* is a bi-chloride of mercury, and by this process, proto-chloride of mercury (calomel) is formed, and the remaining atom of chlorine unites with the phosphorus.

‡ We have said that phosphorus likewise combines with *iodine*, forming an *iodide of phosphorus*. They combine at the temperature of the atmosphere, always with a disengagement of heat, and sometimes of light, according to the mode in which the experiment is conducted. It is a compound of a reddish-brown colour, fusible at about  $212^{\circ}$ , and volatile at a higher temperature. When thrown into water, there is a double decomposition, (that is, both compounds are decomposed,) and hydriodic and phosphorous acids are produced, so that the hydrogen unites with the iodine, and the oxygen with the phosphorus.



It has been generally supposed that there are three, or at least two, definite compounds of phosphorus and hydrogen, which are called *perphosphuretted* and *protophosphuretted hydrogen*,\* but the constitution of the compounds of these two substances are not perfectly understood.†

*How is PERPHOSPHURETTED HYDROGEN GAS procured?*

It may be obtained in several ways, but one of the best is by adding diluted muriatic acid to phosphuret of lime, in a retort or gas bottle, when, with the aid of a gentle heat, perphosphuretted hydrogen gas comes over.‡ To obtain it pure it must be received over mercury.

*What are its properties?*

\* The second compound is Dr. Thomson's *bihydroguret of phosphorus*, called at first by Sir H. Davy *hydrophosphoric gas*, and afterwards simply phosphuretted hydrogen.—See Thomson's *Chem.* vol. i. p. 274, and Davy's *Elem. of Chem. Philos.* p. 296.

† There is a great difference of opinion among chemists respecting the constituents of these compounds. Mr. Dalton denies the existence of different varieties of phosphuretted hydrogen, and concludes from his experiments that the apparent diversities of composition are occasioned by the admixture of various proportions of free hydrogen, and phosphuretted hydrogen.

It was discovered by M. Gengembre, in 1783.

‡ It may be obtained also by the action of phosphuret of lime on water: the water is decomposed; its oxygen, meeting with the phosphorus, forms phosphoric acid, which combines with the lime, while the hydrogen dissolves another portion of phosphorus, constituting phosphuretted hydrogen gas.

The following mode of procuring this gas affords an amusing experiment. Put into five parts of water half a part of phosphorus, cut into very small pieces, with one of finely granulated zinc, and add three parts of strong sulphuric acid. The gas is disengaged in small bubbles, which cover the whole surface of the fluid, and take fire on reaching the air; these are succeeded by others, and a well of fire is produced.



The most remarkable property of this gas is that of its taking fire immediately on coming into contact with the air.\* If the beak of the retort from which the gas issues is plunged under water in a pneumatic trough, the moment a bubble escapes through the water of the trough, it takes fire, and a beautiful white wreath ascends, composed of a large number of small rings, each revolving vertically round its own axis.† Its smell is very disagreeable. Its specific gravity is about 0.9022,‡ Water absorbs about  $\frac{1}{40}$ th of its bulk of this gas, and acquires a yellow colour, a bitter taste, and the characteristic smell of the gas.§ It does not support combustion or respiration.

*How is PROTOPHOSPHURETTED HYDROGEN GAS PROCURED, and what are ITS PROPERTIES?*

By heating the crystalline hydrate of phosphorous acid in a retort out of the contact of air, when solid phosphoric acid is formed, and a

\* It is thus distinguished from all other gases.

† It is the phosphoric acid, formed by the combustion of the phosphorus, wafted up with the watery vapour, generated by the union of the hydrogen and oxygen.

‡ Dalton says its sp. gr. is 1.1 nearly, and Dumas states it to be 1.761. These discrepancies prove how imperfect our knowledge of this substance is.

§ When mixed suddenly with oxygen gas, it detonates, and the product is phosphoric acid. The experiment should be made cautiously, and in small quantity. It detonates also when mixed with chlorine, or nitrous oxide. With chlorine it detonates with a brilliant green light.

By standing, it deposits phosphorus on the inner surface of the receiver, and loses its property of spontaneous ascension, its volume remaining the same. It is also decomposed by electricity, when the phosphorus is precipitated, and hydrogen of the original gaseous volume remains.



large quantity of protophosphuretted hydrogen is disengaged.\* Its smell is fetid, but not so disagreeable as the preceding gas. Water absorbs about  $\frac{1}{8}$ th of its volume. It does not inflame spontaneously when mixed with air or oxygen gas at common temperatures; but at a temperature of  $300^{\circ}$  a violent detonation takes place with oxygen. When potassium is heated in it, its volume is doubled, and the resulting gas is pure hydrogen.†

PHOSPHORUS ALSO COMBINES WITH SULPHUR.  
*In what way is their union effected, and what are the properties of the compound?*

They may be united by fusing them together in a tube exhausted of air, or under water.‡ They unite in many proportions, and these mixtures are more fusible than either of their constituents. The most fusible compound is that of

\* It was discovered by Sir H. Davy in 1812.

† Authors differ respecting its specific gravity. Dr. Thomson estimates it at 0.9722, and M. Dumas at 1.214.

When sulphur is sublimed in 1 volume of it, a sulphuret of phosphorus is formed, and nearly 2 volumes of sulphuretted hydrogen are produced.

Sir H. Davy remarks, "There is not, perhaps, in the whole series of chemical phenomena, a more beautiful illustration of the theory of definite proportions than that offered in the decomposition of hydrophosphorous acid into phosphoric acid and hydrophosphoric gas," the bihydroguret of phosphorus of Dr. Thomson. "Four proportions of the acid contain four proportions of phosphorus, and four of oxygen; two proportions of water contain four proportions of hydrogen, and two of oxygen. The six proportions of oxygen unite to three proportions of phosphorus to form three of phosphoric acid, and the four proportions of hydrogen combine with one of phosphorus to form one proportion of hydrophosphoric gas; and there are no other products."—*Elem. of Chem. Philos.* p. 296.

‡ In the last case, they must be used only in small quantities; as at the moment of their action water is decomposed, sometimes with explosions.



one and a half of sulphur to two of phosphorus.\* This remains liquid at  $40^{\circ}$  Fahr. When solid, its colour is yellowish-white. It is more combustible than phosphorus, and rises undecomposed at a strong heat.

\* This proportion forms the best composition for phosphoric fire-matches or bottles: a little of it attached to a common brimstone match, inflames when gently rubbed against a surface of cork or wood.



## CHAPTER X.

## OF METALS AND THEIR COMBINATIONS.

*The metals form a numerous and most important class of natural bodies.\* How many are there?*

Forty-one.†

*Were they all known to the ancients?*

No; only seven or eight were known in the earliest ages. The remainder are comparatively of recent discovery.‡

*What are the most characteristic* PROPERTIES OF METALS?

\* The metals are connected with each other by close analogies, and by remote analogies to the inflammable solids described in the preceding pages. Their numerous chemical relations, their extensive and important applications to the arts, and the many valuable medicines to which they give origin, render them a most interesting and important class of bodies.

† Some authors reckon 42 metals, but as the supposed metal *thorium* is now rejected, there are in reality only 41. Thorium was received as the metallic basis of the supposed new earth *thorina*, described as such by M. Berzelius in 1816; but he has since found it to be merely a sub-phosphate of yttria. In the above number of 41, I include selenium, which, however, some chemists describe as a simple non-metallic combustible.

‡ The following is a Table of the principal metals, with the dates of their discovery, &c.

<i>Names of Metals.</i>	<i>Discovered by</i>	<i>Date.</i>
1. Gold .....	} Known since the remotest antiquity.	
2. Silver.....		
3. Iron .....		
4. Copper .....		
5. Mercury.....		
6. Lead .....		
7. Tin.....		
8. Zinc .....	Known to Paracelsus, who died ....	1541
9. Bismuth.....	Described by Agricola .....	1520



A high degree of lustre, called the *metallic lustre*, opacity,\* combustibility, and the power of readily conducting electricity and caloric.

*Are there not some other general characters or properties belonging to metals?*

Yes. They are fusible by heat; and in fusion retain their lustre and opacity. When they are united to oxygen, chlorine, iodine, &c., and the

<i>Names of Metals.</i>	<i>Discovered by</i>	<i>Date.</i>
10. Antimony .....	Described by Basil Valentine, 15th century.	
11. Arsenic .....	} Brandt .....	1733
12. Cobalt .....		
13. Platinum .....	Wood, Assay Master, Jamaica ....	1741
14. Nickel .....	Cronstedt.....	1751
15. Manganèse .....	Gahn and Scheele .....	1774
16. Tungsten .....	M. M. Delhuyart.....	1781
17. Tellurium .....	Muller .....	1782
18. Molybdenum .....	Ditto and Hielm .....	1782
19. Titanium .....	Gregor .....	1781
20. Uranium .....	Klaproth .....	1789
21. Chromium.....	Vauquelin .....	1797
22. Columbium .....	Hatchett .....	1802
23. Palladium .....	} Dr. Wollaston .....	1803
24. Rhodium .....		
25. Iridium .....	Descostils and Tennant .....	1803
26. Osmium.....	Tennant .....	1803
27. Cerium .....	Hisinger and Berzelius .....	1804
28. Potassium .....	} Sir H. Davy .....	1807
29. Sodium .....		
30. Barium .....		
31. Strontium .....		
32. Calcium .....		
33. Lithium .....	Arfwedson .....	1818
34. Cadmium .....	Stromeyer .....	1818

\* From their brilliancy and opacity conjointly, they reflect the greater part of the light which falls on their surface, and hence form excellent mirrors. In general the reflecting power is proportionate to the degree of polish, and is impaired by every thing that diminishes this quality. A tin reflector, for example, has its reflecting power diminished nine-tenths by being rubbed with sand paper.



resulting combinations are submitted to the action of galvanism, the metals separate at the negative pole, and for this reason are said to be positively electrified. With the exception of the newly discovered bases of the alkalies and earths, they are distinguished by a high degree of specific gravity.\* They are *malleable*, or capable of being extended under the blows of a hammer; †

\* Great specific gravity was once supposed to be an essential character of metals; but the discovery of potassium and sodium has shown this to be erroneous, since they are lighter than water.

The following Table exhibits the specific gravity of the principal metals in the order of their densities; water at 60° Fahr. being 1.

		Authority.
Platinum .....	20.98 .....	Brisson.
Gold .....	19.257 .....	Ditto.
Tungsten.....	17.6 .....	D'Elhuyart.
Mercury .....	13.568 .....	Brisson.
Palladium .....	11.3 to 11.8.....	Wollaston.
Lead .....	11.352 .....	Brisson.
Silver .....	10.474 .....	Ditto.
Bismuth .....	9.822 .....	Ditto.
Cobalt.....	8.538 .....	Haüy.
Uranium .....	9.000 .....	Bucholz.
Copper.....	8.895 .....	Hatchett.
Cadmium.....	8.604 .....	Stromeyer.
Arsenic .....	8.308 .....	Bergmann.
Nickel .....	8.279 .....	Richter.
Iron .....	7.788 .....	Brisson.
Molybdenum .....	7.400 .....	Hielm.
Tin .....	7.291 .....	Brisson.
Zinc .....	6.861 to 7.1.....	Ditto.
Manganese .....	6.850 .....	Bergmann.
Antimony .....	6.702 .....	Brisson.
Tellurium .....	6.115 .....	Klaproth.
Sodium .....	0.972 } .....	{ Gay Lussac & Thenard.
Potassium .....	0.865 } .....	

† This is a useful property of Metals, but they are not all malleable. The malleable metals are gold, platinum, silver, palladium, mercury in a frozen state, copper, iron, lead, tin, zinc, and nickel. Gold surpasses all metals in malleability. The gold leaf, which is sold in books, is so ex-



are *ductile*,\* or may be formed into wire, and have a peculiar *tenacity*.† They are capable of combining in a melted state with each other, in almost every proportion, constituting the important order of metallic alloys.

*Are not the structure or texture of several of the metals crystalline?*

Yes. All of them that are fusible by common means assume regular crystalline forms by slow cooling, and these forms are usually either cubes or octohedrons.

*Is the point at which the different metals FUSE nearly or quite the same?*

tremely thin, that less than five grains cover a surface of about  $272\frac{1}{4}$  square inches; and the thickness of each leaf does not exceed  $\frac{1}{282.000}$ th of an inch.

\* Almost all the metals that are malleable are also *ductile*, but their ductility and malleability are not always in proportion to one another. Iron, for example, cannot be beaten into very thin leaves, but it may be drawn into wires not thicker than a human hair. The metals most remarkable for ductility are gold, silver, platinum, iron, copper, and zinc. By surrounding the gold with silver, Dr. Wollaston has succeeded in extending a grain into wire of the length of 700 feet, which gives a thickness of only  $\frac{1}{30.000}$ th of an inch.

† The tenacity or cohesive power of metals exists in the different species with very different degrees of force. It is estimated by gradually adding weights till the wire is broken. At the iron cable manufactory of Captain Brown, a cylindrical bar of iron,  $1\frac{1}{2}$  inch diameter, was drawn asunder by a force of 43 tons. Before the rupture, the bar lengthened about five inches, and the section of fracture was reduced nearly three-eighths of an inch. About this part a degree of heat was generated, which rendered it unpleasant, if not in a slight degree painful, to grasp the bar in the hand. A wire of iron 0.078, or  $\frac{1}{128}$ th of an inch, will support 549 pounds, and a similar wire of copper, 302 pounds. In general, iron is about 4 times stronger than oak, and 6 times stronger than deal. The property of tenacity, more particularly as far as iron is concerned, is now more than ever called into use, in the formation of suspension bridges, chain cables, and other useful instruments; and it is a property which, in the formation of hoops, and other similar things, is brought into general use.



The point of fusion is very different for the different metals. Lead, for example, fuses at 500° Fahr., while gold does not fuse till heated to 32° of Wedgwood's pyrometer, each degree of which is equal to 130° Fahr.\*

\* The following Table, extracted from *Thenard's Chemistry*, vol. i. shows the degree of heat at which the different metals fuse.

	<i>Fahrenheit.</i>	<i>Authorities.</i>
Fusible below a red heat.	Mercury.....	39° Different Chemists.
	Potassium.....	136 } Gay Lussac and
	Sodium.....	190 } Thenard.
	Tin.....	430 } Newton.
	Bismuth.....	493 }
	Lead.....	500 Biot.
	Tellurium—rather less fusible than lead.....	Klaproth.
	Arsenic—undetermined.	
	Zinc.....	698 Bronymart.
	Antimony—a little below red heat.	
	Cadmium.....	698 Stromeyer.
<i>Pyrometer of Wedgwood.</i>		
Infusible below a red heat.	Silver.....	20° Kennedy.
	Copper.....	27 } Wedgwood.
	Gold.....	32 }
	Cobalt—rather less fusible than iron.	
	Iron.....	{ 130 } Wedgwood.
		{ 158 } Mackenzie.
	Manganese.....	160 Guyton.
	Nickel.....	160 Richter.
	Palladium, Molybdenum, Uranium, Tungsten, Chromium.	{ Almost infusible, and not to be procured in buttons by the heat of a smith's forge. }
	Titanium, Cerium, Osmium, Iridium, Rhodium, Platinum, Columbium.	
		{ Infusible in the heat of a smith's forge, but fusible before the oxy- hydrogen blow-pipe. }
		Fusible before the oxy-hydrogen blow-pipe.



*We have now spoken of the points of agreement in the physical qualities of metals, but do they not resemble each other, also, in their chemical properties?*

Yes. They all combine with oxygen, forming *metallic oxides*,\* which is a most important class of bodies. All of them likewise combine with chlorine and iodine, and many with sulphur, phosphorus, &c. forming respectively, *chlorides, iodides, sulphurets, phosphurets, &c.*

*Are the phenomena and results of the oxidizement of metals the same in all cases?*

No; they differ very considerably with respect to different metals. Some are oxidized, merely by exposure, at the ordinary temperature of the atmosphere, others require a very high temperature; and some cannot be oxidized but by the intense heat generated by the Voltaic discharge.† All the metals that are oxidized by atmospheric air, are still more readily oxidized by oxygen gas.‡

*What is necessary to these changes of metallic oxidizement?*

That there should exist a stronger affinity between oxygen and the metal, than between the oxygen and light which constitute the gas.§

\* A few of the metals are acidifiable, or become acids, by union with oxygen.

† To convert the metals into oxides, there is therefore a degree of heat peculiar to each metal, and even to different oxides of the same metal.

‡ When heated in oxygen gas, many of them give rise to all the phenomena of combustion. Iron wire, for example, is thus entirely consumed, giving off vivid scintillations. Zinc takes fire at a red heat, and burns with great splendour. This forms a good character of zinc.

§ It appears that fusion, and other modes of promoting the oxidation



*The cases of metallic oxidizement just mentioned are simple cases: Are there not other cases in which the phenomena become more complicated?*

Yes; such are those instances in which the metal acquires oxygen by the decomposition of some other compound, in which that element is present. For example, water, acids, and other oxides, or compounds containing one or more of these substances, are frequent sources of oxygen to metals, by which they become oxidated. Water yields its oxygen to those metals only, which have a strong affinity for that element; and, in general, the change produced is slow at common temperatures, but much accelerated by an elevation of temperature. Thus, iron filings, when moistened with water,\* become very gradually oxidized, and evolve hydrogen gas; but water, brought into contact with red-hot iron, is, as is well known, rapidly decomposed, and hydrogen gas is disengaged in torrents.†

*What acids have the greatest power in the oxidation of metals?*

The NITRIC and NITRO-MURIATIC ACIDS. Generally speaking, the weaker the affinity of the acid base for oxygen, the more rapidly is the

of metals are efficient by overcoming the cohesive attraction of the metallic particles.

\* And confined in an inverted jar over mercury.

† The metallic bases of the alkalies and earths have so powerful an attraction for oxygen, that even at common temperatures they decompose water with astonishing rapidity, and this is the cause of the heat and flame visible when they come into contact with water.



metal oxidized.\* Therefore, the nitric and nitro-muriatic acids, in which there exists a large quantity of loosely combined oxygen, readily abandon a part of it, and act on the metals with great energy.†

*It is remarkable that some of the acids, sulphuric and muriatic acids, for example, which, when concentrated, scarcely act upon the metals, acquire the power of oxidizing them rapidly when diluted with water: How do you explain this?*

The water is decomposed, and yields the oxygen necessary for the oxidation of the metal, to the rapidity of which the acid present materially assists, in a way not perfectly understood.‡

*Can you give an example of the oxidation of metals by the transfer of oxygen from other metallic oxides?*

Iron filings are oxidated by being distilled with the red oxide of mercury, the oxygen passing to the iron, while the mercury is *revived*, or appears in a metallic state.§

\* Therefore, those acids that have not been proved to contain oxygen, are almost inert in their action on metals; and a similar inactivity belongs to other acids, in which the oxygen and base are held combined by a powerful attraction. For this reason, concentrated sulphuric acid, at the ordinary temperature of the atmosphere, scarcely attacks any of the metals—so forcibly do the oxygen and sulphur of which it consists, attract each other.

† Even the more perfect metals, gold and platinum, are oxidized by the nitro-muriatic acid.

‡ That water is, in this instance, the source of the oxygen, is evident; for it has been fully ascertained that no portion of the acid is decomposed; the same quantity of acid existing in combination with oxide of iron, as was originally submitted to experiment.

§ In a similar manner, the oxides, held in solution by acids, are decomposed by immersing, in the solution, other metals. When copper, for ex-



*Do the metals combine with more than one proportion of oxygen?*

Some of them unite with that element only in one proportion, but others combine with it in two or three proportions. Thus, copper forms two oxides, the protoxide consisting of 12.5 grains of oxygen + 100 grains of metal, and the peroxide of 25 of oxygen + 100 of metal. Iron also forms two oxides.\*

*Are these proportions definite?*

They are,† and every oxide after the first contains a quantity of oxygen, which is the precise multiple of the first quantity. For example, the peroxide of copper, as we have just stated, con-

ample, is immersed in a solution of nitrate of mercury (consisting of oxide of mercury and nitric acid) the latter metal is deprived of its oxygen by the former, and appears on the surface of the copper, as metallic mercury.

\* These different oxides have different colours. The protoxide of iron, for example, is *black*, and the peroxide *red*. They are characterized also by different habitudes with respect to the acids, indeed their chemical properties generally are distinct. Thus, the black oxide of iron readily unites with muriatic and sulphuric acids; but the red oxide less easily. And of different oxides of the same metal, the one which contains a larger proportion of oxygen is capable of saturating more acid, than the one which contains less.

The solubility of the metallic salt in water, also bears a proportion to the quantity of oxygen in the oxides; and consequently to the quantity of acid with which that oxide is combined. Salts, containing the metal at the minimum of oxidation, are generally those which are most insoluble. This obtains with respect to the salts of lead, silver, and mercury, metals which, at the minimum of oxidizement, take very little oxygen, and, consequently, very little acid. A similar law appears applicable to the compounds of chlorine, for corrosive sublimate, (*bi-chloride of mercury*,) which contains the largest proportion of that element, is much more soluble than calomel (*proto-chloride of mercury*).

† Thus, 1 proportion of oxygen, or its equivalent, 8, combines with 200 mercury, 110 silver, 64 copper, 40 potassa, 28 iron, 24 soda, &c.; and on the principle of mutual saturation, these numbers, therefore, are the equivalents of the metals, or their proportional numbers.



tains just double the quantity of oxygen that the protoxide does.

*By what means are the metallic oxides REDUCED or REVIVED, that is, brought again to the metallic state?*

There are three methods by which this may be effected, viz. 1, By heat alone; 2, By heat and combustible matter combined; 3, By the agency of Galvanic Electricity.\* Some of the metallic oxides are reduced by mere exposure to heat, such are those of gold, silver, mercury, and platinum; while others require the united agency of heat and combustible matter. Charcoal is a species of combustible matter of great service in such cases.† Thus, potassa and soda are decomposed by exposing them to a white heat after

\* Another method is by the action of deoxidizing agents on metallic solutions. Thus, the phosphorous acid, when added to a liquid containing the oxide of mercury, deprives the oxide of its oxygen, metallic mercury subsides, and phosphoric acid is produced. In like manner, one metal may be precipitated by another, provided the affinity of the latter for oxygen exceeds that of the former.

† Combustible matters are used in these cases from their having a very strong attraction for oxygen, and of course those matters which have the strongest affinity for that element, and are cheap, are commonly the best for this purpose. Besides charcoal, phosphorus, hydrogen, and certain *fluxes*, are employed in such cases. *Fluxes* are compounds formed of very combustible ingredients. The principal fluxes, are the *crude flux*, *white flux*, and *black flux*. Crude flux is a mixture of nitre and tartar, which is put into the crucible with the mineral intended to be fused. White flux is formed by projecting equal parts of nitre and tartar, by moderate portions at a time, into an ignited crucible. Black flux is made in the same way, but the weight of the tartar is double that of the nitre, on which account the combustion, when the mixture is thrown into the ignited crucible, is incomplete, and a considerable portion of the tartaric acid is decomposed by the mere heat, and leaves a quantity of coal behind, on which the black colour depends. The black flux is that which is commonly employed in the reduction of metallic oxides.



being intimately mixed with charcoal in fine powder. The oxides of baryta and strontia resist the combined influence of heat and charcoal, but are reduced by the more energetic agency of Galvanism.

*What is the distinguishing feature of the metallic oxides?*

The property of entering into combination with acids, and forming salts. All salts, those of ammonia excepted, are composed of an acid and a metallic oxide.\*

METALS COMBINE *also* WITH CHLORINE, forming CHLORIDES : † *How is their union effected?*

Most of the metals combine with chlorine at common temperatures, and it is then only necessary to throw the metal into the gas; and those few metals which resist the action of chlorine at ordinary temperatures, all unite with it when heated.‡

\* It is usually stated that the acids in forming salts, enter into union with alkalies, earths, and metallic oxides, but in reality the alkalies and earths are metallic oxides. Potash and soda, lime and magnesia, &c. for example, are respectively formed of potassium, sodium, calcium and magnesium, combined with oxygen.

† All the metals unite likewise with *iodine*, forming compounds which are called *iodides*. They all decompose water, the hydrogen of which forms hydriodic acid with the iodine, while its oxygen is transferred to the metal, and the acid produced combines with the metallic oxide.

The compounds of *metals with hydrogen* are few in number and of little importance. Hydrogen appears to combine with both arsenic and tellurium in two proportions, forming two solid compounds, the *hydrurets* or *hydrogurets* of arsenic and tellurium; and two gaseous compounds, *arsenuretted* and *telluretted hydrogen*.

‡ The action of chlorine on metals is in many instances so violent, that an evolution of light accompanies it. When copper leaf, powdered antimony, arsenic, or zinc, is thrown into a jar of chlorine gas, the metal



*Is the attraction of chlorine for metals as great as that of oxygen?*

It is greater. Thus, even those metals that are most distinguished by their affinity for oxygen, as potassium, sodium, barium, and strontium, abandon it when their oxides are heated in contact with chlorine, oxygen gas being liberated, and chlorides formed.\*

*What are the CHARACTERS of the CHLORIDES?*

Both their physical and chemical properties are various, like those of the oxides. Some are unchanged by heat; others undergo decomposition. They are, for the most part, colourless, do not possess the metallic lustre, and have the aspect of a salt. They are all more or less soluble in water, except the chloride of silver and protochloride of mercury. Several of them decompose water, giving rise to the formation of muriatic acid and an oxide; or in some cases to a muriate.†

instantly inflames. Mercury and iron inflame when gently heated in it; silver, gold, and platinum quietly absorb it. The most readily oxidized metals burn with the greatest brilliancy in it.

\* The elements of the chlorides thus formed, are so strongly united, that no temperature hitherto tried can separate them.

† Many of the metals decompose muriatic acid, when hydrogen is evolved, and the chlorine combines with the metal, forming a chloride. As Dr. Henry remarks, diluted muriatic acid acting on certain metals (iron, for example,) occasions the decomposition of water; hydrogen is evolved; and an oxide is formed, which unites with the muriatic acid and constitutes a true muriate. Or if the oxide of a metal be acted upon by muriatic acid, we have also a muriate formed, which, in some cases, crystallizes as much, but in others in becoming solid is at the same moment changed into a chloride. The oxides of barium, strontium, calcium, magnesium, aluminum, copper, and manganese all form with muriatic acid crystallized muriates, containing definite proportions of water; but the oxides of potassium and sodium when



*In what way is the combination of SULPHUR WITH THE METALS effected?*

It may be accomplished in several ways, although to effect their union, it is sufficient that one of the bodies be brought into a fluid state, and as sulphur is readily fusible, a very moderate heat only is required for the purpose. Thus 45 parts of iron filings and 15 of sulphur, when heated in a glass tube, combine, the moment the fusion of the sulphur is accomplished.\* Sulphur may be also combined with metals by heating it in conjunction with metallic oxides, when they are decomposed, and metallic sulphurets are formed;† or the metallic sulphates may be employed to form sulphurets, by heating them in contact with inflammable substances, as hydrogen or charcoal.

*What are the characters of the sulphurets?*

dissolved in muriatic acid afford muriates only so long as they continue fluid, and in crystallizing become true chlorides. Mercury, silver, and lead, form chlorides only, and not muriates. *Henry's Elem. of Chem.* vol. i. p. 499.

\* The phenomena attending their union are very remarkable, consisting of a free disengagement of caloric, with a sudden and bright glow, like that of intense ignition. This appearance of combustion is quite independent of the presence of oxygen. It is seen in the combination of sulphur with potassium, sodium, copper, iron, lead, and bismuth.

† Thus when potassa and sulphur are heated together, part of the sulphur is acidified at the expence of the potassa, and the rest combines with the potassium.

Sulphurets may be formed also by the action of sulphuretted hydrogen gas. Nearly all the salts of the common metals are decomposed when a current of sulphuretted hydrogen is conducted into their solutions. The salts of uranium, iron, manganese, cobalt, and nickel, are exceptions; but these likewise are precipitated by the hydrosulphuret of ammonia or potassa.



The properties of the metals cease, for the most part, to be apparent in them; they are brittle, and have colours different from those of the metals. Some of them have a metallic lustre,\* others are without lustre. They are all insoluble in water, excepting those which are formed of the metallic bases of the alkalies and earths. They are all fusible by heat; but can only be partially decomposed by that power.† Concentrated sulphuric acid, with the assistance of heat, acts upon metallic sulphurets, and is converted into sulphurous acid, which, being volatile, escapes.‡ Concentrated muriatic acid has no effect on the sulphurets.§ Nitric acid is decomposed by the metallic sulphurets.||

\* Such are the sulphuret of lead, antimony, and iron.

† Most of the proto-sulphurets are capable of supporting intense heat without decomposition; but those which contain more than one equivalent of sulphur, lose part of it when strongly heated. They are all decomposed without exception by exposure to the combined agency of heat and air or oxygen gas; and the products depend entirely on the degree of heat and the nature of the metal. The sulphuret is converted into the sulphate of an oxide, provided the sulphate is able to support the temperature employed in the operation. If this is not the case, then the sulphur is evolved under the form of sulphurous acid, and a metallic oxide is left; or if the oxide itself is decomposed by heat, the pure metal remains.—See *Dr. Turner's Chem.* p. 390.

‡ Metals which, in their separate state, were dissolved by dilute sulphuric acid, continue sensible to its action, after being combined with sulphur. From such action, instead of hydrogen gas simply, we obtain sulphuretted hydrogen. It is, however, chiefly the compounds with the minimum of sulphur, that produce this effect; for the *bi-sulphurets* resist the action of this solvent.

§ Diluted muriatic acid acts like the diluted sulphuric.

|| In this case, nitrous gas is disengaged, and sulphur precipitated. But, although all nitric acid contains water, sulphuretted hydrogen is not formed



*Many of the metallic sulphurets occur abundantly in nature: name those which are most frequently met with?*

They are the *sulphurets of lead, antimony, copper, iron, zinc, molybdenum, and silver.\**

*Does SULPHURETTED HYDROGEN combine WITH METALS?*

It combines with a few of them, as silver and mercury. It unites more readily with the metallic oxides, forming also more permanent compounds. From these, the sulphuretted hydrogen is detached in a gaseous state by some concentrated acids, which seize the metallic oxides.†

*PHOSPHORUS COMBINES WITH the greater number of the METALS: How is their union effected?*

The best method is to expose the metals to heat, in contact with phosphoric acid and charcoal. The charcoal deprives the phosphoric acid of oxygen, leaving phosphorus, which unites with the metal.‡ Phosphorus unites also with some of the metallic oxides.

in this decomposition, because the acid yields its oxygen more easily than the water.—See *Vauquelin*, in *Ann. de Chimie*, tom. xxv. p. 65.

\* It is doubtful whether any definite compounds of sulphur with the metallic oxides exist.

† Most of the sulphuretted oxides undergo, in process of time, spontaneous decomposition, in consequence of the union of the hydrogen and oxygen which they contain, and which, by combination, form water. When this happens, the oxide is partly reduced, and the sulphur unites with the deoxidized metal. Hence the same sulphuretted oxide varies in composition, according to the period which has elapsed since its preparation.

‡ Metals, however, that have a strong affinity for oxygen, decompose the phosphoric acid, and unite with its base, without the intervention of charcoal. Little attention has yet been paid to the metallic phosphurets. The



*What is the principal compound resulting from the union of CARBON WITH A METAL?*

CARBURET OF IRON, or steel.\*

*Most of the metals are capable of combining with each other, forming a class of bodies called ALLOYS.† Do the metals thus unite with one another in their solid state?*

No: the influence of chemical affinity is in this case counteracted by the force of cohesion, and to form an alloy it is, therefore, necessary to fuse one or both of the metals.‡ When melted together they unite.

*What are the physical properties of the alloys?*

In these points they are very analogous to the metals. They are all solid at the temperature of the atmosphere; they possess the metallic lustre, even when reduced to a coarse powder; are completely opaque, and are excellent conductors of electricity and caloric. They, however, often differ materially in some respects, as in ductility, malleability, hardness, and colour, from the separate metals of which they are composed. The

most ample description of them is in Pelletier's papers, in vols. i. and xiii. of *Annal. de Chimie*.

\* Plumbago, or black lead, as it is commonly called, and which is employed for making pencils, is also a *carburet of iron*. These compounds will be described under *iron*.

† Thus brass is an alloy of copper and zinc; bell-metal and bronze are alloys of copper and tin, in different proportions; pewter an alloy of tin, zinc, and bismuth.

‡ There are, however, a few of the metals that do not unite even by being fused together. This is the case with lead and iron. The reason is, that the cohesive attraction of the individual particles of these metals is stronger than their reciprocal attraction.



properties of ductility and malleability are usually impaired.\* On the contrary, the hardness of a metal is in general increased by being alloyed, as in the case of gold or silver and copper.† Brass, which is an alloy of copper and zinc, forms a remarkable instance of a difference in colour.‡

*Are there not some other differences in the character of alloys and the separate metals which form them by combination?*

They differ also in density, or specific gravity, which is rarely the mean of the component parts of an alloy;§ in fusibility, which is greatly augmented;|| in the greater facility with which they unite with oxygen,\*\* and in the difference of their solubility in acids.

\* Alloys formed of two brittle metals are always brittle, and when composed of a ductile and brittle metal, they are generally brittle, especially if the latter predominate. An alloy of two ductile metals is sometimes brittle, which is very remarkably the case with gold and lead, the latter of which, even in the trivial proportion of half a grain to an ounce of gold, renders the alloy quite destitute of tenacity. Again, an alloy of platinum, copper, and zinc, though eminently ductile and malleable, is rendered brittle by a quantity of iron not exceeding half a grain in four ounces of the alloy.

† In fabricating gold or silver ornaments or utensils, a small quantity of copper is, for this reason, always added to those precious metals. By a very small addition of gold, iron is said to gain so much hardness, as to be even superior to steel for the manufacture of cutting instruments.

‡ Thus, a minute quantity of arsenic added to copper, renders it white.

§ The specific gravity of an alloy is sometimes greater, sometimes less, than the mean of its component parts.

|| Platinum, for example, which is infusible in any common furnace, forms, when united with arsenic, a very fusible alloy; and an alloy of lead, tin, and bismuth, melts at a temperature below that of boiling water, though the most fusible of the three, which is tin, requires for its fusion a much higher degree of heat than  $212^{\circ}$ . This is the principle of *solders*.

\*\* The greater tendency of alloys to combine with oxygen is owing partly to a diminution of their cohesive power, but in some instances to the formation of a galvanic combination. Thus, lead when united with mercury, is



*Are not the articles called DUTCH GOLD, and PINCHBECK, alloys?*

Yes. They are alloys of copper and zinc,\* in different proportions. The *Dutch Gold* is a fine kind of brass, supposed to be made by cementation of copper plates with calamine, hammered out into leaves in Germany, and thence forwarded to this country.†

*Do metals unite with one another in every proportion?*

They appear to do so; yet it is certain that they have a tendency to combine in definite proportions.‡

*What is meant by the term AMALGAM?*

It is applied to the combinations of *mercury* with other metals. It is an amalgam of tin that is employed in making looking glasses, the back surface being covered with it. And an amalgam of zinc and tin is used for promoting the action of the electrical machine.§

oxidized by merely shaking the compound with water, or exposing it to the air. An alloy of steel with 100th of its weight of platinum is dissolved with effervescence in dilute sulphuric acid, which is so weak as scarcely to act on common steel. This effect Mr. Faraday, by whom it was first observed, attributes to the steel in the alloy being rendered positive by the presence of the platinum.

\* Cannons are cast with an alloy of a similar kind.

† Printing types are formed from an alloy of three parts of lead to one of antimony.

‡ Dr. Henry says, (*Elem. of Chem.* vol. i. p. 509,) "A careful examination of those alloys which are characterized by peculiar properties, and adapted to specific uses, has shown that such compounds are definite, and fall within the general laws of the atomic system. This proposition has been ably maintained by Berzelius, as well as by Dalton." The *arbor Dianæ* is a definite compound of silver and mercury.

§ This amalgam is made by fusing one part of zinc with one of tin, and



*Before we proceed to speak of the metals individually, I would inquire whether you are acquainted with the composition of METEORIC STONES, many of which have very much of a metallic appearance?*

Their composition is peculiar, consisting of earthy and metallic matters, of a singular aspect. They all appear to consist nearly of the same substances, which are of four different kinds.\*

*What is the origin of these stones?*

I believe them to be of atmospheric origin, although different opinions have been, and are perhaps still, entertained on this subject. The circumstances which give great support to the opinion that they are actually formed in the air, are, 1st. That at whatever period, and in whatever part of the world they may have fallen, they appear, as far as they have been examined, to consist of the same substances; and 2dly, That they have nothing similar to them, not only among the minerals in the neighbourhood of the places where they were found, but among all

then agitating the liquid mass with two parts of mercury placed in a wooden box.

\* The first and most abundant kind of substance is one that has a little lustre like that of enamel, of a grey colour, sometimes inclined to brown, and very hard. Another is a martial pyrites, of a reddish-yellow colour, black when powdered, not very firm in its texture, and not attractible by the magnet. A third consists of small particles of iron in a perfectly metallic state, which give to the mass the quality of being attracted by the magnet. These are connected together by a fourth substance, of an earthy consistence in most, so that they may be broken to pieces by the fingers with more or less difficulty.

These stones are all covered with a thin crust of a deep black colour, they are without gloss, and their whole surface is raised in small nodules or asperities.



that have hitherto been discovered in our earth, as far as men have been able to penetrate.\*

*We have now to speak of the metals individually. How are they divided?*

It is not an easy thing to classify them, but that division which is founded on the nature of their relation to oxygen appears to me the best. The most inflammable metals produce, by combination with oxygen, *alkalies*, *alkaline earths*, and *earths*. Other metals afford the substances called *oxides*, which are analogous to earths; and a few are converted into *acids*. The metals that produce alkalies are potassium, sodium, and lithium. The alkaline earths are formed from metals, which have been called barium, strontium, calcium and magnesium. The metals sup-

\* We are indebted to Mr. Howard for the greater part of the best information we possess respecting meteoric stones. His valuable dissertation will be found in the *Philos. Transactions* for 1802, and in the 13th vol of *Tilloch's Magazine*. The celebrated French chemist Vauquelin has paid our countryman a high compliment. "While all Europe," says he, "resounded with the rumour of stones fallen from the heavens; and while philosophers, distracted in opinion, were framing hypotheses to explain their origin, each according to his own fancy, the Hon. Mr. Howard, an able English chemist, was pursuing in silence the only route which could lead to a solution of the problem. He collected specimens of stones which had fallen at different times, procured as much information as possible respecting them, compared the physical or exterior characters of these bodies; and even did more, in subjecting them to chemical analysis, by means equally ingenious and exact.

"It results, from his researches, that the stones which fell in England, in Italy, in Germany, in the East Indies, and in other places, have all such a perfect resemblance, that it is almost impossible to distinguish them from each other; and what renders the similitude more perfect and more striking is, that they are composed of the same principles, and nearly in the same proportions."—*Tilloch's Magaz.* vol. xv. p. 346.



posed\* to be contained in common earths are silicium, aluminum, zirconium, yttrium, and glucinum. The metals that produce oxides are cobalt, manganese, zinc, uranium, cerium, titanium, rhodium, iridium, osmium, iron, tin, cadmium, lead, copper, nickel, bismuth, antimony, mercury, palladium, silver, gold, and platinum. Those which are acidifiable, or produce acids, by combination with oxygen, are tellurium, arsenic, chromium, molybdenum, tungsten, columbium, and selenium.†

It is remarkable that nickel or chromium is found to be the constant associate of the iron in meteoric stones. They are never found in mineral native iron, and are therefore characteristic of meteoric iron. The solitary masses of native iron that are found in Siberia and South America contain nickel, and although some of them weigh several tons, there is the strongest probability that they are of meteoric origin.

\* These have not yet been exhibited in a *separate* form, and are arranged among the metals from analogy; chiefly because the earths in which they exist, present a striking resemblance, in regard to their properties, to the oxides of ascertained metals.

† By some authors the metals are divided into two great classes, thus—

1. *Metals that afford oxides, which cannot be reduced to a metallic form without the addition of combustible matter*; that is, are not reduced by the sole action of heat.

This class comprehends the greater number of the metals;—of course, all the metals not included in class—

2. *Metals, the oxides of which are decomposed by heat only.*

These are eight in number, viz.—

Mercury,	Palladium,
Silver,	Rhodium,
Gold,	Iridium, and
Platinum,	Osmium.

In respect to the relations of metals to oxygen, Dr. Ure makes the following just and able remarks, (*Dict. of Chem.* p. 600,) “By arranging metals according to the degree in which they possess the obvious qualities of unalterability, by common agents, tenacity, and lustre, we also conciliate their most important chemical relations, namely, those to oxygen, chlorine, and iodine; since their metallic pre-eminence is, popularly speaking, inversely as their affinities for these dissolvents. In a strictly scientific view,



their habitudes with oxygen should perhaps be less regarded in their classification than with chlorine, for this element has the most energetic attraction for the metals. But, on the other hand, oxygen, which forms one-fifth of the atmospheric volume, and eight-ninths of the aqueous mass, operates to a much greater extent among metallic bodies, and incessantly modifies their form, both in nature and art."

The order that I propose to follow in this volume is, as near as may be, that described in the text in the preceding page. Beginning with the alkalies, I shall then proceed to notice, in order, the alkaline earths, earths proper, ordinary metallic oxides; and lastly, the acidifiable metals. The student is here presented with a general table of the metals with their precipitants, &c. It will be perceived that in this table the numbers denoting the specific gravity of the metals are a little different from those given at page 287. The present numbers are subjoined on the authority of Dr. Ure, and since they are the results of late investigations and calculations, they may probably be considered the more correct.



NAMES.	Sp. Gr.	Precipitants.	Colour of Precipitates by			
			Ferrocyanide of Potassa.	Infusion of Galls.	Hydro-Sulphurets.	Sulphuretted Hydrogen.
1 Platinum ..	21.47	Mur. Ammon.	0	0	.....	{ Black met. powd.
2 Gold .....	19.30	{ Sulph. Iron } { Nitr. Merc. }	Yellowish-white	Green; met. ..	Yellow ....	Yellow
3 Silver .....	10.45	Common Salt..	White .....	Yellow-brown	Black .....	Black
4 Palladium ..	11.8	Cyan. Mercury	Deep orange ....	.....	Blackish-brown ....	{ Black-brown
5 Mercury....	13.6	{ Common Salt } heat	White passing to yellow ....	Orange-yellow	Brownish-black ....	Black
6 Copper ....	8.9	Iron .....	Red-brown .....	Brown .....	Black .....	Ditto
7 Iron .....	7.7	{ Succin. Soda } { with Perox..	Blue or white } passing to blue }	Protox. 0 } Perox. black }	Black .....	
8 Tin.....	7.29	Corros. Sublim.	White .....	0	{ Protox. black } { Perox. yellow }	Brown
9 Lead .....	11.35	Sulph. Soda ..	Ditto .....	White .....	Black .....	Black
10 Nickel ....	8.4	Sulph. Potass..	Ditto .....	Grey-white....	Ditto .....	0
11 Cadmium ..	8.6	Zinc .....	Ditto .....	0	Orange-yellow } ..	{ Orange-yellow
12 Zinc .....	6.9	Alk. Carbonates	Ditto .....	0	White .....	{ Yellow-white
13 Bismuth....	9.88	Water.....	Ditto .....	Yellow .....	Black-brown	{ Black-brown
14 Antimony ..	6.70	{ Water } { Zinc.....	With dilute solutions white }	White from water }	Orange ....	Orange
15 Manganese	8.	Tartr. Pot. ....	White .....	0	White .....	Milkeness
16 Cobalt.....	8.6	Alk. Carbonates	Brown-yellow ..	Yellow-white..	Black .....	0
17 Tellurium ..	6.115	{ Water } { Antimony }	0	Yellow .....	Blackish ....	
18 Arsenic ....	{ 8.35 ? } { 5.76 ? }	Nitr. Lead ....	White .....	.....	Yellow.....	Yellow
19 Chromium ..	5.90	Ditto .....	Green .....	Brown.....	Green .....	
20 Molybdenum	8.6	Ditto ? .....	Brown.....	Deep brown ..		Brown
21 Tungsten ..	17.4	Dilute Acids				
22 Columbium	5.6 ?	Zinc or inf.galls.	Olive .....	Orange .....	Chocolate	
23 Selenium ..	4.3 ?	{ Iron } { Sulphite Am.				
24 Osmium ....	?	Mercury .....	.....	{ Purple passing to deep blue.		
25 Rhodium ..	10.65	Zinc.....	0	.....	0	
26 Iridium ....	18.68	Ditto ? .....	0	0		
27 Uranium....	9.0	Ferrocyan. Pot	Brown-red .....	Chocolate ....	Brown-yellow } ..	0
28 Titanium ..	.2	Inf. Galls.....	Grass-green ....	Red-brown....	Grass-green	0
29 Cerium ....	.2	Oxal. Amm. ..	Milk-white ....	0	White .....	0
30 Potassium ..	0.865	{ Mur. Plat. } { Tart. Acid }	0	0	0	0
31 Sodium ....	0.972					
32 Lithium ....						
33 Calcium ....						
34 Barium ....						
35 Strontium ..						
36 Magnesium						
37 Yttrium ....						
38 Glucinum ..						
39 Aluminum ..						
40 Zirconium ..						
41 Silicium ....						



*How is POTASSIUM procured, and when was it discovered?*

This metal was discovered by that illustrious philosopher Sir H. Davy, in 1807, and is obtained from potassa (or potash), which is an oxide of potassium. If a small piece of solid potassa \* be placed between two discs of platinum, connected with the extremities of a voltaic apparatus of 200 double plates, four inches square, it will soon undergo fusion; oxygen will separate at the positive surface, and small metallic globules will appear at the negative surface, which consists of potassium.†

\* There is a difficulty in subjecting potassa to electrical action, from its being in a perfectly dry state a complete non-conductor of electricity. When rendered, however, in the least degree moist by breathing on it, it readily undergoes fusion and decomposition, by the application of strong electrical powers.

† The extraordinary power of electrical decomposition has been described at page 120, and it appeared to be a natural inference, that the same powers, applied in a state of the highest possible intensity, might disunite the elements of some bodies, which had resisted all other instruments of analysis. If potassa, for example, were an oxide, composed of oxygen united to an inflammable base, it seemed probable, that when subjected to the action of opposite electricities, the oxygen would be attracted by the positive wire, and repelled by the negative. At the same time, the reverse process might be expected to take place with respect to the combustible base, the appearance of which might be looked for at the negative pole. In his first experiments, suggested by these views, Sir H. Davy did not succeed in effecting the decomposition of potassa, owing to his employing the alkali in a state of aqueous solution, and to the consequent expenditure of the electrical energy in the mere decomposition of water. In his next trial, the alkali was in a solid state, and he perfectly succeeded in decomposing it as above described.

That the production of metallic globules at the negative surface of the pile is entirely independent of the action of the atmosphere, is proved by its being produced *in vacuo*. Sir H. Davy's description of his experiments may be read in the *Philos. Trans.* for 1808.



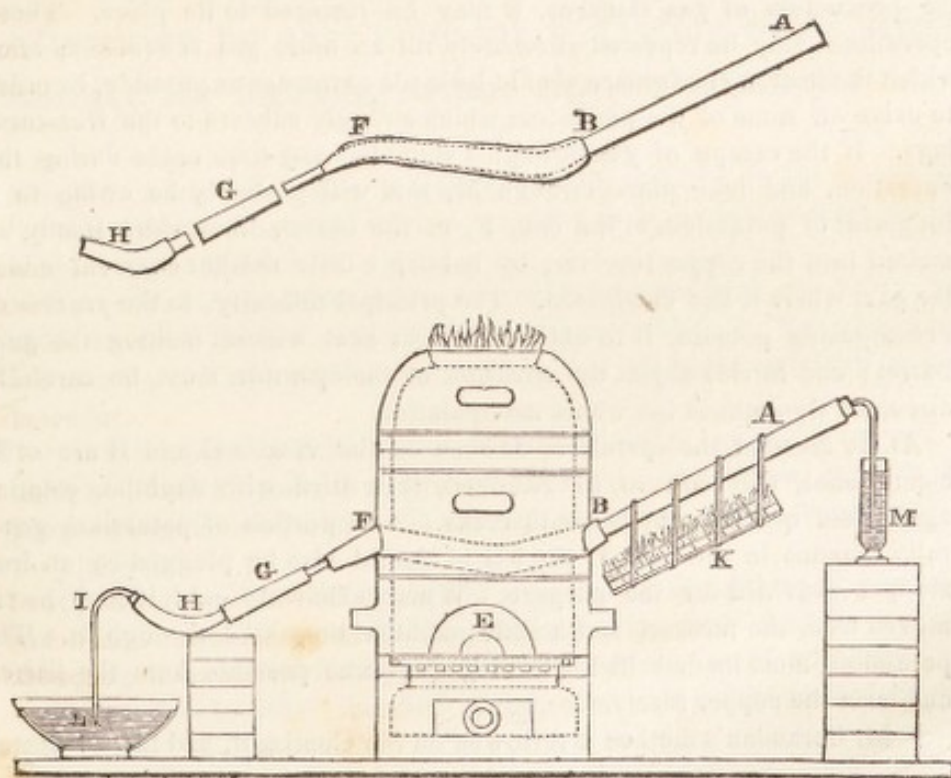
*But may not potassium be procured by chemical means, without electricity?*

Yes. If iron turnings be heated to whiteness in a curved gun-barrel, and potash be melted, and made slowly to come in contact with the turnings, air being excluded, potassium will be formed, and will collect in the cool part of the tube.\* This method of procuring it was dis-

\* In this process, the iron deprives the water and potassa of oxygen, hydrogen gas is evolved, and pure potassium sublimes.

Potassium may be obtained in greater quantity by this method, than by electricity, but it does not appear so pure as that procured by the Voltaic apparatus. It is always heavier, and not so bright: to what this is owing has not been explained.

The apparatus used by Gay Lussac and Thenard, for obtaining potassium, has a general resemblance to that which is employed for decomposing water by means of iron. It consists of a gun-barrel curved as in the annexed sketch. At one end the barrel is drawn out to rather a smaller diameter; and, before being used, it is to be covered between B and F with a lute of infusible clay, which should be suffered to dry thoroughly. Into the barrel





covered by MM. Gay Lussac and Thenard, in 1808. Another method was recommended in the same year by M. Curaudau, of Geneva, which consists in igniting potash with charcoal in a strong iron pot.\*

between F and B, clean iron turnings are to be introduced, and between A and B, pieces of solid hydrate of potassa. A tube of safety is to be luted to the end A, and is to be immersed in mercury in the glass vessel M. To the smaller end of the barrel, a short piece of copper tube, G, is accurately ground, and to this last a small copper receiver, H, destined to collect the potassium, is fitted by grinding. To the other end of H, a tube of safety, I, is to be luted, and made to dip into mercury contained in the vessel L, but to a less depth than the safety tube M.

A strong heat is now to be raised in the furnace, and, while this is doing, the part of the barrel containing the potassa, as well as the end F, and the attached copper tube and receiver, should be kept cool by wet cloths: If gas now issues abundantly through the safety tube I, the junctures may be concluded to be tight. When the barrel has become white hot, the potassa may be melted by burning charcoal contained in a moveable cage K. It will then flow upon the intensely ignited iron turnings, and a large quantity of hydrogen gas, holding some potassium in solution, will issue through the safety tube, I. The cage may now be removed for a short time; and, when the production of gas slackens, it may be restored to its place. These operations may be repeated alternately till no more gas is evolved; after which the heat in the furnace should be made as intense as possible, in order to drive off some of the potassium which strongly adheres to the iron-turnings. If the escape of gas through I should at any time cease during the operation, and take place through M, this will probably be owing to a lodgment of potassium at the end, F, of the barrel, from which it may be melted into the copper receiver, by holding a little red-hot charcoal under the part where it has condensed. The principal difficulty, in the process of decomposing potassa, is to excite sufficient heat without melting the gun-barrel; and to this object the attention of the operator must be carefully directed, throughout the whole manipulation.

At the close of the operation, as soon as the vessels G and H are sufficiently cool, they are to be removed, then filled with naphtha, emptied again, and quickly stopped with corks. As a portion of potassium generally remains in the end F, the barrel should also be plugged by an iron stopper provided for the purpose. When sufficiently cold it may be removed from the furnace, and a little naphtha be passed through it. The potassium must be detached in as large pieces as possible from the barrel, and from the copper receiver.

\* M. Curaudau's method is followed on the Continent, and the celebrated



*What are the PROPERTIES OF POTASSIUM?*

They are very extraordinary. Although a metallic substance, it is lighter than water, its specific gravity being 0.865, water being 1.0. At common temperatures it is solid, soft, and easily moulded by the fingers. At 150° Fahr. it fuses, and rises in vapour in a heat a little below redness.\* It is perfectly opaque. When newly cut, its colour is splendant white, like that of silver, but it rapidly tarnishes in the air, from its absorbing oxygen. It is a perfect conductor both of electricity and heat. It inflames when gently heated in the air, burns with a red light and throws off fumes, which are alkaline. It burns spontaneously in chlorine with intense brilliancy. It possesses the property of welding like iron.

*Has it a very strong attraction for oxygen?*

Of all known substances, it has the strongest attraction for that element.† Owing to its strong affinity for oxygen, when thrown upon water, it

Swedish chemist, Berzelius, is said to have made half a pound at one time by this means. It is made with such facility as to be sold in every apothecary's shop in Sweden.

\* At about the freezing point of water, it becomes hard and brittle, and exhibits, when broken, a crystallized texture, which, in the microscope, seems composed of beautiful facets of a perfect whiteness and high metallic splendor.

† It acts upon all fluid bodies containing water, or much oxygen, or chlorine; and its general powers of chemical combination, says its discoverer, may be compared to the alkahest, or universal solvent imagined by the alchemists.

It produces such a condensation of oxygen, that the oxides of potassium are denser than the metal itself. Potassium has been skilfully used for detecting the presence of oxygen in bodies. A number of substances, undecomposable by other chemical agents, are readily decomposed by this substance.



acts with great violence, and swims upon the surface, burning with a beautiful light of a red colour, mixed with violet. The water becomes a solution of pure potassa.\*

*With what substances does potassium combine?*

With oxygen, chlorine, iodine, hydrogen, sulphur, phosphorus, and some metals.

*In what proportions does potassium combine with oxygen?*

In two proportions, forming a protoxide and peroxide of potassium. The *protoxide of potassium* is pure *potash* or *potassa* (the substance from which potassium is procured,) and is always formed when potassium is put into water, or when it is exposed at common temperatures to dry air or oxygen gas. The *peroxide of potassium* is obtained by gently heating potassium in common air or in oxygen. It is an orange-coloured fusible substance.†

\* If a globule of potassium be placed on ice it instantly burns with a bright flame, and a deep hole is made in the ice, filled with a fluid which is found to be a solution of potassa. The production of alkali, by the action of water on potassium is most satisfactorily shown, by dropping a globule of the metal upon moistened paper, which has been tinged with turmeric. At the moment when the globule comes into contact with the paper, it burns, and moves rapidly, as if in search of moisture, leaving behind it a deep reddish-brown trace, and acting upon the paper exactly like dry caustic potassa. So strong, indeed, is the affinity of potassium for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when carefully purified, and disengages, from both these fluids, hydrogen gas.

On account of its strong affinity for oxygen, potassium can be kept only under *naphtha*, a species of petroleum of great purity, and which contains no oxygen.

† Pure anhydrous potassa, or the *protoxide of potassium*, is constituted of 1 atom of potassium = 40, and 1 atom of oxygen = 8; its representa-



*How is pure potash or potassa obtained?*

By boiling the purest sort of pearl-ash,\* (which is a carbonate of potassa,) in clean iron vessels, with half its weight of quick lime: the lime separates the carbonic acid, forming a carbonate of lime, which falls down insoluble: the mother liquor is then to be strained through clean linen, concentrated by evaporation, again strained, and set by to cool in a close vessel. When the liquor can be decanted clear from the sediment, this is to be done, and the solution evaporated to dryness.†

tive number is therefore 48. The *peroxide of potassium* is composed of 1 atom of potassium = 40, and 3 atoms of oxygen = 24; its representative number is consequently 64.

\* The common potash or pearl-ash of the shops is, in reality, a *carbonate of potash*. The best is commonly brought from America, and Dantzic. Potash is usually called the vegetable alkali, because it is obtained (in an impure state) by the incineration of vegetables. It appears, from Mr. Kerwan's experiments, 1. that in general weeds yield more ashes, and their ashes much more salt, than woods; and that, consequently, as to salts of the vegetable alkali kind, as potash, pearl-ash, catsup, &c. neither America, Trieste, nor the northern countries, have any advantage over Ireland; 2. that of all weeds fumitory produces most salt, and next to it wormwood. But if we attend only to the quantity of salt in a given weight of ashes, the ashes of wormwood contain most. The following table exhibits the amount of saline product obtained from the incineration of the vegetables named:

Wormwood .....	748lb.	Fir .....	132lb.
Fumitory .....	360	Fern cut in August .....	116
Stalks of sun-flower .....	349	Heath .....	115
Beech .....	219	Oak .....	111
Stalks of Turkey Wheat or		Sallow .....	102
Maize .....	198	Box .....	78
Elm .....	166	Aspen .....	61
Vine branches .....	162.6		

† It may be further purified by the action of alcohol, which dissolves the potash, and leaves the other substances it is usually mixed with untouched. The alcohol may then be evaporated in close vessels, so as not to be lost, and the caustic potash is thus obtained pure.



*Is this an absolutely pure potassa, that is, a protoxide of potassium, uncombined with any other substance?*

No. As usually formed, caustic potassa always contains an atom of water, combined with an atom of potassa.\* It is therefore a solid *hydrate of potassa*, or an *hydrated protoxide of potassium*. Its atomic weight is therefore 57.†

*What are the properties of this caustic potassa?*

It is solid, white, and so extremely caustic that it destroys the skin, and all animal textures, when applied to them.‡ It has a powerful affinity for water, which it rapidly attracts from the air, passing into the oil of tartar, *per deliquium* of the older chemists.§ It possesses, even in

\* So strong is its affinity for water, that this portion cannot be separated from it by the strongest heat alone; it requires to be decomposed, and then it is converted into a hard grey substance, which is again converted into the hydrate by the action of water. The hydrate may therefore be considered as a chemical compound.

† Because it contains 48 parts or one equivalent of potassa, and 9 parts or one equivalent of water, making together 57.

‡ From its highly corrosive qualities, it is used in surgery as a caustic. It was formerly called *lapis causticus*, but is now termed *potassa fusa*. A little of this applied to the skin immediately produces an eschar. This preparation is made by evaporating the aqueous solution of potassa (*liquor potassa*) in a silver or clean iron capsule to the consistence of oil, and then pouring it into moulds. In this state it contains impurities from which it is purified by dissolving it in alcohol, and evaporating the solution to the same extent as before, in a silver vessel. The operation must be performed expeditiously.

§ Dissolved in water, it produces a considerable degree either of heat or cold, as it may have been prepared. If put into water in its fused state, heat is the result; but if it has been crystallized, on being mixed with water, and particularly if mixed with snow, it produces a degree of cold sufficient to depress the thermometer more than 40°. This difference, therefore, depends on the presence or absence of water in the potassa: if it be already present, cold is the result of the solution.



minute quantities, all the properties to which the name of alkaline has been given, that is, it changes vegetable blues to green, and yellows to a reddish-brown.

*How is the aqueous solution of potassa, that is, the LIQUOR POTASSÆ of the Pharmacopœia, usually prepared?*

By decomposing carbonate of potassa by quicklime. To accomplish this object perfectly, it is advisable to employ equal parts of quick lime and carbonate of potassa. After slaking the lime in an iron vessel, the carbonate of potassa, dissolved in its own weight of hot water, is added, and the mixture boiled briskly for about ten minutes. The liquid, after subsiding, is filtered through a funnel, covered with clean linen. This process is employed because quick lime deprives carbonate of potassa of its acid, forming an insoluble carbonate of lime, and setting the pure alkali at liberty.\*

*What are the USES OF POTASSA?*

In chemistry, it is very extensively employed, both in manufactures and as a re-agent in analysis. With oils of various kinds it forms the common soft soaps. It is also of great use in medicine.†

\* When the decomposition is complete, the filtered solution does not effervesce when neutralized with an acid.

† This solution of potassa, as well as the solid hydrate of potassa, is highly caustic, and possesses alkaline properties in an eminent degree. Its taste is intensely acrid, and it absorbs carbonic acid gas from the atmosphere rapidly, which renders it necessary to keep it in well-stopped bottles.

† Chiefly in disorders of the stomach and urinary organs, and some



*How is the PEROXIDE OF POTASSIUM formed?*

By heating potassium in a glass jar filled with oxygen gas. A vivid combustion takes place, a great deal of oxygen is absorbed, and an orange-coloured solid body is produced.\* This is the peroxide of potassium. It fuses when exposed to a temperature higher than is requisite to fuse common potash. When thrown into water, oxygen is evolved, and a solution of the protoxide results, constituting common aqueous potash.†

POTASSIUM COMBINES *also* WITH CHLORINE.‡

*What is the result?*

The salt commonly called MURIATE or POTASSA; which is in reality a CHLORIDE OF POTASSIUM.§

anomalous cutaneous affections, when it is given largely diluted with water, and in which complaints it is occasionally of remarkable service.

\* For every grain of potassium consumed, about a cubical inch and  $\frac{7}{10}$  of oxygen disappear. To make the experiment accurately, the metal should be burnt in a tray of platinum, covered with a coating of muriate of potassa which may be easily done by fusing it in contact with the platinum. This salt is one of the few substances that has no action on potassium or its oxides.

† When it is heated in carbonic acid, oxygen gas is expelled, and it is converted into the compound called subcarbonate of potassa. It is composed of

Potassium.....	100
Oxygen .....	60

Which shows it to be a compound of 1 atom potassium and 3 atoms oxygen. Its atomic weight will therefore be 64.

‡ Chlorine acts on potassium, as we have already remarked, even more energetically than oxygen; the metal takes fire when put into the gas, and burns vividly, though sometimes, owing to a film of the resulting compound forming a crust over the metal, the action stops, but is renewed and continued if the metal be heated.

§ It was formerly called *febrifuge salt of Silvi*, and by Boerhaave *regenerated sea salt*. Sir H. Davy ascertained its true nature in 1807. It was called *muriate of potash* because it is generally obtained by the mutual



*What is the proportion in which the elements of this compound unite?*

One proportion of potassium = 40, unites with one of chlorine = 36. The equivalent of the salt is consequently 76.\* This compound forms another strong proof of the validity of the chemical doctrine of equivalents, as we find potassium combining with precisely that quantity of oxygen and chlorine, which combines with one proportion of hydrogen.

*What is the compound called which is formed from the union of POTASSIUM AND HYDROGEN?*

These elements unite so as to form two compounds, the one gaseous, called *potassuretted hydrogen*, the other solid, which is named *hydruret of potassium*. The first may be formed directly, by heating potassium in hydrogen gas. It is spontaneously inflammable in the air, and burns with a very brilliant light, which is purple at the edges. The solid hydruret of potassium is formed in the

action of muriatic acid and potash; but it is worthy of particular remark, that when potassium is heated in muriatic acid; or potash is mixed with liquid muriatic acid; or potassium is burned in chlorine, we have always the same substance produced, namely, the *chloride of potassium*. The fact is, that in all these cases the chlorine unites with the potassium, and the hydrogen of the muriatic acid and the oxygen of the oxide to form water.

The chloride of potassium is white, and seems to crystallize in cubes. Its taste is somewhat similar to that of common salt, but more inclined to bitter. It therefore differs from the oxide of potassium (caustic potassa) in possessing no acrid or intense powers. Its specific gravity is 1.836.

\* In watery solution this salt must always exist as muriate of potash, and then it may be regarded as constituted of an atom of muriatic acid = 37, and an atom of potash = 48; and its equivalent number is, therefore, 85.



same way, the temperature employed being just under ignition. It is a greyish solid, destitute of metallic lustre.\*

*When POTASSIUM AND SULPHUR are heated together, they unite with great energy, and with an evolution of heat and light: the resulting compound is a sulphuret of potassium: What are its characters?*

It is of a dark grey colour, and acts with great energy on water, producing sulphuretted hydrogen. It burns brilliantly when heated in the air, becoming sulphate of potash. It consists of 2 atoms of sulphur + 5 of potassium.†

*In what way is SODIUM procured?*

Exactly in the same manner as potassium, by electrical or chemical decomposition, pure soda (that is, pure hydrate of soda) being used instead of potassa.‡

*What are its characters and properties?*

In many of its characters it resembles potassium. It is as white as silver, possesses great lustre, and is a good conductor of electricity. It enters into fusion at about 200° Fahr., and rises in vapour at a strong red heat. Its specific

\* Potassium unites also with iodine, forming an *iodide of potassium*. The combination is effected by heating potassium in a tube of green glass with an excess of iodine.

† Potassium likewise combines with phosphorus, and with some of the metals, as mercury, gold, silver, and copper.

‡ It is more difficult to obtain than potassa, a rather higher degree of heat, and greater voltaic power, being required to decompose soda than potassa.

It was discovered by Sir H. Davy a few days after he discovered potassium.



gravity is 0.972 at the temperature of 590° Fahr. When heated strongly in oxygen or chlorine, it burns with great brilliancy.\* When thrown upon water it effervesces violently but does not inflame, swims on the surface, gradually diminishes with great agitation, and renders the water a solution of soda. It acts upon most substances in a manner similar to potassium, but with less energy. It tarnishes in the air, but more slowly than potassium.†

*With what substances does sodium combine?*

Excepting hydrogen, it unites with the same substances as potassium. Its most important compounds are those resulting from its union with oxygen and chlorine.

*In what proportions does it combine with oxygen?*

In two proportions, forming two distinct compounds. One is *pure soda*; the other is the orange coloured *oxide of sodium*. The former is the *protoxide* of sodium, the latter the *peroxide*.‡

*How is SODA formed?*

By burning sodium in a quantity of air, containing no more oxygen than is sufficient for its conversion into this alkali: that is, the metal must be in excess. It is necessary to employ a strong degree of heat.

*What are ITS PROPERTIES?*

\* In the cold, it exercises scarcely any action on *dry* air, or oxygen.

† It is soft and malleable, and may be pressed into plates and welded. Like potassium, it is best preserved under naphtha.

‡ Both these oxides were discovered by Sir H. Davy in 1807, but the true nature of the latter was first pointed out by MM. Gay Lussac and Thenard, in 1820.



In many of its properties it has a strong resemblance to potassa, being the same sort of acrid corrosive alkaline substance. It is of a grey colour, of a vitreous fracture, and requires a strong red heat for its fusion. It is a non-conductor of electricity. When a little water is added to it, there is a violent action between the two bodies; the soda becomes white, crystalline in its appearance, and much more fusible and volatile. It is then the substance properly styled the *hydrate of soda*.\* It is constituted of an atom of sodium = 24, and an atom of oxygen = 8, which makes its equivalent 32.† Its specific gravity is 1.336.

*And how is the PEROXIDE OF SODIUM formed?*

By burning sodium in an excess of oxygen. It is of a deep orange colour, very fusible, and a non-conductor of electricity. When acted on by water, it gives off oxygen, and the water becomes a solution of soda. It deflagrates when strongly heated with combustible bodies. It ap-

\* Hydrate of soda contains  $22\frac{1}{2}$  per cent. of water, which considerably exceeds the proportion in the similar compound of potassa.

† The proportions of oxygen in soda, and the orange oxide, or peroxide of sodium, are easily learned by the action of sodium on water, and on oxygen. If a given weight of sodium, in a little glass tube, be thrown by means of the finger, under a graduated inverted jar filled with water, the quantity of hydrogen evolved will indicate the quantity of oxygen combined with the metal, to form soda; and when sodium is burnt slowly in a tray of platinum, lined with dry common salt in oxygen in great excess, from the quantity of oxygen absorbed, the composition of the peroxide may be learned. From the experiments of Sir H. Davy, compared with those of Gay Lussac and Thenard, the prime of equivalent of sodium is 24, as stated above, and that of dry soda, or protoxide of sodium (as above) 32.



pears to be composed of 2 atoms of sodium = 48, and 3 atoms of oxygen = 24.

*In what way do you distinguish between soda and potassa?*

Soda is distinguished from potassa, by forming an *efflorescent* paste when exposed to the atmosphere; potassa, under the same circumstances, *deliquesces*. Again, when sulphuric acid is added to soda it forms a very soluble salt, (sulphate of soda, or Glauber's salt,) but when added to potassa, a sparingly soluble salt. Muriate of platinum and tartaric acid occasion precipitates with potash salts, but not with those of soda.

*What are the USES OF SODA?*

Soda and its compounds are of great importance in the arts and in medicine, and are subservient to many of the wants of life. Soda is the most important ingredient of plate and crown glass, and of all hard soaps. Glass is composed of soda united to earths and oxides, and hard soap of soda combined with oily substances.

SODIUM COMBINES WITH CHLORINE: *What is the result?*

That important substance *common salt*, which is therefore a chloride of sodium.\* This is the only combination of chlorine and sodium known.

\* The true nature of common salt was first shown by Sir H. Davy. It was formerly considered a muriate of soda. Indeed, when chloride of sodium is dissolved in water, it passes, by the decomposition of that fluid, to the state of muriate of soda, and it is this salt, and not the chloride of sodium, (which last can only exist in a solid form,) that is the ingredient of sea water, and other solutions of common salt. Muriate of soda is composed, in 100 grains, of about (Berzelius) 46.56 acid + 53.44 base.



*How is chloride of sodium formed?*

It is well known to be an abundant natural product,\* but it may be formed artificially by burning sodium in chlorine gas, or by heating it strongly in muriatic acid.†

*What are its properties?*

They are well known. It crystallizes in regular cubes, is a non-conductor of electricity, is fusible at a strong red heat, and volatile at a white heat. One part is soluble in  $2\frac{1}{2}$  of cold water, and in a little less of hot. In the fire it decrepitate, melts, and is at length volatilized. When pure it is not deliquescent.‡ It is composed of 1 atom of chlorine = 36, added to 1 of sodium = 24; its equivalent is therefore 60.§

*SALT is universally used at table as a condiment, but has it not many other uses?*

\* Common salt is found native in great abundance in England, and elsewhere. The waters of the ocean everywhere abound in it. Indeed, it exists in minute quantities in almost all waters and all soils. Sea water appears to contain it in different proportions in different places. The water of the Baltic Sea is said to contain one sixty-fourth of its weight of salt; that of the sea between England and Flanders one thirty-second part; and that on the coast of Spain one sixteenth part.

† In the latter case the hydrogen is liberated, while the chlorine combines with the metal.

‡ The common varieties of salt always contain a small quantity of sulphate of magnesia and lime, and muriate of magnesia, and to the presence of the latter salt is owing the deliquescent property of ordinary kitchen salt.

§ It is not decomposed when ignited in contact with inflammable substances, except with potassium, which sets at liberty half its weight of sodium.

Sodium has a much stronger attraction for chlorine than for oxygen; and soda, or its hydrate, is decomposed by chlorine, oxygen being expelled from the first, and oxygen and water from the second.

Potassium has a stronger attraction for chlorine than sodium has; and one mode of procuring sodium easily, is by heating together to redness common salt and potassium.



Yes. ITS USES are various, and of the highest importance.\* It is the principal source of all the muriatic acid used, and of all the chlorine employed by bleachers;† it forms a glaze for earthenware, by being thrown into the oven where it is baked; it improves the whiteness and clearness of glass; it gives hardness to soap; in small quantities it is employed as a manure; in melting metals it preserves their surface from oxidation, by defending them from the air, and is employed with advantage in some assays. It is likewise employed as a mordant, and for improving certain colours.‡

\* Dr. Henry says, (*Philos. Transact.* for 1810,) "That kind of salt which possesses most eminently the combined properties of hardness, compactness, and perfection of crystals, will be best adapted to the purpose of packing fish and other provisions, because it will remain permanently between the different layers, or will be very gradually dissolved by the fluids that exude from the provisions; thus furnishing a slow but constant supply of saturated brine. On the other hand, for the purpose of preparing the pickle, or of striking the meat, which is done by immersion in a saturated solution of salt, the smaller grained varieties answer equally well; or, on account of their greater solubility, even better, provided they be equally pure."

† See pages 146—177.

‡ It enters more or less into many other processes of the arts. Its power of diminishing the tendency of animal and vegetable bodies to decomposition is fully known. It probably preserves the ocean in a state fitted for the purposes of animal life, and, although taken in small quantities, seems to perform an important part in the nourishment and economy of man and all animals.—See my *Modern Domestic Medicine*, p. 21.

A recent traveller says, that on visiting the celebrated salt mines of Wiliska, near Cracow, in Poland, he was assured that animals which die there do not putrify, but merely assumed the appearance of stuffed birds and beasts; and that when, in 1696, the bodies of some workmen who, it was supposed, had perished in the great conflagration, were found in a retired and deserted corner of the mine, they were as dry and hard as mummies. It is said the wood used in these mines becomes as hard as rock, which is probably quite true, for we know that wood steeped in a solution



*There is a compound called CHLORIDE OF SODA which has lately attracted much attention: What is it?*

It is a compound of chlorine and soda, and is found to be extremely valuable as a disinfectant, in purifying places contaminated with offensive or infectious effluvia.\* It is easily prepared by transmitting a current of chlorine gas through a cold and rather dilute solution of caustic soda, till it is saturated with the gas.

*Does sodium combine with sulphur?*

It combines readily with sulphur, phosphorus, iodine, and some of the metals, presenting phenomena similar to those presented by potassium.†

*What is LITHIUM?*

It is the metallic basis of *lithia*, a new alkali, lately discovered by M. Arfvredson, a young Swedish chemist. Lithia was found in a mineral from the mine of Uto, in Sweden, called *petalite*.‡

of salt, so as to be thoroughly impregnated with it, is very difficult of combustion. In Persia salt is supposed to prevent timber from the attack of worms, for which purpose it is therefore used in that country. Bruce, the traveller, remarks, that in Abyssinia it is used as money; and it is very probable, that the pillars of fossil glass, in which the Abyssinians are said by Herodotus to have enclosed the bodies of their relations, were nothing but masses of rock salt, which is very common in that part of Africa.

\* In its properties it is very analogous to the bleaching powder called chloride of lime. Diluted with water it is now used by surgeons as a very useful lotion to certain kinds of ulcers, particularly to such as have an offensive discharge. A full account of its disinfecting powers may be seen in my book already referred to in noticing the chloride of lime, page 149.

† Potassium and sodium combine with great facility, and form peculiar compounds, which differ in their properties, according to the proportions of the constituents.

‡ It is found also in triphane or spodumene, a mineral which is not so scarce as petalite. M. Berzelius has found lithia to be a constant and essential element in the mineral waters of Bohemia.



Sir H. Davy discovered that the basis of this alkali is a metal, to which the name of *lithium* has been given.\*

*How do you procure lithia?*

It may be obtained by fusing petalite with carbonate of potassa, dissolving the whole in muriatic acid, evaporating to dryness, and digesting in alcohol. The muriate of lithia thus formed being very soluble in alcohol, is taken up, while the other salts remain. By a second solution and evaporation in alcohol, it is obtained perfectly pure.†

*What are the PROPERTIES OF LITHIA?*

Like the preceding alkalies, it has an acrid burning taste, and destroys the cuticle of the tongue. It changes vegetable blue colours to green. It dissolves in water, but not with very great facility.‡ Heat is evolved during its solution in water. When exposed to the air it does

\* Sir H. Davy applied the power of a galvanic battery to a portion of the carbonate of lithia, fused in a platinum capsule. The alkali was decomposed with bright scintillations; but the reduced metal burned again so rapidly, that it was only observed to be of a white colour and very similar to sodium. The proportion in which this metal combines with oxygen has not therefore been determined by direct experiment. Dr. Gmelin, from whom we have the most complete account of lithia and its compounds, deduces the composition of lithia to be 58.05 metal + 41.95 oxygen. The atomic weight of lithium is therefore considered to be 10, and that of lithia ( $10 + 8$ ) 18.

† Berzelius says that the most economical way of preparing lithia is to mix triphane or spodumene, in powder, with twice its weight of pulverized fluor spar and with sulphuric acid; then to heat the mixture till the fluoric acid with the silica is volatilized, and afterwards to separate the sulphate of lithia by solution.

‡ It appears not to be much more soluble in hot than in cold water, in which respect it has an analogy with lime.



not attract moisture, but absorbs carbonic acid, and becomes opaque.

*How is it distinguished from potassa and soda?*

By its possessing the power of neutralizing a much greater quantity of the different acids than either of those alkalies; in which respect it even surpasses magnesia. It is also distinguished by forming sparingly soluble salts with carbonic and phosphoric acids, and by the circumstance of the chloride of lithium being highly deliquescent, and dissolving freely in strong alcohol.\*

*We have now noticed all THE ALKALIES: Say how many there are?*

FOUR; three of which are called fixed alkalies, viz. POTASSA, SODA, and LITHIA; and one the volatile alkali, which is AMMONIA.†

*What are the CHARACTERISTIC PROPERTIES of the ALKALIES?*

They change the purple colour of many vegetables to a green, the reds to a purple, and the yellows to a brown;‡ and they possess this power over vegetable colours, *after* being

\* When lithia is fused in platinum foil, it attacks that metal, and leaves a dull yellow trace round the spot on which it lay. *Berzelius on the Blow-pipe.*

† Ammonia being a compound of hydrogen and nitrogen has already been treated of.

Besides the alkalies noticed above, it has been lately discovered that there are *vegetable alkalies*, which are found in stavesacre, henbane, opium, nuxvomica, Peruvian bark, &c. These are termed respectively delphia, hyosciana, morphia, strychnia, quinia, and cinchonia, &c. The German chemists call them *alkaloids*; but they are generally considered true vegetable alkalies, and will be treated of in the chapter on *Vegetable Chemistry*.

‡ If the purple have been reddened by acid, alkalies restore the purple.



saturated with carbonic acid, by which criterion they are distinguished from the alkaline earths. They combine with water in every proportion, and continue to be soluble in water when neutralized with carbonic acid; while the alkaline earths thus become insoluble.\*

*We shall presently notice the Earths: Pray how many earths are there?*

NINE. Four of these are called *alkaline earths*, namely, LIME, BARYTES, or BARYTA, STRONTIA, and MAGNESIA. The remaining five are termed *earths proper*; they are ALUMINA or clay, SILICA, GLUCINA, ZIRCONIA, and YTTRIA.

*Is there not a metal called CALCIUM?*

Yes. It is the base of lime, and was discovered by Sir H. Davy.

*How is this metal obtained?*

Hitherto it has only been obtained in a very minute quantity, but sufficient for demonstrating its existence. If lime or its sulphate be negatively electrized in contact with mercury, an amalgam will be obtained, which will yield a white metal by distillation—this is calcium.

*What are the distinguishing CHARACTERISTICS OF THIS METAL?*

Its properties are but little known. It has so great an affinity for oxygen, that if it be only

\* As we have already stated, when treating of the alkalies separately, they possess in addition to the above properties, an acrid and urinous taste; are powerful solvents or corrosives of animal matter, with which, as well as with fat oils in general, they combine so as to produce neutrality; are decomposed, or volatilized, at a strong red heat; and combine largely with alcohol.



exposed to the air, and gently heated, it burns by combining with the oxygen of the air, and becomes lime.\*

*Does CALCIUM combine WITH OXYGEN in any other proportion than that forming lime?*

Yes. Oxygen and lime combine to form what is called deutoxide of calcium.†

*Is lime met with in nature in a pure state?*

No. It is always met with in combination with some other body.

*With what is it most commonly found combined?*

With carbonic acid, forming a variety of carbonates of lime, known under the forms of marble, Iceland spar, chalk, common lime-stone, &c.‡

*Is lime obtained equally pure from these different forms of its carbonate?*

It may be obtained most pure from Iceland spar or from perfectly white marble—That which is brought from Carrara is held in the highest estimation by chemists.

\* Lime is a metallic oxide, consisting of

1 atom calcium = 20

1 atom oxygen = 8

—  
28

† The deutoxide or peroxide of calcium, according to the statement of Thenard, consists of

1 atom calcium = 20

2 atoms oxygen = 16

—  
36

This compound is formed by conducting dry oxygen gas over pure lime at a red heat.

‡ For a description of the several varieties of carbonate of lime, see *Carbonates*, in another part of this work.



*Lime then of the kind used for building is not quite pure?*

No. It serves very well for ordinary purposes, but the chemist requires to have every body in its purest form.

*How is lime separated from its carbonate?*

By the action of heat. In the case of lime employed for building, it is obtained by burning or calcining common lime-stone in kilns, by which process the carbonic acid is driven off in a gaseous state.

*But when lime in a purer state is required how is it obtained?*

Let a little white marble or Iceland spar be put into a crucible, and submitted to the action of heat for several hours; by this method the carbonic acid is driven off as before. Lime in a very pure state may also be obtained by calcining oyster shells, which consist of carbonate of lime with animal matter—The latter being also separated by heat.\*

*What are the principal properties of lime?*

It is of a white colour; it is caustic and alkaline, turning vegetable blues green, and uniting with acids to form a variety of salts. Its specific gravity is 2.3. It is extremely infusible,† and

\* If lime of a still greater degree of purity be required, let white marble be dissolved in muriatic acid, and to the solution add carbonate of ammonia in solution, a precipitate of carbonate of lime will be obtained which must be well washed, and then submitted, as above, to the action of heat in a crucible.

† Lime fuses with difficulty even before the oxy-hydrogen blow-pipe, or the Voltaic flame. Although so infusible itself, it has the property of facilitating the fusion of most earthy bodies: it is, therefore, frequently employed as a flux in several processes, such as the reduction of metals from their ores.



very phosphorescent when heated strongly to redness.

*But does not some particular action take place if we add water to fresh burnt lime?*

Yes; this constitutes what is termed *slaking*.

*In what does this process consist?*

In the solidification of part of the water poured upon the lime.

*Water in a solid state is ice: is slaked lime then ice and lime?*

Such a question naturally arises, and perhaps the best way of solving it, is to describe more particularly the nature of the action which takes place during the process. Water to exist in a liquid state is combined with a considerable portion of latent heat; when poured upon lime, the affinity between water and lime is greater than between water and its latent heat, so that giving up the heat necessary to its liquidity, it must necessarily remain in a solid state with the lime.\*

*How is water thus solidified to be described as differing from ice?*

Bodies containing water in this state are called *hydrates*. A *hydrate* may be defined a body containing water in a solid form, and in a definite proportion.†

\* The heat which is disengaged during the slaking of lime may be shown by pouring water on fresh burnt lime in a saucer, and putting thereon a small bit of phosphorus when the action has commenced: the phosphorus takes fire.

† Water combines with a number of bodies forming *hydrates*. In some of these it is retained so forcibly as not to be given up on the application of an intense heat, while from others it is separated by a red heat. The hydrates of lime and sulphur are readily decomposed by heat, while those of potassa, baryta, and strontia, remain permanent under its action.



*By the term definite proportion, I am then to understand that the water is chemically combined with the lime?*

Certainly.

*To what purposes is hydrate of lime applied?*

It is used for making mortar for building, and it is the best form of keeping lime in the laboratory, for the different purposes for which it may be required.\*

\* If quick-lime, in its perfectly dry form, be put in glass stoppered bottles, it almost constantly breaks them, on account of its swelling, from the moisture which it attracts from the atmosphere, when the bottle is occasionally opened.

The most important applications of lime are to agriculture and building. Quick-lime, in its pure state, whether in powder or dissolved in water, is injurious to plants. Grass is killed by watering it with lime water. But lime in its state of combination with carbonic acid, is an useful ingredient in soils. Calcareous earth is found in the ashes of the greater number of plants; and exposed to the air, lime cannot long continue caustic, but soon becomes united to carbonic acid.

When lime, whether freshly burnt or slacked, is mixed with any moist fibrous vegetable matter, there is a strong action between the lime and the vegetable matter, and they form together a kind of compost, of which a part is usually soluble in water. By this kind of operation, lime renders matter which was before comparatively inert, nutritive; and as charcoal and oxygen abound in all vegetable matters, it becomes at the same time converted into carbonate of lime.

Mild lime, powdered limestone, marles, or chalks, have no action of this kind upon vegetable matter: by their action they prevent the too rapid decomposition of substances already dissolved; but they have no tendency to form soluble matters.

It is obvious from these circumstances, that the operation of quick lime, and marle or chalk, depends upon principles altogether different. Quick lime, in the act of becoming mild, prepares soluble out of insoluble matter.

It is upon this circumstance that the operation of lime in the preparation for wheat crops depends; and its efficacy in fertilizing parts, and in bringing into a state of cultivation all soils abounding in hard roots or dry fibres or inert vegetable matter.

The solution of the question, whether, quick lime ought to be applied to a soil, depends upon the quantity of inert vegetable matter that it contains. The solution of the question, whether marle, mild lime, or



*Does not lime, when made into mortar, undergo some change during its exposure to air?*

Yes; it abstracts carbonic acid from the atmosphere, and becomes carbonate of lime, and is in that state more firm and compact.\*

*If water and lime have so great an affinity for each other, will not water dissolve lime very readily?*

By no means; for, on the contrary, lime is dissolved very sparingly by water; and what is singular, cold water will dissolve more lime than hot water.†

powdered lime-stone, ought to be applied, depends upon the quantity of calcareous matter already in the soil. All soils are improved by mild lime, and ultimately by quick lime, which do not effervesce with acids, and sands more than clays.

The bases of all cements that are used for works which are to be covered with water, must be formed from *hydrate of lime*. Puzzolana, a decomposed lava, is mixed with this hydrate to form such cements. Mr. Smeaton, in the construction of the Eddystone light-house, used a cement composed of equal parts by weight of slacked lime and puzzolana.

\* It is astonishing that lime in the middle of walls several feet in thickness is found in the state of carbonate, although when placed there in the state of mortar, it must have been nearly pure lime, as regards its combination with carbonic acid. Mr. Maugham analyzed mortar which had been for centuries in the walls of St. Catherine's Church, lately pulled down to make room for the new docks, and the lime which was contained in it was in the form of a perfect carbonate.

† Lime is very sparingly soluble in water, namely, in the proportion of about 1 to 700; according to Thomson, 1 to 758; to Davy, 1 to 450; and to Dalton, at 60° Fahrenheit, 1 to 778. From a wine pint of lime water prepared at 60° Fahr. Mr. R. Phillips precipitated by carbonate of ammonia 17.3 grains of carbonate, equivalent to 9.7 lime. And as a wine pint of this lime water weighs about 7300 grains, it follows that water at 60° Fahr. takes up about  $\frac{1}{752}$  of its weight of that earth. The experiments of Mr. Dalton tend to establish a curious fact respecting the solubility of lime, namely, that it dissolves more plentifully in cold than in hot water. He has given the following table, the first column of which expresses the temperature of the water; the second, the number of grains of water required to take up one grain of lime; and the third, the number required to dissolve one grain of hydrate of lime.



*Is lime water of any particular use?*

Yes. It is used for medicinal purposes, and is employed by chemists as a test for detecting carbonic acid uncombined with a base, or combined in excess.\* It is also a test of corrosive sublimate, and of white arsenic.†

Temperature.	Grains of water that dissolve		Grains of water that dissolve	
	1 grain of lime.		1 grain of hydrate.	
60°.....	778	.....	584	
130°.....	972	.....	720	
212°.....	1270	.....	952	

At the freezing point, or nearly so, Mr. Dalton thinks it probable that water would take up nearly twice as much lime as is dissolved by boiling water. This inference has been confirmed by Mr. R. Phillips, who, after satisfying himself of the correctness of Mr. Dalton's statement of the composition of lime water prepared at 212°, determined by experiment that water at, or near 32° Fahr. dissolved  $\frac{1}{6.50}$  of its weight of lime, or as nearly double as possible. He found, also, that the solution prepared at this temperature, when heated to ebullition in a glass vessel, from which a long tube issued to allow the escape of steam, and to prevent the access of carbonic acid, deposited small white particles of lime. These separated in such quantity, that though only  $\frac{1}{13}$  of the solution was evaporated, the proportion of lime was reduced to  $\frac{1}{50.00}$ . The cause of this crystallization Mr. Phillips supposes to be the influence of heat in increasing the aggregative affinity of the lime; but it is probable that the heat may also operate in diminishing the affinity of water for lime, (*See Ann. of Philosophy*, N. S. vol. i. p. 107).—*Henry's Chemistry*.

\* Lime has so great an affinity for carbonic acid, that if lime water be exposed to the atmosphere, it abstracts carbonic acid therefrom, and the surface of the solution is covered with a pellicle of carbonate of lime. The solution should therefore be kept in closely stopped bottles, and they should always be filled to the stopper.

As already observed, the delicacy of lime water, as a test for carbonic acid, is shown by blowing the air from the lungs through an ale glass of lime water by means of a glass tube.

† Lime water produces, with solution of corrosive sublimate, either a yellow or a brick-dust coloured precipitate, according to the quantity added; the precipitate is peroxide of mercury. Calomel shaken with lime water gives a black precipitate, which is the protoxide of mercury.

When added in excess to solutions containing white arsenic, it forms a white precipitate of arsenite of lime. Arsenite of lime is soluble in excess of the arsenious solution, and it may be farther observed, that it is



*Is lime a volatile body?*

Not at all.

*Then whence proceeds the strong smell produced during the slaking of lime?*

Part of the water employed in the slaking of lime is driven off in vapour by the high temperature produced by the solidification of the other part, and this vapour carries up with it mechanically small particles of lime, occasioning apparent volatility.

*What acid has the greatest affinity for lime?*

The oxalic, and on this account the oxalates of ammonia and potash are employed for detecting the presence of lime.\*

*Does CALCIUM combine WITH CHLORINE?*

Yes, and forms a compound called *chloride of calcium*.

*How is the combination effected?*

By heating lime in chlorine gas: the oxygen of the lime is set free. It may also be obtained by dissolving marble in muriatic acid, and evaporating the solution to dryness, and then exposing the dried mass to heat in close vessels.†

dissolved by all acids which will dissolve lime. Lime water has lost the reputation it formerly had, as a test for shewing the presence of arsenious acid; for, in mixed fluids, on account of its lightness, it is readily suspended by a variety of substances.—*Accum's Tests improved by Maugham.*

\* If a little solution of oxalate of ammonia or potash be added to common pump water, if lime in any form be present, there will be a white precipitate of oxalate of lime. The oxalic acid is the more eligible as a test for lime, on account of the oxalate of lime being a remarkably insoluble compound. On account of the strong affinity between oxalic acid and lime, and the insolubility of the oxalate formed by their union, chalk is the best antidote that can be given when that acid has been taken as a poison: but the lime should not be given in its pure state.

† Muriates, as before remarked, with a few exceptions, become chlorides



*What are the peculiarities of this compound?*

It has a very great affinity for water, and on that account it is employed by chemists for abstracting moisture from gases, and other bodies. It deliquesces on exposure to air, and then forms what used to be formerly called *oil of lime*. Chloride of calcium is very soluble in alcohol, much heat being evolved during the solution. It becomes phosphorescent by fusion.\* If it be mixed with snow, it produces a very great degree of cold.†

*But does not chlorine combine with lime as well as with the metal calcium?*

The compound called *oxymuriate of lime*, or *bleaching powder*, and which is formed by submitting thin layers of finely powdered and recently slaked lime to the action of chlorine, is considered *chloride of lime*.

when evaporated to dryness from their solutions. The muriatic acid of the muriate is decomposed by its hydrogen uniting with the oxygen of the metallic base of the salt, water being formed and evaporated; and the chlorine of the muriatic acid uniting with the metal forms a chloride. On the other hand, if a chloride be dissolved in water, its chlorine uniting with the hydrogen of the water, forms muriatic acid, and the metallic base combining, at the same time, with the oxygen of the water, an oxide of the metal is produced, and this oxide forms with the muriatic acid a *muriate*. So that as a general rule, chlorides dissolved in water become muriates, and muriates by evaporation to dryness become chlorides.

\* The property of chloride of calcium to become phosphorescent by fusion was first observed by Homberg, and on that account it received the name of *Homberg's phosphorus*.

† For the production of cold, the crystallized muriate of lime is preferable. The muriate of lime contains 6 atoms of water of crystallization. In some of Mr. Walker's experiments on the production of cold, this substance, in the proportion of 3 parts to 2 parts of snow, sunk the thermometer from 32° to — 50°, and in the proportion of 3 parts to 1 part of snow, the thermometer fell from — 40° to — 73°; so that the great degree of cold thus produced is abundantly more than sufficient to freeze quicksilver, that body becoming a malleable solid at 40°.—See page 78.



*What are the properties of this compound?*

It is a dry white powder, which has a slight smell of chlorine, and possesses a strong taste. Water dissolves it partially, and the solution thus obtained contains chlorine and lime, and it has the property of bleaching in a very eminent degree.\*

*Does this solution undergo any change by being exposed to the atmosphere?*

Yes. The chlorine becomes liberated, and the lime abstracts carbonic acid from the air, and carbonate of lime is formed.†

\* That part of the compound which remains undissolved by the water is hydrate of lime, containing a small portion of chlorine.—See page 147.

† When the bleaching liquid is boiled, muriatic acid is formed. Dr. Turner thinks chloric acid is also formed. The dry powder undergoes a similar change by long keeping. If a strong heat be applied to the chloride of lime it is reduced to the state of chloride of calcium, chlorine and oxygen being evolved.

The nature of this compound was first observed by Mr. Dalton (*Annals of Philos.* vol. i. 15, and ii. 6), and it has also been analyzed by Thomson, (*Annals of Philos.* xv. 401) by Welter, (*Ann. de Chim. et de Physique*, vol. viii.) and by Ure, (*Quar. Jour.* vol. xiii. 1.) The three first mentioned chemists infer from their researches that the bleaching powder is a hydrated sub-chloride or di-chloride of lime, in which 36 parts or 1 equivalent of chlorine are united with 56 parts or 2 equivalents of lime.

They are also of opinion that, on mixing this sub-chloride with water, a real chloride is dissolved, and 1 equivalent of lime separated as an insoluble powder. Dr. Ure, on the contrary, denies that the bleaching powder is a sub-chloride; and maintains, according to the result of his own analysis, that the elements of this compound do not constitute a regular atomic combination. He found that the quantity of chlorine absorbed by hydrate of lime is variable, depending not only on the pressure and degree of exposure, but on the quantity of water which is present. The following is the result of his analysis of three specimens; No. 1, being good commercial bleaching powder, No. 2, made by himself with pure proto-hydrate of lime, and No. 3, prepared by himself with lime containing more water than in No. 2.



*Are the compounds of calcium and lime with iodine of importance?*

Iodide of calcium possesses nothing of interest, and the two salts, *iodate and hydriodate* of lime, will be noticed under the classes of salts.

*What other simple non-metallic body is known to unite with calcium and with lime?*

Sulphur and phosphorus form individually with lime *sulphuret and phosphuret of lime*; but these compounds are not worthy of notice.\*

*By whom was the metal BARIUM discovered?*

By Sir H. Davy in the year 1808. He formed

	No. 1.	No. 2.	No. 3.
Chlorine .....	23 .....	40.32 .....	39.5
Lime .....	46 .....	45.40 .....	39.9
Water .....	31 .....	14.28 .....	20.6
	<hr/> 100	<hr/> 100	<hr/> 100

The experiments of Dr. Ure appear to have been made with great care, and his results seem to be entitled to equal if not greater confidence than those of the other chemists. Upon the whole it is probable, that common commercial bleaching powder consists of chloride of lime, a compound of 36 parts or 1 equivalent of chlorine, and 28 parts or 1 equivalent of lime; and that this, the essential ingredient, is mixed with variable quantities of hydrate of lime. Several methods have been proposed for estimating the value of different specimens of the chloride of lime. Perhaps the most convenient for the artist is that of Welter, which consists in ascertaining the power of the bleaching liquid to deprive a solution of indigo, of known strength, of its colour, and directions have been drawn up by Gay Lussac for enabling manufacturers to employ this method with accuracy.—(*Annals of Philos.* vol. xxiv. 218.) For analytical purposes, the best method is to decompose chloride of lime, confined in a glass tube over mercury, by means of muriatic acid. Muriate of lime is generated, and the chlorine being set free its quantity may easily be measured.—See *Turner's Elements of Chemistry*.

\* *Canton's phosphorus*, which is made by exposing a mixture of calcined oyster shells and sulphur to a red heat, as described at p. 102, is supposed to be a sulphuret of lime. This substance possesses phosphorescent properties.



carbonate of barytes into a paste with water, and then inserted a globule of mercury in a small depression made in its surface. The paste being then laid upon a platinum tray, which was connected with the positive pole of a galvanic battery of 100 double plates, the negative wire at the same time being in contact with the mercury, an amalgam was formed, which being heated in a vessel freed from air, the mercury became expelled, and barium was obtained in a pure state.\*

*What are the properties of this metal?*

It is said to be of a dark-greyish colour, having a specific gravity more than double that of water. Its lustre is not so great as that of cast iron. Its affinity for oxygen is very great, and if gently heated it burns with a deep red-coloured light, and oxide of barium or the earth barytes is the product. When thrown into water it produces a considerable degree of effervescence on account of its decomposing that fluid by uniting with its oxygen, and the hydrogen thus being liberated.

*Has it no other properties?*

It may have other properties; but from the very minute quantity in which it has been as yet obtained, they have not been investigated.

*Does its oxide, baryta or barytes, exist in a pure state in nature?*

No.

*How then do we obtain the earth barytes in a pure state?*

\* The above method of obtaining the metallic base of the earth barytes seems to have been originally suggested by Pontin and Berzelius.



If the crystals of the salt called nitrate of barytes be exposed for a long time to a fierce red-heat, the nitric acid of the salt will be expelled, and pure barytes will remain.\*

*Whence does this earth derive its name?*

From βαρύς heavy, all its salts possessing remarkable density.

*Has the existence of the pure earth been long known?*

It was discovered in 1774 by Scheele.

*What are its properties?*

Its specific gravity is about 4. It is of a grey colour, and exceedingly difficult of fusion. It has a sharp alkaline taste, and acts on vegetable blues like the alkalies, and forms salts with acids, neutralizing the strongest of them. It is insoluble in pure alcohol. It has a great affinity for water, and it unites with that body after the manner of lime, much more heat, however, being evolved; a white hydrate is formed.†

*What are the peculiarities of hydrate of barytes?*

It differs from that of lime in retaining its

\* Dr Hope obtained barytes from the carbonate by exposing it to an intense white heat in a black lead crucible. The decomposition of the carbonate will be more rapidly effected by mixing it with charcoal.

The combining proportions of the elements constituting this earth have perhaps not been very accurately determined. Dr. Thomson's estimation is most usually received in this country. He makes the earth to consist of 70 parts or one atom barium, and 8 parts or one atom oxygen, its atomic weight being consequently 78.

† Hydrate of barytes, admitting Dr. Thomson's composition of the earth to be correct, consists of 1 atom barytes = 70 and 1 atom of water = 9.



water with a greater degree of force.\* It is fusible at a red heat, and is soluble in twice its weight of boiling water, and as the solution becomes cool, crystals are deposited of a flattened hexagonal prismatic shape. These crystals which are readily fusible contain a great quantity of water.†

*Is the solution of barytes in water applied to any use?*

It is employed as a test for free or combined carbonic acid, the presence of which it determines by the production of an insoluble precipitate of carbonate of barytes. It is also a valuable test of sulphuric acid.‡

*Do oxygen and barium unite in any other proportion than that forming barytes?*

Yes. If dry oxygen gas be passed over barytes heated to redness in a glass or porcelain tube, or if barytes be heated in oxygen gas, *deutoxide* or *peroxide of barium* will be formed.§

\* The water cannot be separated from hydrate of barytes by the most intense heat of a smith's forge.

† Crystallized hydrate of barytes consists of 1 atom of barytes = 78 and 20 atoms of water = 180.

‡ The precipitate thrown down by barytic water, if carbonic acid be present, effervesces in dilute muriatic or nitric acid. The precipitate which it throws down with sulphuric acid is insoluble in water, as well as in dilute muriatic or nitric acid.

§ The following process of forming the peroxide of barium is recommended by M. Quesneville, Jun.—Introduce nitrate of barytes into a luted retort of porcelain, to which there is attached a Welter's tube of safety, terminating under an inverted jar filled with water. Apply heat gradually to the retort, and let a red heat be kept up as long as either nitric oxide or nitrogen gas is liberated. The process is to be stopped, when pure oxygen gas comes over, that being the proof of the nitrate being effectually decomposed. The peroxide of barium remaining in the retort consists, according to Thenard, of double the quantity of oxygen contained in barytes.



*Is the peroxide of barium of any particular use?*

Yes. It is this substance which Thenard used in forming the *deutoxide or peroxide of hydrogen*. (See page 174.)

*How may the salts of barytes be known?*

Those which are soluble have their bases precipitated from their solutions by the addition of an alkaline carbonate in solution; decomposition takes place, and carbonate of barytes falls down. Sulphuric acid or any of the soluble sulphates also throw down from the solution of a barytic salt, sulphate of barytes, which is a perfectly insoluble compound in water, in acids, and in alkaline solutions.

*Have the barytic salts any peculiar action on the animal system?*

Yes. The muriate has been employed medically in *very minute doses*; but the salts of this earth it should be remembered are all highly poisonous, except the sulphate, the insolubility of which renders it inert.

*But is not the carbonate also very insoluble?*

Yes. But while the sulphate is not acted upon by the fluids contained in the stomach, the carbonate becomes decomposed by them.

*Does BARIUM COMBINE WITH CHLORINE?*

Yes, forming *chloride of barium*.

*How is the compound produced?*

By heating baryta in chlorine, or by passing the gas over the earth while exposed to a red heat: the chlorine combines with the barium and



at the same time oxygen is liberated. Chloride of barium may also be obtained by exposing the crystallized muriate of barytes to a red heat.\*

*Do sulphur and barium combine?*

Yes. If sulphate of baryta be acted upon by charcoal or by hydrogen at high temperatures, a sulphuret of barium is the product.†

*Is there any-thing peculiar in this compound?*

It is of a brown colour, and dissolves in water by decomposing it, and forming *hydrosulphuret of baryta*.‡

*Do iodine and barium form a definite compound?*

An *iodide of barium* may be formed, but this, as well as *phosphuret of barium*, formed by the union of phosphorus and barium, is unimportant in its properties.§

\* The chloride of barium consists of one atom of chlorine = 36, and one atom of barium = 70. It is soluble in 5 times its weight of water at 60° Fahr., but boiling water dissolves it more readily. It is insoluble in alcohol.

† M. Berthier put into a crucible, lined with a mixture of clay and charcoal, a given weight of sulphate of baryta; the crucible being closed so as to exclude atmospheric air, it was exposed to a white heat for the space of two hours. On examining the contents, decomposition had effectually taken place, and it was found that in the formation of the sulphuret of barium the sulphate had suffered a loss equal to the amount of oxygen contained in its sulphuric acid and base, while the whole of the sulphur of the sulphuric acid was left in combination with the barium.

‡ Pure baryta may be obtained by boiling the hydrosulphuret with peroxide of copper, until the solution after being filtered does not give a dark-coloured precipitate with solution of acetate of lead. The hydrate of baryta may be separated by crystallization.

From this solution we may also obtain the principal salts of barytes by the addition of the respective acids.

§ If hydriodic acid be added to barytes and the solution evaporated, or if barytes be heated in hydriodic acid gas, water and *iodide of barium* will be generated. The union of phosphorus and barium is effected by passing



*Who discovered the metal STRONTIUM, and how is it obtained?*

It was obtained first by Sir H. Davy, in the year 1808. It is the base of the earth *Strontia*, and is procured from it in a similar manner to that which has been described for obtaining barium from barytes.

*What are its peculiarities?*

In its appearance it is very similar to barium, and, like that metal, is characterized by its great weight. If exposed to air or water it rapidly attracts oxygen, and is converted into strontia.

*Whence does the earth strontia, or strontites, take its name?*

From Strontian, a place in Scotland, where its carbonate was first found.

*Has it been long known?*

The strong resemblance in many respects between barytes and strontia, caused these two earths to be confounded with each other by analysts; but a difference between them was observed by M. Sulzer and Dr. Crawford. It was not, however, before the year 1791 that Dr. Hope, of Edinburgh, pointed out strontia as a substance entirely distinct from barytes; \* and about the same time Klaproth also proved it to be a distinct compound.

phosphorus over baryta whilst in a heated state: the action takes place with great rapidity, and *phosphuret of barium* is the result. This compound decomposes water, and the solution obtained contains *hypophosphite of baryta*.

\* Dr. Hope's experiments are related in the *Edinburgh Philosoph. Trans.* vol. iv. p. 44.



*The earth then is not found pure in its native state?*

No; but it may be obtained very readily by submitting its carbonate or nitrate to the action of heat.

*Point out the peculiarities of this earth?*

It has just been stated that in several respects it resembles barytes, namely, in being, like that earth, extremely infusible when free from water; possessing alkaline properties; slaking on the addition of water, and giving out an intense heat, and forming a white pulverulent hydrate.\* This hydrate, like that of barytes, is insoluble in alcohol but soluble in boiling water.†

*Is the solution of strontia like that of lime or barytes a test of carbonic acid?*

It acts in exactly the same manner when it meets with that acid, an insoluble carbonate of the earth being thrown down.

*Is there any other oxide of strontium, besides the earth just noticed?*

Yes. If oxygen gas be passed over pure

\* The hydrate of strontia, like that of barytes, is fusible at a red heat; but the strongest heat of a smith's forge will not compel it to yield up its water. It contains 1 atom of water to 1 atom of strontia; the combining atom of the latter is estimated, by analyses made by Thomson, Berzelius, and Stromeyer, at 52.

† As the solution cools, a crystallized hydrate is deposited; this was pointed out to be the case when the hydrate of barytes is similarly treated. The crystallized hydrate of strontia contains 12 atoms of water, and in this respect it differs from the crystallized hydrate of barytes, which contains 20 atoms of water. The crystals of strontia, according to Dalton, are soluble in 50 times their weight of water at 60° F. and twice their weight at 212° F.



strontia at a red heat, a deutoxide of strontium will be formed.\*

*Do chlorine and strontium combine?*

Yes; their combination may be effected in a manner similar to that already described for obtaining the chloride of barium.† The compound is insoluble in alcohol, but very soluble in boiling water.‡

*Is there an iodide of strontium?*

Yes; it is formed like the iodide of barium, and is like that compound, too unimportant to be dwelt upon.

*Do sulphur and strontium form any definite compound?*

If strontia and sulphur be fused in a green glass tube; or if the sulphate be exposed to a red heat with charcoal, after the manner already explained for obtaining the similar compound of sulphur and barium, a sulphuret of strontium will be the result.§

*Does phosphorus unite with strontium?*

I believe no specific compound of these two bodies has been obtained; but under the descrip-

\* The deutoxide of barium was shown to be formed in a similar manner. Another mode of procuring the deutoxide of strontium is to pour solution of strontia in water into the peroxide of hydrogen. The deutoxide, according to the statement of Thenard, is possessed of as much more oxygen as strontia.

† Chloride of strontium is composed of one atom of each of its elements.

‡ Chloride of strontium requires twice its weight of water at 60° F. for its solution.

§ Sulphuret of strontium consists of one atom of each of its elements: the salts of strontia may be prepared from its solution in the same way as the salts of baryta are prepared from the sulphuret of barium.



tion of salts we shall have to notice certain combinations of the acids of phosphorus with strontia.

*Are the various salts of strontia easily prepared?*

Very easily. They are produced by decomposing the carbonate by the several acids.

*Are they, like the salts of barytes, poisonous?*

They are not at all poisonous.

*How must I distinguish strontia and its salts?*

Alkaline carbonates, sulphuric acid, or any of the soluble sulphates, throw down precipitates from the solutions of the salts of strontia.

*But is not this also the case with the salts of baryta, and of lime?*

Yes; but the sulphates of strontia and lime are soluble, while the sulphate of barytes is the most insoluble compound known.\*

*But is there no other distinguishing feature by which strontia, or its salts, may at once be known?*

Strontia in solution in muriatic acid, affords a salt crystallizable in slender hexagonal prisms, deliquescent on being exposed to the atmosphere, and soluble in highly rectified alcohol; and if this solution, or that of any other salt of the earth in alcohol, be set on fire, it burns with a deep red coloured flame. If the salts of strontia

\* "On adding Glauber's salt in excess to a soluble salt of baryta, that base is so completely precipitated that its presence cannot be afterwards detected in the solution by any re-agent. But when a salt of strontia is thus treated, so much sulphate of strontia remains in solution that the filtered liquid yields a white precipitate with carbonate of potash or soda."—*Turner's Chemistry.*



be exposed on platinum foil to the blow-pipe flame, the flame also assumes a red colour.\*

*How is the metal MAGNESIUM obtained?*

This metal has perhaps not been obtained in a completely insulated state; but the experiments of Sir H. Davy have sufficiently demonstrated its existence.

*In what way?*

On the earth *magnesia* being negatively electrized with mercury, an amalgam was obtained which decomposed water with the formation of *magnesia*.†

\* The property which the salts of strontia have of tinging flame red has been taken advantage of by players for heightening stage effect. Thus, we see the fiend Zamiel, in the celebrated opera of *Der Freischutz*, rise enveloped in red flames, produced by the combustion of strontia. The following is one of the recipes for forming what is called the *red fire*, as employed at the theatres, Vauxhall, &c.

40 parts of nitrate or muriate of strontia, heated so as to deprive the salt of its water of crystallization,  
 13 ————— powdered sulphur,  
 5 ————— chlorate of potash,  
 4 ————— sulphuret of antimony,  
 and a small quantity of powdered charcoal.

Be careful to powder the chlorate of potash, (see the properties of *chlorate of potash* in the chapter on *Salts*;) and the other ingredients separately, after which, let the whole be mixed gently on paper by means of the hand; but they must not be pounded in a mortar.

It is sometimes found more convenient to cheat the imagination by causing his satanic majesty, or his agents, to appear in green or other coloured flames, which may be accomplished by a similar combustion of other bodies.

† In attempting to distil its amalgams, the remaining metal appeared to act upon the glass before the whole of the mercury was driven over; and in an experiment, wherein the process was stopped before the whole of the mercury had distilled over, a solid, possessing a similar whiteness and brilliancy to that characterizing the metallic bases of other earths, was the result. In water it instantly sunk, although surrounded by globules of glass, *magnesia* being produced; and by the action of the atmosphere ano-



*How many oxides are there of this metal?*

There is only one oxide known at present, and that is magnesia.

*Is this body found pure in nature?*

Yes; but *native magnesia* is a very scarce mineral.\* The pure earth may be readily separated by calcination from the carbonate.

*Is the carbonate of magnesia found native like the carbonates of lime, barytes, and strontia?*

It has been found native but not plentifully.†

*What are the properties of magnesia?*

It is white, pulverulent, has an earthy appearance, and has neither taste nor smell when perfectly pure, and is very infusible. Its specific gravity being about 2.3.

*Does it unite with water like the earths already described?*

Yes; but its affinity for water is not so great, the union being effected without the production of much caloric, and the separation of the water is easily accomplished at a red heat.‡

ther portion fell into a white powder, which was magnesia. Magnesium is, therefore, a white metal, heavier than water, and has a powerful attraction for oxygen.

\* Magnesia, in a native state, has only been found at Hoboken, in New Jersey. This mineral is of a greenish-white colour, of a lamellated and soft texture. Dr. Bruce states it to consist of 70 magnesia and 30 water, in 100 parts, which is in the proportion of 1 atom water and 1 atom magnesia, and agreeing with the analyses of Stromeyer, Berzelius, and Dr. Fyfe.

† See carbonate of magnesia under the salts.

‡ It appears that water combines with magnesia to form several compounds, but the native hydrate, above described, is the only one whose composition is known with any degree of certainty.



*But are these all the properties of this earth: has it not some action on vegetable colours?*

It is very sparingly soluble in water. According to the experiments of Dr. Fyfe, it requires 5.142 times its weight of water at 60°, and 36.000 times its weight at the boiling temperature. The solution does not act upon the colour of the violet; but the pure earth put upon moistened turmeric paper has an alkaline re-action, and it acts upon the blue colour of the violet when similarly applied, turning it green. So that this earth nearly resembles those earths which do not possess alkaline properties.

*If the pure earth be exposed to the air is it converted into a carbonate?*

When exposed to the air it abstracts water, and then carbonic acid; but not so rapidly as the earths already noticed when similarly exposed.

*Does it readily form salts with the several acids?*

Yes. These will be noticed in their proper place.

*But does its base not unite with the non-metallic substances CHLORINE, SULPHUR, IODINE, and PHOSPHORUS?*

The compounds formed by the union of magnesium, or magnesia, with these bodies, are entirely devoid of any interest, so that we shall pass them by.\*

\* Nevertheless it may be proper to notice the chloride of magnesium. This compound is obtained by passing chlorine gas over red-hot magnesia, in a porcelain tube, oxygen gas escapes, and the chloride formed consists of



*How is the character of magnesia known in solution or combination from that of other bodies?*

It is readily known from barytes, lime, and strontia, by forming, with sulphuric acid, a sulphate remarkably soluble in water. The pure alkalies, added to solutions of its salts, throw it down as a hydrate, by abstracting the acid with which it may be combined, and the carbonates of potash and soda precipitate it in the form of carbonate, but their bicarbonates, and the carbonate of ammonia do not act upon solutions containing it, without heat. Oxalate of ammonia, which is a very delicate test of lime, has only a feeble action on magnesia.\*

*To what purposes has magnesia been applied?*

It is chiefly employed in medicine,† but is not

one atom of each of its elements. It dissolves in water, and becomes a muriate.

In this place may also be noticed the chloride of magnesia, which is formed by passing chlorine gas through water in which lime is mechanically suspended, or by mixing together solutions of chloride of lime and sulphate of magnesia. The nature of this compound has not been accurately defined. It is employed in certain processes of bleaching.

\* The precipitate, when magnesia is present, is some time before it is thrown down, and it is requisite the magnesia be present in considerable quantity, whereas the smallest portion of lime is immediately affected by this test, so that by oxalate of ammonia the two earths, lime and magnesia, may be separated from each other.

† Magnesia has been extensively employed in medicine as an aperient and antacid, and it is undoubtedly of considerable service in many cases, but I have been lately led to question whether it is so valuable as has been generally supposed, for it appears to me to have, in many instances, a strong tendency to irritate the last intestine (*rectum*.) and to produce piles, and other painful symptoms. Never having met with any remark to this effect in any publication, I am induced to notice the circumstance here that it may be more fully investigated. If it has the effect of irritating the rectum, which recent occurrences lead me to believe, it certainly is a much less useful medicine than is generally imagined.



applied to the arts. The chloride of magnesia is, however, used in bleaching.—(See Note p. 147).

*Has the metal ALUMINUM been long obtained—and from what is it procured?*

From the experiments of Sir H. Davy upon the earth *alumina*, it had long been suspected that it was a metallic oxide like the earths already noticed, but M. Wöhler has recently succeeded in obtaining the metallic base in a pure state.\*

*What are the characters of aluminum?*

It is stated to be a grey powder, very similar in appearance to platinum in the powdered state,

\* The preparation of this metal depends on the property which potassium possesses of decomposing the chloride of aluminum. Decomposition is effected by the aid of a moderate increase of temperature; but the action is so violent, and accompanied with such intense disengagement of heat and light, that the process cannot be safely conducted in glass vessels. Dr. Wöhler succeeded in effecting the decomposition in a platinum crucible, retaining the cover in its place by a piece of wire. The heat developed during the action was so great, that the crucible, though but gently heated externally, suddenly became red hot. The platinum is scarcely attacked during the process; but to prevent the possibility of error from this source, the decomposition was effected in a crucible of porcelain. The potassium employed for the purpose should be quite free from carbon, and the quantity operated on at one time not exceed the size of ten peas. The heat was applied by means of a spirit lamp, and continued until the action was completed. The proportion of the materials requires to be carefully adjusted; for the potassium should be in such quantity as to prevent any chloride of aluminum from subliming during the process, but not so much as to yield an alkaline solution when the product is put into water. The matter contained in the crucible at the close of the operation is in general completely fused, and of a dark grey colour. When *quite* cold, the crucible is put into a large glass full of water, in which the saline matter is dissolved, with slight disengagement of hydrogen of an offensive odour; and a grey powder separates, which on close inspection, especially in sunshine, is found to consist solely of minute scales of metal. After being well washed with *cold* water, it is pure aluminum. The solution is neutral, and contains a quantity of alumina, owing to a combination being formed between chloride of aluminum and chloride of potassium during the action.

*Turner's Chemistry.*



when procured as explained in the note below. It is generally in small scales or spangles, which have a metallic lustre; and it sometimes is seen in small spongy masses, in which the particles adhere but slightly; these in some parts have the lustre and appearance of tin.\* It is a conductor of electricity in its fused state, but not when in the form of powder.† The heat required to fuse aluminum is greater than that which is requisite to melt cast iron. If it be heated red-hot in the open air, it burns with a bright light, and aluminous earth of a white colour, and possessing a great degree of hardness, is the product. If it be sprinkled in its powdered state in the flame of a candle, its combustion then resembles that of iron in oxygen gas; and if heated to redness in a vessel of pure oxygen gas, it burns with the emission of much light and heat.‡ If it be heated to redness in chlorine gas, it also takes fire, and chloride of aluminum is formed.

*What action has aluminum upon water?*

Water has not the power to oxidize it at common temperatures, neither does it become tarnished if allowed to remain in that fluid whilst

\* The same appearance is occasioned by pressure either on steel or in an agate mortar; the lustre of aluminum is therefore metallic.

† Dr. Wöhler observed that iron, when in the state of powder, is also a non-conductor of electricity. So that a metal may be a conductor of electricity in one form but not in another, and in these instances the power of conducting the electric fluid appears lost when the cohesive property of the metal is destroyed.

‡ The alumina which is formed by the combustion of the metal in oxygen is in part vitrified, and is of a yellowish colour, and possesses the hardness of the corundum.



evaporating; but if the water be heated to near its boiling point, oxidation of the metal begins, and hydrogen gas is slowly liberated.\* The aluminum does not, however, become much oxidized, for after long boiling, its small particles appear very little changed.

*How is this metal affected by the acids?*

Concentrated sulphuric and nitric acids do not affect it at ordinary temperatures. But with the assistance of heat, the former rapidly dissolves it, sulphurous acid gas being at the same time liberated. Dilute sulphuric and muriatic acids dissolve it, and hydrogen gas is set free.

*Is it acted upon by the alkalies?*

It is readily and effectually dissolved by even a dilute solution of potash, hydrogen gas being evolved. Soda and ammonia produce a like effect.†

*Is alumina a very common earth? ‡*

It is met with very plentifully in nature, being present in all parts of the world. It constitutes a great portion of the different clays, which are used for making bricks, pipes, and different vessels of earthenware, and it likewise enters into the composition of several oriental gems.§

\* Hydrogen gas continues to be given off long after the water has cooled, but at last the action ceases.

† The hydrogen gas is given off in consequence of the water being decomposed by its oxygen uniting with the aluminum, and forming alumina.

‡ Alumina takes its name from being the base of the salt called alum; it is sometimes called *argil* on account of its being also the base of clays.

§ The term *corundum* is applied to certain mineral substances which are found to contain the earth in nearly a pure state.

1. *Perfect corundum* occurs crystallized in six-sided prisms, transparent



*Name the principal of the varieties of clay which are employed for certain useful purposes.*

*Porcelain clay*: this is chiefly procured from the decomposition of feldspar; it contains alumina,

and colourless. Its specific gravity is about 4. When blue, it constitutes the *sapphire*; when red, the *ruby*; when yellow, the *oriental topaz*, or *chrysolite*. These gems are principally found in alluvial deposits. They are mostly procured from Ceylon and Pegu; they have also been found in France and Bohemia.

2. *Imperfect corundum*, or *adamantine spar* and *emery*, are nearly analogous in composition to the former; they contain from 3 to 5 per cent. of silica, and from 1 to 2 of oxide of iron.

3. *Spinnelle*, or *balass ruby*, is found in octohedral crystals, of a red colour. It is composed of 74.5 alumina, 15.5 silica, 3.25 magnesia, 1.5 oxide of iron, and traces of lime and oxide of chrome. The *ceylanite*, or *pleonaste*, is a variety of *spinnelle*. A variety containing oxide of zinc, is called *zinc spinelle*, or *automalite*.

4. The mineral called *wavellite*, or *hydrargillite*, is a compound of alumina, phosphoric acid, and water. It is found in Devonshire, in small radiated nodules upon clay slate. According to Berzelius, 100 parts afford

Alumina.....	35.35
Phosphoric acid .....	33.40
Fluoric acid .....	2.06
Lime .....	0.50
Oxides of iron and manganese .....	1.25
Water.....	26.80
	<hr/>
	99.36

5. The *occidental topaz*, found chiefly in Saxony, Siberia, Brazil, and Scotland, consists of alumina, silica, and fluoric acid. The *schorlous beryl*, or *pycnite*, and the *pyrophysalite*, are nearly of the same composition.

6. *Chryolite*, a rare substance, hitherto only found in Greenland, consists of alumina, soda, and fluoric acid. It is white, amorphous, and translucent.

7. A mineral, called *native alumina* is found upon the Sussex coast, near Newhaven. It is white and friable, and occurs massive and incrusting. It contains alumina and sulphate of lime.—*Brandé's Chemistry*.

The *chryolite* mentioned in the above list was brought from Greenland by a Danish Missionary. It melts like ice in the flame of a candle: it is the fluated alkaline alumina of Haüy. These very opposite results from combinations, in which the same substance predominates, ought to teach us,



silica, with sometimes traces of oxide of iron. This species is very difficult of fusion.—*Marly clay*; this kind, which is much used for making pale bricks, and for manure, consists of alumina, silica, and carbonate of lime. It is fusible at a high temperature.—*Pipe clay*, which is the sort employed for making tobacco pipes, and some kinds of white pottery, is extremely tenacious, and fuses only at very high temperatures.—*Potter's clay* is of a grey or reddish colour, becoming red on the application of heat, and fusing at a bright red heat. It is mixed with sand, and in this state it forms tiles, red bricks, and the coarser kinds of pottery.\*

that in forming a true theory of the earth, we should employ with the utmost circumspection the principles and analysis which chemistry affords.—*Geographie de Malte-Brun*.

A numerous and important class of minerals, consisting of *alumina* with *silica*, will be found noticed under the description of the latter earth.

\* The reader should bear in mind the presence of silica in these different sorts of clay. It may probably not be irrelevant to name in this place the mode of manufacturing some of the principal kinds of pottery, we therefore select the following particulars, which are taken from *Brande's Chemistry*, and *Aikin's Chemical Dictionary*.

“ The better kind of *pottery*, called in this country *Staffordshire ware*, is made of an artificial mixture of alumina and silica; the former obtained, in the form of a fine clay, from Devonshire chiefly; and the latter, consisting of chert or flint, which is heated red-hot, quenched in water, and then reduced to powder. Each material, carefully powdered and sifted, is diffused through water, mixed by measure, and brought to a due consistency by evaporation: it is then highly plastic, and formed upon the potter's wheel and lathe into various circular vessels, or moulded into other forms, which, after having been dried in a warm room, are enclosed in baked clay cases resembling band boxes, and called *seggars*: these are ranged in the kiln, so as nearly to fill it, leaving only space enough for the fuel; here the ware is kept red-hot for a considerable time, and is thus brought to the state of *biscuit*. This is afterwards *glazed*, which is done by dipping the biscuit ware into a tub containing a mixture of about 60 parts of litharge,



*What action has alumina when employed as a manure?*

10 of clay, and 20 of ground flint, diffused in water to a creamy consistence, and when taken out, enough adheres to the piece to give an uniform glazing when again heated. The pieces are then again packed up in the seggars, with small bits of pottery interposed between each, and fixed in a kiln as before. The glazing mixture fuses at a very moderate heat, and gives an uniform glossy coating, which finishes the process when it is intended for common white ware.

“ The patterns upon ordinary porcelain, which are chiefly in blue, in consequence of the facility of applying cobalt, are generally printed off upon paper, which is applied to the plate or other articles while in the state of biscuit, and adheres permanently to the surface when heat is properly applied.

“ The manufacture of *porcelain* is a most refined branch of the art, the materials are selected with the greatest caution, it being necessary that the compound should remain perfectly white after exposure to heat ; it is also required that it should endure a very high temperature without fusing, and at the same time acquire a semivitreous texture, and a peculiar degree of transparency and toughness. These qualities are united in some of the oriental porcelain or *china*, and in some of the old Dresden, but they are rarely found co-existent in that of modern European manufacture.

“ The colours employed in painting porcelain are the same metallic oxides enumerated for colouring glass, and in all the more delicate patterns they are laid on with a camel-hair pencil, and are generally previously mixed with a little oil of turpentine. Where several colours are used, they often require various temperatures for their perfection, in which case those that bear the highest heat are first applied, and subsequently those which are brought out at lower temperatures. This art of painting on porcelain, or in enamel, is of the most delicate description ; much experience and skill are required in it, and with every care there are frequent failures ; hence it is attended with considerable expense. The gilding of porcelain is generally performed by applying finely-divided gold mixed up with gum-water and borax ; upon the application of heat, the gum burns off, and the borax vitrifying upon the surface causes the gold firmly to adhere ; it is afterwards burnished.

“ In the manufacture of various kinds of pottery employed in the chemical laboratory, and especially in regard to *crucibles*, many difficulties occur ; and many requisites are necessary which cannot be united in the same vessel ; to the late Mr. Wedgwood we are indebted for vast improvements in this as well as in other branches of the art.

“ Crucibles composed of one part of pure clay mixed with about three parts of coarse and pure sand, slowly dried and annealed, resist a very high temperature without fusion, and generally retain metallic substances ; but



It is of use to render a dry soil retentive of moisture; but if it be added in too great a quantity, the soil instead of being improved will be rendered too stiff.

*Hitherto alumina has only been mentioned as existing in an impure state, is there not some method of obtaining it pure?*

Yes, it may be separated in a pure form from alum, a salt consisting of sulphate of alumina and potash, which will be described more fully in its proper place. After the alum has been purified from the oxide of iron which it is usually found to contain,\* it is to be dissolved in four or

where the metals are suffered to oxidize, there are few which do not act upon any earthen vessel, and some cause its rapid fusion, as the oxides of lead, bismuth, &c. Where saline fluxes are used, the best crucibles will always suffer, but platinum may often be employed in these cases, and the chemist is thus enabled to combat many difficulties which were nearly insurmountable before this metal was thus applied.

“Whenever siliceous and aluminous earths are blended, as in the mixture of clay and sand, the compound softens, and the vessel loses its shape when exposed to a long-continued white heat, and this is the case with the Hessian crucibles; consequently, the most refractory of all vessels are those made entirely of clay, coarsely-powdered burned clay being used as a substitute for the sand. Such a compound resists the action of saline fluxes longer than any other, and is therefore used for the pots in glass furnaces. A Hessian crucible lined with purer clay is rendered much more retentive; and a thin china cup or other dense porcelain resists the action of saline matters in fusion for a considerable time.

“Plumbago is a very good material for crucibles, and applicable to many purposes; when mixed with clay it forms an infusible compound, and is protected from the action of the air at high temperatures; it is well calculated for small table furnaces. Wrought-iron crucibles are used for the fusion of several metallic substances which melt at a bright red heat.”

\* Alum may be freed from the oxide of iron which it contains by repeatedly crystallizing it. Alum is always known to be uncontaminated with this substance if it dissolve in solution of pure potash without any residue.



five times its weight of boiling water, and to the solution, carbonate of potash is to be added slightly in excess; \* allow the whole to stand a short time, and then by filtration, the alumina, which is thrown down in the state of hydrate, will be separated, and is to be repeatedly washed with hot water. As some potash is retained in the aluminous precipitate, which is not capable of being separated by washing, let the precipitate be re-dissolved in dilute muriatic acid, and then add solution of carbonate or of pure ammonia; the precipitate thus obtained, on being well washed and submitted to a white heat, will afford alumina in an anhydrous state.† Other methods have also been employed for obtaining the pure earth.‡

*What are the physical and chemical properties of this earth?*

It is destitute of smell and taste; insoluble in water, though it has a very great attraction for that fluid, abstracting it from the atmosphere with great rapidity. It is less infusible than magnesia and lime. Its specific gravity is 2. It has no action on vegetable colours. The fixed alkalies dissolve it, but ammonia dissolves it only in a

\* The carbonate of potash must be added in excess to prevent any sulphuric acid being retained by the precipitate.

† It is observed by Berzelius, that ammonia cannot be used for directly separating alumina from alum, on account of the sulphate of alumina not being efficiently decomposed by it.

‡ Gay Lussac obtains pure alumina by exposing the triple sulphate of alumina and ammonia (*ammoniacal alum*) to a strong heat, which drives off the sulphuric acid and ammonia, leaving the alumina pure.



slight degree; and the alkaline carbonates do not dissolve it at all. It forms compounds with baryta, strontia, lime, and silica, and the combination may be effected either by fusion or in the humid way.\* It may be also united by fusion with the fixed alkalies. Alumina has a great affinity for colouring matter. See next chapter.

*But have you not forgotten to name the peculiarities of alumina in regard to its combining with water?*

When water has been added to it, it can never be entirely separated from it except by the application of a strong white heat, and it diminishes in volume in proportion as it parts with its water, or in proportion to the intensity of the heat applied.

*Has not some advantage been made of this property which alumina has of thus shrinking on the application of heat?*

Yes, on this property Mr. Wedgewood has constructed a *pyrometer*, the form and use of which has already been explained.†

*From what has just been said, it appears that alumina cannot be readily separated from water?*

No. It has so great an affinity for that fluid, that chemists have even remarked that it cannot be placed on the scale of a balance without

\* When the union takes place by fusion, a green or bluish coloured mass is the result; when in the humid way, two compounds are obtained. One contains an excess of alumina, and is in the state of an insoluble powder; the other containing an excess of alkaline earth remains in solution.

† See page 68.



acquiring weight by the rapid abstraction of moisture from the atmosphere.\*

*You have not named the combining proportion or atomic weight of this earth?*

There is some difference of opinion regarding its combining proportion; but its number at present is considered as 18, that number having constantly resulted in a series of experiments instituted by Dr. Thomson.

*How is this earth detected?*

By being precipitated by pure alkalies, and by the precipitate being re-dissolved when the alkali is added in excess; and, as has been already observed, the alkaline carbonates, and solution of pure ammonia, separate it from its salts in the form of a hydrate.

*Do chlorine and aluminum form a definite compound?*

Yes, the *chloride of aluminum*, which was first discovered by Professor Oersted. He obtained it by passing dry chlorine gas over a mixture of alumina and charcoal heated to redness.†

\* It has been remarked by Berzelius, (*Annales de Chimie*) that 100 parts after ignition, gained  $15\frac{1}{2}$  from a dry atmosphere, and 33 from a moist atmosphere; and that for full saturation, 100 grains of alumina require 54 of water.

It appears that this earth forms hydrates containing water in different proportions.

† After acting on this compound with an amalgam of potassium, and expelling the mercury by heat, a metallic substance resulted, which the Professor believed to be aluminum, but as he had not time to investigate the subject further, he advised Dr. Wöhler to pursue the inquiry. Dr. Wöhler was obliged to depart from the method pointed out by Professor Oersted, but his manner of obtaining aluminum has already been shown.

The chloride of aluminum has been obtained by Dr. Wöhler as follows:



*What are the properties of this compound?*

It is of a pale greenish-yellow colour, of a lamellated crystalline texture, having the appearance of talc. It fumes slightly on exposure to air, emitting an odour of muriatic acid gas, and deliquesces forming a clear liquid. It decomposes water very rapidly when thrown into it, occasioning a hissing noise, and a degree of heat is evolved which is sufficient to cause the water to boil, if there be only a small quantity of that fluid. It is volatile a little above  $212^{\circ}$ , and fuses at about the same temperature.

*Does aluminum combine with any of the other non-metallic substances?*

It combines with sulphur forming *sulphuret of aluminum*; with phosphorus forming *phosphuret of aluminum*; and with selenium forming *seleniuret of aluminum*. It is not necessary to enter into a minute description of these several compounds.

*Is there any thing else to observe respecting alumina?*

Not in this place, but under the salts, alum will be particularly noticed as being applicable to several processes in the arts.

He mixed the hydrate of alumina, as obtained from solution of alum, when dry, with powdered charcoal, sugar, and oil, to the consistence of a thick paste; this he heated in a covered crucible till the whole of the organic substance was expelled. The alumina thus became intimately mixed with finely-divided charcoal, and while still hot was placed in a tube of porcelain, in a convenient furnace. The atmospheric air being expelled from the inner part of the apparatus by means of a current of dry chlorine gas, the tube was made red hot. The chloride of aluminum was forming during an hour and a half, carbonic oxide gas being liberated at the same time. It became necessary at the end of that time to stop the process, on account of the tube being closed by the collection of the sublimed chloride of aluminum within it.



*Has SILICIUM been long obtained?*

No. Such a metal had long been from analogy supposed to exist, and to form the base of the earth *silica*.

*What reason was there for supposing that silica had a metal for its base?*

When Sir H. Davy brought the vapour of potassium into contact with pure silica heated to whiteness, he obtained a compound of silica and potassa, and diffused through this was seen the supposed metal silicium in the form of black particles, having the appearance of plumbago.

*Is not the base of the earth silica supposed to be a non-metallic body by some chemists?*

Yes; and Dr. Thomson places it with carbon and boron, and distinguishes it by the appellation of *silicon*.\*

*What is the motive for considering it a non-metallic substance?*

It has not a metallic lustre, and is a non-conductor of electricity, as would appear from the experiments which have been lately instituted by Berzelius.†

*When did Berzelius eventually succeed in obtaining silicium in a pure state?*

\* Sir. H. Davy believes the base of silica to be a non-metallic substance, resembling boron, charcoal, sulphur, and phosphorus.

† Berzelius, since the first experiments of Sir H. Davy, has succeeded in effecting the decomposition of silica, by fusing it with iron and charcoal in a blast furnace. The result was an alloy of iron and *silicium*. This alloy when acted upon by a dilute acid gave more hydrogen than the same weight of iron alone. Stromeyer afterwards repeated the process, and investigated the properties of the different alloys.



In the year 1824, by the process described below.\*

*What are the properties of this body?*

It has just been said that it is wanting of metallic lustre, and of the power of conducting electricity. It is of a dark nut-brown colour, incombustible in air, and in oxygen gas; and if it be exposed to the blow-pipe flame, it is not at all acted upon. Sulphuric, muriatic, nitric, and hydrofluoric acids have no power of oxidizing or dissolving it; but it is dissolved by a mixture of the two last mentioned acids without heat.†

*Does the earth silica exist plentifully in nature?*

\* Berzelius first procured silicium by the action of potassium on fluo-silicic acid gas; but it is more conveniently prepared from the double hydro-fluate of silica and potassa or soda, previously dried by a temperature near that of redness. In this state the compound may be regarded as a double fluoride, in which neither oxygen nor hydrogen are present; and when heated in a glass tube with potassium, this metal unites with fluorine, and silicium is separated. The heat of a spirit-lamp is sufficient for the purpose, and the decomposition takes place, accompanied with feeble detonation, before the mixture becomes red-hot. When the mass is cold the soluble parts are removed by the action of water; the first portions of which produce disengagement of hydrogen gas; owing to the presence of some siliciuret of potassium. The silicium thus procured is chemically united with a little hydrogen, and at a red heat burns vividly in oxygen gas. In order to render it quite pure, it should be first heated to redness, and then digested in dilute hydrofluoric acid to dissolve adherent particles of silica. (*Annals of Philos.* vol. xxvi. p. 116.)

† If ignited with chlorate of potash it is not altered; and with nitre it does not deflagrate before the temperature is raised so high as to decompose the acid of that salt. The oxidation in this case takes place in consequence of the affinity of the disengaged alkali for silica acting in conjunction with the attraction which oxygen has for silicium. A similar reason serves to explain why it burns vividly when brought into contact with carbonate of potassa or soda; in the latter instance, combustion takes place at a temperature below redness. When dropped upon the fused hydrates of potassa, soda, or baryta, explosion takes place from the rapidity with which hydrogen gas is evolved.



Extremely so; and is found under a variety of forms. A description of some of these different varieties is given below.\*

\* Quartz (or *hyaline quartz*) has crystallized silica for its base, and comprehends some varieties very different in their aspect to the eye of the ignorant; but the severe method of modern mineralogy, established upon chemical analysis, rejects all false classifications founded upon external appearances.

When hyaline quartz is found in round or angular grains without cohesion, having a vitreous surface, it is esteemed of no value, being nothing but *sand or gravel*, and fit to be used only in the formation of roads; if these small grains are united by a natural cement, they form siliceous quartz, (*grès quartzeux*.) When the same substance has by natural friction been fashioned into small round masses, it is raised into the rank of crystalline flints, (*cailloux cristallins*). Lastly, when hyaline quartz, in consequence of a more regular crystallization, is of uniform density, and perfectly transparent, it occupies a distinguished place in the collections of amateurs under the name of rock crystal; it ornaments our lustres; is used even in some kinds of jewellery. In Madagascar, these crystals are found in the greatest purity, and in large tables or flat layers, and this seems to confirm the truth of the reports mentioned by Herodotus and Pliny, of the abundance of crystal in Upper Ethiopia. When of a violet or purple colour, the rock crystal becomes amethyst, and is in this state highly valued, and classed among the gems. When blue, it is the sapphire, (*saphir d'eau*,) which is not so precious. When it assumes the colour of a rose, it is the ruby of Bohemia, the most valuable of all; when yellow it is the occidental topaz; in short, the crystals of this substance take the names of the different gems which they resemble in colour.

The species of quartz agate, of which concreted silica constitutes the base, and which many mineralogists still continue to form a distinct genus under the name of *silica*, contains the following among other varieties; the chalcedony, which is of a bluish or grey colour, and of an imperfect and cloudy transparency; the cornelian, which is red, and of a cherry-like semi-transparency, and sometimes of a beautiful carnation hue; and lastly the crysopræse, a stone of a delicate and clear green. They give the name of onyx to agates formed of two translucent stripes of different colours. Oriental agate is distinguished by the fineness of its composition, and by the peculiar appearance given to its interior by its various undulated laminæ.

When the quartz agate is less fine in its composition, it is used for gun-flints and mill-stones, and even for common flints. The enhydros, celebrated by Pliny, is only an eagle stone of quartz agate, containing a small quantity of water, which is perceptible through the semi-transparency of the stone. There is a variety of quartz, which floats upon the water till it has imbibed a certain quantity of that fluid.



*How is silica obtained pure?*

It may be procured sufficiently pure for most purposes, by igniting transparent pieces of rock

The noble or perfect *opal*, as it is termed, is a milky resinous quartz, exhibiting a beautiful play of colours, like those in the rainbow, and varying their shades according to the position. It is highly prized on account of this brilliant appearance, which, however, arises solely from imperfections, that is, very minute cracks or fissures with which it is filled. When divided it no longer displays this pleasing and changeable effulgence. The hydrophane, or semi-opal, becomes of a beautiful transparency when plunged in water.

*Jasper* is a quartzagate, blended with argil or clay, and a little iron, which gives it a variety of colours. It was formerly confounded with porphyry; but it is now ascertained that jasper is of a secondary formation, and has nothing in common with the primitive rocks of porphyry. In general, all quartz agates belong to the secondary earths. The beds of common silica, properly so called, namely, gun-flints, mill-stones, and common flint-stones, though inconsiderable in regard to the whole globe, present, in respect of their situation, some remarkable peculiarities. Strata of silica very often alternate with those of chalk. Hence, some naturalists have thought that they were the petrified remains of certain marine animals. In several vast regions of the globe, as, for example, Siberia, and the plains in the neighbourhood of the Caspian Sea, gun-flints, or "*silex pyromaque*," is very seldom found.

Hyaline quartz, without ever forming the entire substance of any mountain, abounds in every soil. It is one of the integral parts of most varieties of the granite rocks. It also enters, in the form of crystallized grains, into the composition of many rocks of porphyry. It forms the base of a great number of fossil micaceous rocks. Its crystals occupy the fortuitous cavities which are found in almost all the large masses of rocks. They ornament the walls or sides of such cavities, sometimes in transparent prisms of nearly a foot in diameter. Hyaline quartz forms veins frequently of a great extent, which pass through the primitive mountains; and these veins, becoming exposed, and projecting by the wearing away of the rocks in which they were imbedded, have given rise to the opinion, that there existed mountains entirely composed of quartz. There is scarcely any secondary rock, in which we do not find common, or unshapen quartz, in masses, in veins, or in crystals.

Arenaceous quartz, (*quartz arénace*,) or quartz in the form of sand, covers almost entirely the bottom of the sea. It is spread over the banks of rivers, and forms vast plains, even at a very considerable elevation above the level of the sea, as the desert of Sahara in Africa, of Kobi in Asia, and many others. This quartz is produced, at least in part, from the disintegration



crystal, and putting them in a state of ignition into water, after which they may be readily powdered.

of the primitive granite rocks. The currents of water carry it along, and when it is in very small, light, and rounded grains, even the wind transports it from one place to another. The hills thus are made to move like the waves, and a deluge of sand frequently inundates the neighbouring country.

Arenaceous quartz furnishes, by fusion, one of the most useful substances we have, namely, glass, which, being less hard than the crystals of quartz, can be made equally transparent, and is equally serviceable to our wants and to our pleasures. There it shines in walls of crystal in the palaces of the great, reflecting the charms of a hundred assembled beauties; here, in the hand of the philosopher, it discovers to us the worlds that revolve above us in the immensity of space, and the no less astonishing wonders that we tread beneath our feet.—*Malte-Brun*.

The perfectly transparent crystals of quartz met with near Bristol, and in Cornwall, are called *Bristol and Cornish diamonds*. The pebbles used as a substitute for glass in spectacles are formed from the fine crystals. They are preferable to glass in being harder and not so easily scratched.

*Brown and yellow crystals of quartz* are found in great beauty in the mountain of Cairn Gorm, in Scotland. They are improperly called topazes, and are used for seals.

*Purple quartz*, or *amethyst*, is tinged with a little iron and manganese.

*Rose quartz* derives its colour from manganese. *Prase*, or *green quartz*, contains actinolite; *chrysoprase* is tinged of a delicate apple-green by oxide of nickel. *Avanturine* is a beautiful variety of quartz, of a rich brown colour, which, from a peculiarity of texture, appears filled with bright spangles; the finest specimens are from Spain; it is often imitated. Small crystals of quartz, tinged with iron, are found in Spain, and have been termed *hyacinths of Compostella*.

*Flint, chalcedony, cornelian, onyx, sardonyx, and bloodstone, or heliotrope*, and the numerous varieties of *agates*, are principally composed of quartz with various tinging materials.

*Pitchstone*, so called from its resinous appearance, contains 73 per cent. of silica. *Obsidian*, a volcanic product, contains 78 per cent. of silica, and much resembles glass in appearance; and the different kinds of *pumice* are nearly of similar composition.—*Brande's Chemistry*.

The principal of the *silico-aluminous minerals*, that is, minerals consisting of a combination of silica with alumina, in various proportions, and with the occasional addition of the fixed alkalies or alkaline earths, and a few of the other metallic oxides are the following:—

1. *Zeolite*.—There are several varieties of this mineral. They fuse and intumesce before the blow-pipe, and mostly form gelatinous solutions in the acids.



*What are the peculiarities of this earth?*

It is perfectly white, tasteless and inodorous. It has a harsh dry feel, if rubbed between the

2. *Apophyllite* and *chabasite* are nearly of the same composition.

3. *Garnet* occurs massive, but generally crystallized in dodecaëdra. The *precious garnet* is red and transparent; the *common garnet*, red, brown, or green. The *cinnamon stone* of Ceylon is nearly of similar composition to the precious garnet, which consists of silica, alumina, oxide of iron, and lime.

4. *Melanite*, or *black garnet*.

5. *Leucite*, or *white volcanic garnet*.

6. *Vesuvian*, or *idocrase*, is brown or yellow-red, and is found crystallized in the masses of rock ejected by Vesuvius and Etna. It has also been found in the Alps and in Siberia. The Neapolitan lapidaries call it *chrysolite of Vesuvius*. It differs but little from melanite.

7. *Staurotide*, or *grenatite*, crystallizes in four and six-sided prisms.

8. *Sodalite* and *natrolite* are minerals containing a considerable portion of soda. The former has hitherto only been found in Greenland and on Vesuvius. Its colour is light green. It occurs massive and crystallized in rhomboidal dodecaëdra.

9. *Prehnite* is of a greenish colour, and radiated fracture. It occurs massive and crystallized in prisms. It is found near the Cape of Good Hope and in France and Scotland.

10. *Spodumene*, or *triphane*, is a mineral nearly allied to feldspar.—(See *Lithium*.)

11. *Scapolite* and *elaolite*, or *fettstein*, are minerals found only in Norway.

12. *Nephritic stone*, or *jade*, is found in the Alps, in China, and India. The Chinese cut this substance into figures, and it is used sometimes for the handles of cutting-instruments. In New Zealand, and other islands of the Pacific Ocean, it is used for cutting-instruments, in consequence of its hardness and toughness. Hence it has been called *axe-stone*.

13. *Schorl* and *tourmaline*. They occur in prismatic crystals of a black colour.

14. *Thallite*, *epidote*, or *pistacite*, is nearly allied to schorl. It occurs in green prismatic crystals.

15. *Axinite*, or *thumerstone*, is found crystallized in flat oblique rhombs, of a brown, bluish, or grey tint, and transparent.

16. *Cyanite* is of a blue and grey colour, translucent, and occurs massive and prismatic.

17. *Lepidolite* occurs massive, and of a purplish colour, and lamellar texture.

18. *Actinolite* is of a green colour, and generally occurs in aggregated masses of prismatic crystals.



fingers. It is infusible, even by the heat of Voltaic electricity, but Dr. Clarke succeeded in fusing it by means of the oxy-hydrogen blow-pipe, under the action of which it is more readily fusible than lime or magnesia similarly treated. It is insoluble in water: but according to Klaproth water will retain about  $\frac{1}{1000}$  of its weight of silica in solution. Berzelius also has proved that when silica in the nascent state is in contact with water, it is dissolved in a considerable quantity. It does not act upon vegetable colours. Its specific gravity is 2.66.

*Does it unite with water to form a HYDRATE?*

Yes. If the solution obtained in the manner just alluded to be gently evaporated, a bulky gelatinous hydrate is the result.\*

*What action has heat upon this hydrate?*

A very moderate degree of heat is sufficient partially to decompose it, but the whole of the

19. *Tremolite* is nearly white, fibrous, and semi-transparent.

20. *Asbestos* is a soft, fibrous, flexible mineral, of a white or greenish tint. *Amianthus*, *mountain cork*, and *mountain wood*, are varieties of asbestos.

21. *Lapis lazuli*. The blue colour of this mineral is prepared for painters under the name of *ultra-marine*.

22. *Harmotome*, *staurolite*, or *cross-stone*, occurs in small quadrangular prisms, terminated by four rhombic planes crossing each other. It is also found in single crystals. It is found at Andreasberg, in the Hartz, and at Strontian, in Scotland.

23. *Augite* is a mineral of a black or brownish-green colour, found in volcanic products, and in some basalts. *Sahlite* and *coccolite* are varieties of augite.

24. The *Datholite* has only been found in Norway.—*Ibid*.

In the above list of minerals silica is the predominating ingredient.

\* According to Dr. Thomson, silica and water combine in several proportions.



water cannot be expelled at a heat below redness.

*Does silica combine with the acids to form salts like the other earths?*

No. The only acid which acts upon silica is the hydrofluoric.

*Does it not then enter into combination with any other bodies?*

It is dissolved by solutions of the fixed alkalies, and it unites with several of the metallic oxides, thus evincing more the properties of an acid than of an earth or oxide.

*Is it placed from this circumstance with acids?*

Yes, and is called by some chemists *silicic acid*, and the compounds which are generated by its union with bases are termed *silicates*.

*Is not silica an important ingredient in GLASS?*

Glass consists of silica in combination with the fixed alkalies. If the alkali be added in excess, the silica will be dissolved, and what was formerly called *liquor silicum*, or *liquor of flints*, will be obtained instead of glass.\*

*In what way then is glass formed?*

By allowing the proportion of silica in the mixture to predominate. The proportions and

\* The *liquor silicum* abstracts carbonic acid from the atmosphere when exposed to its action, and becomes decomposed. Other acids also precipitate the silica in the state of a gelatinous hydrate by being united with the alkali of the solution. Mr. Brande observes, "This alkaline solution, after having been kept for several years, has formed small crystals of silica. I have seen in it a deposit much like chalcedony, and as hard."

If water be copiously added to the solution of silica, the latter will not be precipitated on the gradual addition of the acids, but will remain in the solution after the alkali has become neutralized.



the quality of the ingredients vary in the different kinds of glass.\*

*Are not the artificial gems, called pastes, used for beads, a kind of glass?*

Yes. This kind of glass is coloured by certain metallic oxides, and generally contains borax.

\* The exact composition of the different kinds of glass is scarcely known; the following proportions of the materials are, however, given in *Aikin's Dictionary*.

*Flint glass.* Specific gravity about 3.2.

120 parts of fine clear white sand,  
40 ——— purified pearlash,  
35 ——— litharge or minium,  
13 ——— nitre,  
a small quantity of black oxide of manganese.

*Crown glass, or best window glass.*

200 parts of soda,  
300 ——— fine sand,  
33 ——— lime,  
250 ——— ground fragments of glass.

*Green bottle glass.*

100 parts of sand,  
30 ——— coarse kelp,  
160 ——— lixiviated earth of wood-ashes,  
30 ——— fresh wood-ash,  
80 ——— brick clay,  
100 ——— fragments of glass.

*Plate glass*, invented by Abraham Thevart in 1688, was first manufactured in Paris. It may be composed of

300lbs. fine sand,  
200lbs. soda,  
30lbs. lime,  
32oz. manganese,  
3oz. cobalt azure,  
300lbs. fragments of good glass.

These materials are brought into perfect fusion, and poured upon a hot copper plate, the mass is then rolled out, annealed, and afterwards polished by grinding with sand, emery, and colcothar. The difficulty of producing a perfect plate without specks, bubbles, or waves, may easily be conceived, and this, with the risk of breakage, renders a large plate extremely expensive.



*What is ENAMEL?*

It is glass made more or less milky and opaque by adding to it oxide of tin.—(See *Tin*.) The coloured enamels are formed by the addition of metallic oxides.

*What is meant by the process of ANNEALING in the manufacture of glass?*

It consists in allowing every article to cool slowly. If this be not attended to they become remarkably brittle, and are liable to crack, and even fly to pieces on the slightest touch of any hard substance. This is shown in what are called *Rupert's Drops*. These are made by dropping green glass while in a state of fusion into water, by which means they are instantly cooled. If the thin end of one of these be broken off, they explode and fall into powder.\* *Bologna phials* are likewise made of unannealed glass, and if an angular substance, such as a small bit of flint, be dropped into them, they instantly break to pieces.

*Is not Silica also employed in the manufacture of porcelain?*

From what has already been said under alumina as respects its contracting by heat, it is evident that earth could not be applied in a pure form for the manufacture of the different varieties of earth-

\* Mr. Aikin thinks this phenomenon depends upon some permanent and strong inequality of pressure, for when they are heated so red as to be soft, and merely let cool of themselves, the property of bursting is lost, and the specific gravity of the drop increased.



enware, but by being united with silica, the disadvantage it possesses is overcome.

*Is silica an important ingredient in fertile soils?*

Yes. It renders them porous, and thus allows of the transmission of moisture, without which no soil can be fertile.

*You have not yet stated the combining proportions of the ingredients forming silica.*

Chemists are not yet perfectly agreed on the subject. Berzelius found, by careful experiment, that in the oxidation of silicium 100 parts of silica consist of 48 parts of silicium and 52 parts of oxygen. Dr. Thomson with equal care calculates the atomic weight of silica at 16. Berzelius considers silica constituted of 1 atom of silicium, and 3 atoms of oxygen. Dr. Thomson, on the other hand, states it to consist of 1 atom of each of its elements.\*

*Is there a combination of silicium and chlorine?*

Yes. *Chloride of silicium* is formed when silicium is heated in a current of chlorine gas.†

*Is silicium known to combine with any of the other simple non-metallic substances?*

\* Dr. Thomson's opinion is preferred by chemists as most compatible with the atomic weight of silica. So that if the atomic weight of that body be 16, as above stated, according to Dr. Thomson's views, the atomic weight of silicium is 8.

† Silicium heated in chlorine gas takes fire. The compound formed is at first rapidly converted into vapour, which afterwards condenses into a liquid. This liquid has a yellowish tint from the presence of uncombined chlorine. It is exceedingly limpid and volatile, and when exposed in open vessels it speedily evaporates, escaping in the form of a white vapour. When put into water it is decomposed, muriatic acid and silica being formed by the union of its elements with those of the water. The odour of the chloride of silicium is suffocating, and resembles cyanogen.



There is a *sulphuret of silicium*, which is formed by heating silicium in the vapour of sulphur; whilst the combination is taking place there is the appearance of combustion.\*

*What is the FLUOSILICIC ACID GAS?*

It is a compound, which is formed by bringing hydrofluoric acid in contact with silica or siliceous earth.

*It is on account of the strong affinity then, between the hydrofluoric acid and silica, that the former cannot be retained in glass vessels?*

Yes, and therefore metallic vessels are substituted.

*How is the fluosilicic acid gas prepared?*

The best mode of obtaining it is to mix one part of powdered fluor spar with its own weight of sand or pounded glass, and two parts of strong sulphuric acid, in a proper retort. By applying a gentle heat, the fluosilicic acid is evolved with effervescence, and it may be collected over a mercurial bath,† in glass vessels, on which it does not act.

\* Sulphuret of silicium is a white substance, of an earthy appearance, When thrown into water it decomposes that fluid, sulphuretted hydrogen, and silica being formed: the former is given off with effervescence, but the latter is very copiously dissolved. A similar change takes place when the compound is exposed to a moist atmosphere, but in dry air it remains unchanged.

† There is some difference of opinion entertained, as regards the nature of the changes which take place between the elements of the ingredients employed. If fluor spar be considered a compound of fluoric acid and lime, the formation of the fluosilicic acid may be explained on the ground of the fluoric acid of the fluate, uniting with the silica which is present. On the other hand, if fluor spar consists of fluorine and calcium, as is now almost universally admitted, the play of affinities may be explained as



*What are the properties of this gas?*

It is colourless, destructive of combustion and animal life, and produces great irritation of the lungs. It has not the power of corroding glass if it be quite free from moisture. Like muriatic acid it attracts water from the atmosphere when exposed to it, and a white cloud is thereby produced. Its specific gravity is 3.61111.

*Is it very absorbable by water?*

Yes. According to Dr. J. Davy, water takes up 365 volumes of the gas.\*

*What is its solution in water called?*

Silicated fluoric acid.

follows:—The fluoride of calcium being acted upon by the sulphuric acid, hydrofluoric acid is formed (see page 182,) and this acid acting on the silica, the two bodies are mutually decomposed, the fluorine of the acid combining with silicium of the silica, and the oxygen of the silica with the hydrogen of the acid; *fluoride of silicium* (and not *fluete of silica* as before explained) and water are the result.

\* The gas undergoes decomposition when it comes in contact with the water, and part of its silica is precipitated in the form of hydrate. The liquid contains all the hydrofluoric acid, and  $\frac{2}{3}$  of the silica originally present in the gas. It reddens litmus paper, and has a sour taste. The solution formed by fully saturating water with fluosilicic acid gas, is very acid, and gives off fumes on exposure to air. The solution is called *silicated fluoric acid*, but the term *silico hydrofluoric acid*, has been proposed as more definite. It appears to consist of 3 atoms of hydrofluoric acid and 2 atoms of silica. The *silicated fluoric acid* cannot exist without water. It does not act upon glass, but if it be evaporated in glass vessels, hydrofluoric acid is formed, and this acts upon the vessels.

A number of compounds are formed by double decomposition, or by acting on the metallic oxides, with the silicated fluoric acid. The greater part of these are soluble in water, those of potash, soda, lime, baryta, and yttria are the only ones which are sparingly soluble in that fluid. The salts thus constituted were until lately known under the term of *fluo-silicates*, silica and fluoric acid being thought to exist as a compound acid. This view of their composition is incorrect: they ought rather to be regarded as double salts, consisting of two atoms of hydrofluete of silica, and one atom of hydrofluete of some other base which may be present. These salts have a sour bitter taste, they act upon litmus paper, and at a high temperature they are decomposed, fluosilicic acid gas being liberated—*Berzelius*.



*Of what is the fluosilicic acid composed?*

It consists of one atom of fluorine and one atom of silicium ; or if considered as a compound of fluoric acid and silica, it then consists of one atom of each of these components.\*

*By whom was GLUCINUM discovered?*

The metal glucinum has never yet been obtained, but we are led to infer from analogy the existence of such a metal.†

*Of what is this supposed metal the base?*

Of the earth *glucina*. This earth was first noticed by Vauquelin, in the year 1798.

*Is this a very common earth?*

It has only been met with in three minerals, namely, in the *beryl*,‡ in which it was recognized by Vauquelin ; in the *emerald*§ of Peru,

\* Dr. Davy, and Dr. Thomson proceeded in their analysis of this body, by conducting it into a solution of ammonia ; in which case the hydrofluoric acid combined with the ammonia forming a hydrofluat of that alkali, and the silica was precipitated.

† If the earth glucina be ignited with the metal potassium, the latter is converted into potash.

‡ The *beryl*, or *aqua marina*, is found in primitive rocks in various parts of the earth ; this stone is of a pale green colour, and is possessed of much hardness. Its crystals are six-sided prisms. That brought from Siberia is esteemed the finest.

§ The *emerald*, which is chiefly brought from Peru, is of a green colour, and translucent or transparent. Its crystals are regular six-sided prisms.

The composition of these two gems, as given by Vauquelin in the *Journal des Mines*, is as follows :—

	<i>Beryl.</i>	<i>Emerald.</i>
Silica .....	68 .....	64.5
Alumina .....	15 .....	16
Glucina .....	14 .....	13
Oxide of chrome .....	— .....	3
Oxide of iron .....	1 .....	—
Lime .....	2 .....	1.5
Water .....	— .....	2
	<hr/> 100	<hr/> 100.0



and in the *euclase*,\* a very rare Peruvian mineral.

*How is glucina separated from these minerals?*

The stone is first to be reduced to a fine powder, and then fused with three times its weight of pure potash. The mass thus obtained is then dissolved in dilute muriatic acid, and the solution evaporated to dryness. The dry mass being dissolved in water, carbonate of potash is added as long as any precipitate takes place: this precipitate is dissolved in sulphuric acid, and a little sulphate of potash added, and then crystals of alum are obtained by evaporation; by which process the alumina of the gem is in great part removed. The remaining liquor contains the glucina and a small portion of alumina. The latter is thrown down by solution of carbonate of ammonia in excess, and the glucina remains dissolved by excess of carbonate, and is separated by filtration; the filtered liquor being evaporated to dryness, and a red heat being applied to the residue to drive off the carbonic acid, as well as the alkaline carbonate, glucina will be obtained.

*What are the properties of this earth?*

It is in the form of a white powder, possessing neither taste nor smell, and is perfectly insoluble in water, but forms with it a ductile paste. It

\* The composition of the *euclase* is, according to Berzelius:—

Silica .....	44.33
Alumina .....	31.83
Glucina .....	23.84
	<hr/>
	100.00



adheres to the tongue like the earth alumina. Its specific gravity is about 3. Its combining proportion, as estimated by Thomson and Berzelius, is 26.\* Vegetable colours are not acted upon by it, therefore it does not come under the denomination of an alkaline earth.† It is infusible.‡ It dissolves in the solutions of potassa and soda, but not in solution of ammonia.

*Does it unite with acids to form salts?*

Yes; and these compounds possess a sweetish taste, from which circumstance its name is derived, *γλυκύς* signifying *sweet*.

*How is glucina distinguished?*

Solutions of pure potassa or soda, if not added in excess, precipitate the earth from its salts; but added in excess, the precipitate is re-dissolved. Pure ammonia throws it down, in the form of a hydrate. A cold solution of carbonate of ammonia dissolves it; but if the solution be boiled, the earth is precipitated.§ The carbonates of soda and potassa precipitate it in the form of carbonate, by yielding it carbonic acid.

\* Glucina, from the experiments of Davy, appears to consist of

1 atom of the supposed metal glucinum = 18

1 atom of oxygen ..... = 8

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26

† Those bodies which do not act upon vegetable colours, such as glucina and the earths following, and the oxides of metals which are not acid, and which form salts with acids, after the manner of alkalies, and alkaline earths, no doubt owe their inaction to their want of solubility.

‡ Glucina does not contract or harden like alumina on the application of heat; but, like that earth, it appears to have an affinity for colouring matter.

§ This property distinguishes it from alumina, and affords a ready method of separating it from that earth.



*What is YTTRIUM?*

The supposed metallic base of the earth *yttria*.

*Has this earth been long discovered?*

It was discovered in 1794 by Professor Gado-  
lin, in a mineral obtained from the quarry of  
Ytterby, in Sweden.\*

*What are the properties of this earth?*

It is perfectly white,† and has neither taste  
nor smell, and has no action on vegetable colours.  
It is easily kept suspended in water, though per-  
fectly insoluble in that liquid. It dissolves in  
solutions of the carbonated alkalies; but is in-  
soluble in solutions of the pure alkalies. It is a  
heavy earth, its specific gravity being 4.842.

*Does it form salts with acids?*

Yes; but they have been little examined.‡

\* Ekeberg gave the mineral the name of *yttria* in 1797, and the term *Gadolinite*, from the name of its discoverer, has since been applied to it. Klaproth and Vauquelin have also confirmed the distinct nature of this earth. The following is the mode of procuring this earth, as described by Berzelius, and inserted in *Thomson's Chemistry*:—

“Pulverize the mineral and boil in repeated portions of nitro-muriatic acid; evaporate nearly to dryness, dilute with water, and filter; evaporate to dryness, ignite the residue for some hours in a close vessel, re-dissolve, and filter. To this solution add ammonia, which throws down yttria and oxide of cerium; heat the precipitate red-hot, dissolve it in nitric acid, and evaporate to dryness; dilute with 150 parts of water, and put crystals of sulphate of potash into the liquid. The crystals gradually dissolve, and, after some hours, a white precipitate appears of oxide of cerium, the whole of which must be separated by a repetition of this process. The liquor is then to be filtered, and the addition of pure ammonia forms a precipitate of yttria, which is to be washed and heated red-hot.”

A process somewhat different to the above, is described by Vauquelin in the 36th volume of the *Annales de Chimie*.

† It has, however, usually a slight tinge from being contaminated with oxide of manganese.

‡ Thomson makes the atomic weight of yttrium 42, from the results of Berzelius's analyses.



*What is ZIRCONIUM?*

The earth *zirconia* was discovered by Klaproth in the year 1789; but although, from certain experiments instituted by Sir H. Davy, it was supposed to have a metallic base, yet this base was not obtained in an uncombined state until the year 1824. Berzelius first succeeded in obtaining it.

*Where is the earth zirconia found?*

It was first found in the *zircon*, or *jargon*, a mineral of Ceylon, and it has also been obtained from the *hyacinth*, another mineral of Ceylon, and which is also met with in several parts of Europe.\*

\* MM. Dubois and Silveira have recommended the following method of obtaining pure zirconia:—Powder the zircons very fine, mix them with two parts of pure potash, and heat them red-hot in a silver crucible for an hour. Treat the substance obtained with distilled water, pour it on a filter, and wash the insoluble part well; it will be a compound of zirconia, silica, potassa, and oxide of iron. Dissolve it in muriatic acid, and evaporate to dryness, to separate the silica. Re-dissolve the muriates of zirconia and iron in water; and to separate the zirconia which adheres to the silica, wash it with weak muriatic acid, and add it to the solution. Filter the fluid, and precipitate the zirconia and iron by pure ammonia; wash the precipitates well, and then treat the hydrates with oxalic acid, boiling them well together, that the acid may act on the iron, retaining it in solution whilst an insoluble oxalate of zirconia is formed. It is then to be filtered, and the oxalate washed, until no iron can be detected in the water that passes through. The earthy oxalate is, when dry, of an opaline colour; after being well washed, it is to be decomposed by heat in a platinum crucible. Thus obtained, the zirconia is perfectly pure, but is not affected by acids. It must be re-acted on by potassa as before, and then washed until the alkali is removed. Afterwards dissolve it in muriatic acid, and precipitate by ammonia. The hydrate thrown down, when well washed, is perfectly pure, and easily soluble in acids. *Annales de Chim. et Phys.*

Zirconium is obtained by heating a mixture of potassium, and hydrofluat of zirconia and potassa, carefully dried, in a glass or iron tube, by means of a spirit lamp. The reduction is effected at a temperature below redness, and without light being emitted. The mass is then washed with boiling water,



*What are the properties of zirconia?*

It is a white insipid substance, without smell; its specific gravity is 4.3; it is insoluble in pure alkalies, but soluble in their carbonates; it is insoluble in water; when exposed to a powerful heat it fuses, and becomes of a lightish grey colour, and when cool is so hard as to strike fire with steel, and will scratch glass; it is readily dissolved by acids, which form salts that may be easily recognized from those of alumina or glucina by being precipitated by all the pure alkalies, an excess of which does not dissolve the precipitate.\*

*What are the properties of the base of this earth?*

Zirconium is in the form of a black powder, and may be boiled in water without decomposing that liquid, or without being oxidized. It is not easily acted upon by the sulphuric, muriatic, or nitro-muriatic acids; but the hydrofluoric acid readily dissolves it, hydrogen gas being at the same time evolved. When heated in the open air it takes fire at a temperature far below luminousness, burns brightly, and is converted into zirconia. There is much doubt as to its being of a metallic nature. It may be pressed out into thin shining scales of a dark grey colour, and metallic lustre; but its particles do not cohere firmly,

and afterwards digested for some time in dilute muriatic acid, and the residuum is pure zirconium. *Poggendorff's Annalen*, vol. iv.

\* The composition of zirconia has not as yet been determined. Sir H. Davy supposed it to consist of 1 atom of zirconium, and 1 atom of oxygen; and its atomic weight as deduced from Berzelius's experiments is 30 or 33.



neither does it appear capable of conducting electricity. These points require further investigation before any thing decisive can be said on the subject.\*

*Does zirconium unite with the non-metallic substances?*

Berzelius describes a compound of zirconium and sulphur, which is called *sulphuret of zirconium*; but its composition is not defined.

*How is the metal called COBALT obtained?*

By dissolving *zaffre* of commerce in muriatic acid, and passing sulphuretted hydrogen gas through the solution, by which means the arsenic of the arsenious acid, with which the cobalt is commonly combined, is precipitated in the form of sulphuret of arsenic. The liquid is to be filtered, and boiled with a little nitric acid, so as to convert the protoxide of iron present into peroxide. Carbonate of potassa is then added, and the precipitate thus obtained, which consists of peroxide of iron and carbonate of cobalt, is to be well washed with water, and then digested in a solution of oxalic acid, which will dissolve the iron, and leave the cobalt in the form of an insoluble oxalate.† On heating the oxalate in a retort, from which the atmospheric air is excluded, carbonic acid is copiously evolved, and metallic cobalt, in the form of a black powder, remains.‡

\* *Poggendorf's Annalen*, vol. iv.

† *Laugier*.

‡ *Thomson*.

Cobalt may also be obtained by fusing *zaffre* with three times its weight



*What is ZAFFRE AND SMALT?*

Zaffre is a substance which is prepared by calcining the ores of cobalt,\* by which process, sulphur and arsenic are volatilized, and the oxide of cobalt remains in an impure state, which is then mixed with three parts of sand, or finely powdered flints. By mixing zaffre with sand and potash, a blue glass is obtained by fusion, which forms, when reduced to powder, *smalt*.†

*What are the characters of cobalt?*

It is a brittle metal, of a reddish-grey colour, possessing but little metallic lustre. It is difficultly fusible; it is attracted by the magnet;‡ its specific gravity is 8.538. It is not much altered by exposure to air, but absorbs oxygen if heated in open vessels.

of black flux. It may also be procured by passing a current of dry hydrogen gas over oxide of cobalt, made red hot in a porcelain tube.

Other modes of obtaining this metal are mentioned in chemical works; but it is not necessary to enumerate them here, as those laid down above are sufficient. Cobalt in its metallic state may be purchased at a moderate price.

\* Cobalt seems to be of two formations of different ages. The white cobalt of Werner, (or grey cobalt of Haüy) is frequently found in veins in the secondary mountains of Hesse and Thuringia. The arsenical cobalt of Haüy, which Werner calls shining cobalt, exists only in the primitive rocks, and is accompanied by quartz and primitive limestone—*Malte-Brun*.

Cobalt is a constant ingredient of meteoric iron; at least Professor Stromeyer informs me that he has analyzed several varieties, in every one of which he has detected the presence of cobalt—*Dr. Turner*.

The native combinations of cobalt are the oxide, and compounds of the metal with iron, nickel, arsenic, and sulphur. It is also found combined with arsenic acid. In the white and grey cobalt ores the metal is combined with iron and with arsenic: some of the varieties are crystalized in cubes, octahedrons and dodecaëdrons. The red ore is an arseniate. The finest specimens are the produce of Saxony—*Brande*.

† Smalt is employed as a colouring substance for linen, and for colouring glass, earthenware and porcelain blue.

‡ It may be rendered permanently magnetic.



*How many oxides of cobalt are there?*

Two. The protoxide is of an ash-grey colour. It may be obtained by decomposing carbonate of cobalt, by heating it in a vessel excluded from atmospheric air.

*How is the peroxide of cobalt obtained?*

By heating the protoxide to redness, in open vessels, it absorbs oxygen from the air, and becomes the peroxide.

*Have the acids any action on the pure metal?*

It is oxidized by nitric acid, but sulphuric and muriatic acids do not readily act upon it.

*What action have the acids upon the oxides of cobalt?*

The several salts of cobalt are formed by the union of acids with the protoxide of the metal;\* but the peroxide will not unite with acids to form salts.†

*How are the two oxides known from each other?*

The protoxide is of an ash-grey colour, and is known by giving a blue tint to borax, when fused with it. Potassa throws it down, from solutions of its salts, in the form of a blue hydrate, which becomes black by absorbing oxygen from the air. Pure ammonia also precipitates it, but if that alkali be added in excess, the precipitate is

\* The muriate of cobalt is well known as a sympathetic ink. When diluted with water, and then employed as ink, the letters, which are invisible in the cold, become blue if gently heated.

† If the peroxide of cobalt be digested in muriatic acid, chlorine gas is given off, and protomuriate of cobalt is formed.

The salts of cobalt are chiefly of a pink colour.



re-dissolved. The carbonates of potassa, soda, and ammonia, precipitate it in the form of a pale pink carbonate, but the precipitate is re-dissolved by carbonate of ammonia in excess. It is not affected by sulphuretted hydrogen;\* but the alkaline hydrosulphurets produce a precipitate of black sulphuret of cobalt.

The peroxide of cobalt is black.†

*Will cobalt combine with other metals to form alloys?*

It seems to unite with most of the metals, except bismuth and zinc; but the alloys are unimportant.

*Does it combine with the non-metallic bodies?*

If cobalt be introduced in a finely powdered state into chlorine gas, it takes fire. It also unites directly with sulphur and phosphorus, but the compounds obtained possess no interesting properties, and have not been much examined.

*How long has the metal MANGANESE been known, and by whom was it discovered?*

It was first discovered by Gahn and Scheele in the year 1774.

*It is not then met with in nature in a metallic state?*

No; but the substance called in commerce *manganese*, or *black oxide of manganese*, is a very

\* Except the solution containing it be quite neutral, or it be combined with a weak acid.

† The protoxide, according to Rothoff, is composed of 29.5 parts of cobalt, and 8 parts of oxygen, so that the atomic weight of cobalt is 29.5. Dr. Thomson makes its atomic weight 26. According to Rothoff the oxygen in the protoxide and peroxide is as 1 to 15.



abundant mineral;\* and it is from this that the metal was first obtained.†

\* Manganese very often accompanies mines of iron, particularly in the secondary mountains; it is a colouring principle very extensively distributed in nature; and it is that which gives a violet hue to the crystals of fluat of lime, and to a number of the schorls.—*Malte-Brun*.

† The *manganese* of commerce is a very impure oxide of the metal, containing at times carbonate of lime, and the oxides of iron, copper and lead, and frequently baryta. It may be purified by heating it with an equal part of sulphuric acid until the vapour ceases to appear. By this process the sulphates of baryta and lead are separated from the sulphates of manganese, iron, and copper, the latter of which sulphates remain in solution. The iron and copper may be separated from the solution by passing sulphuretted hydrogen gas through it, and then concentrating it by evaporation. If spirit of wine, containing from 80 to 90 per cent. of alcohol, be then added, the solution separates into two portions, the lower of which soon deposits sulphate of manganese, from which carbonate of manganese may be obtained by double decomposition on the addition of carbonate of potassa. The carbonate of manganese thus obtained is capable of yielding all the different oxides of that metal.—*See Annals of Philos. N. S. vol. i. p. 50.*

In order to prepare a pure salt of manganese from the common peroxide of commerce, either of the following processes may be resorted to. The impure deutoxide left in the process for procuring oxygen gas from the peroxide by means of heat, is mixed with  $\frac{1}{6}$ th of its weight of charcoal in powder, and exposed to a white heat for half an hour in a covered crucible. The protoxide thus formed is to be dissolved in muriatic acid, the solution evaporated to dryness, and the residue kept for a quarter of an hour in perfect fusion, being protected as much as possible from the air. By this means the chlorides of iron, calcium, and other metals are decomposed. The fused chloride of manganese is then poured out on a clean sandstone, dissolved in water, and the solution separated from insoluble matters by filtration. If free from iron, it will give a white precipitate with ferrocyanate of potash, without any appearance of green or blue, and a flesh coloured precipitate with hydrosulphuret of ammonia. The absence of lime may be proved, or traces of it separated by oxalate of potash. The manganese is then thrown down as a white carbonate by the bi-carbonate of potash or soda; and from this salt, after being well washed, all the other salts of manganese may be prepared. The other method of forming a pure muriate was suggested by Mr. Faraday (*Quar. Journ. vol. vi.*), and consists in heating to redness a mixture of peroxide of manganese with half its weight of muriate of ammonia. Owing to the volatility of the sal ammoniac it is necessary to apply the required heat as rapidly as possible, and this is best done by projecting the mixture in small portions at a time into a crucible kept red hot. In this process the chlorine of the muriatic acid unites with the metal



*How is the metal obtained?*

It may be separated from the oxygen with which it is combined in the *black* or *peroxide*, by exposing that substance, surrounded by charcoal, in a crucible to the most intense heat of a smith's forge, and in this manner it was obtained by Gahn.\*

*What are the characters of manganese?*

It is a brittle metal, of a bluish white colour, of a bright and shining fracture, and extremely difficult of fusion.† It is not attracted by the magnet when quite pure. It has so great an affinity for oxygen that if it be exposed to the air it is converted into oxide, becoming grey, violet, brown, and eventually black. Its specific gravity is stated at 8, and 6.85.

*As manganese has so great an affinity for oxygen, does it decompose water?*

If it be put into cold water it will decompose that fluid, though the action takes place very slowly; but on the application of heat the action

of the oxide to the exclusion of every other substance, provided an excess of manganese be present. The resulting chloride is then dissolved in water, and the insoluble matters separate by filtration.—*Turner's Elements of Chemistry.*

\* Metallic manganese may be obtained from the oxide, by mixing it, after being finely powdered, with pitch; making it into a ball, and putting this into a crucible with powdered charcoal,  $\frac{1}{10}$ th of an inch thick on the sides, and  $\frac{1}{4}$ th of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed for one hour to the strongest heat that can be raised. Mr. Faraday has succeeded in obtaining metallic manganese in large globules from the triple tartrate of manganese, by heating it in a crucible in a wind furnace *per se*.

† It enters into fusion at 160° of Wedgwood.



is rapid. It will also decompose water like some of the other metals, if muriatic or sulphuric acid be present.\*

*In how many proportions does oxygen combine with manganese?*

There is much discrepancy of opinion on this point amongst chemists, not only as regards the number but the composition of such substances as have been deemed oxides of manganese. There are, however, four *distinct* compounds of oxygen and manganese; but as the *red oxide* is apparently composed of two of the others the number of perfect oxides may be reduced to three:†—namely.

	Manganese.	Oxygen.	Weight of Atom.
Protoxide . . . .	28	+ 8	= 36
Deutoxide . . . .	28	+ 12	= 40
Peroxide . . . . .	28	+ 16	= 44

*How is the peroxide obtained?*

As already remarked, it forms the native *black oxide of manganese*,‡ but it may be formed artificially by exposing the nitrate of manganese to a

\* When manganese decomposes water a protoxide of the metal is formed; and if an acid be present a protosalt is formed.

† The composition of the oxides of manganese have been much attended to by Dr. Thomson, M. Arfwedson, M. Berthier, and Dr. Turner. The results obtained by the latter will be found in the *Edinburgh Philos. Trans.* for 1828. *Philos. Mag. Annals* for July, 1828, and *Maugham's Annals of Chemical-Philosophy*, for Feb. 1829.

‡ Besides the black oxide of commerce, there is a species called *native peroxide of manganese*, which is found in Devonshire, Somersetshire, and Aberdeenshire, compact and crystallized. The crystallized varieties have a grey metallic lustre. The crystals are rhomboidal prisms, acicularly radiated.



red heat, until the whole of the nitric acid is expelled.\*

*What are the properties of this oxide?*

It is not soluble in water, and will not unite either with acids or alkalies.

*What action then have acids upon it?*

If it be boiled with sulphuric acid, there will be a sulphate of the protoxide of manganese formed, with the consequent evolution of 1 atom of oxygen gas for every atom of that compound.† If muriatic acid be boiled with it, a muriate of the protoxide will be formed, for every atom of which 1 atom of chlorine from the decomposition of the acid will be evolved.‡

*As peroxide of manganese forms an important article in commerce, to what purposes is it applied?*

It is extensively employed for procuring chlorine for the purpose of bleaching. When it is mixed in a small quantity with the substance of white glass, it contributes to its transparency, and frees it from false colours; when added in excess, the glass becomes of a red or violet colour. It is used in porcelain painting; and by mixing it with the ingredients used for forming common earthenware, it gives the vessels manufactured a black colour. It is also kept in the laboratory as a source of oxygen and chlorine gases.

\* As Dr. Turner very justly remarks, the heat required to drive off the whole of the acid, also expels part of the oxygen from the peroxide, which is formed by the process

† See page 141.

‡ See page 145.



*Do not oxygen and manganese combine to form an acid or acids; and is there not a peculiar compound called CAMELEON MINERAL, formed by manganese and some other body?*

Yes. By considering the nature of the *cameleon mineral* we shall be led to speak of the *manganeseous* and *manganesic* acids. If peroxide of manganese be mixed with an equal weight of nitrate or carbonate of potassa, and the ingredients be exposed to a red heat, a fused mass of a green colour will be obtained, which is *cameleon mineral*.

*Why is the compound so called?*

Because, by putting it in water, we obtain a green solution, which soon becomes blue, then purple, and lastly red. Afterwards the red oxide of manganese separates and is deposited, and the solution remains colourless.\*

*What reason is ascribed for these remarkable changes taking place?*

The nature of them have been explained as follows, by MM. Chevillot and Edwards.† The peroxide of manganese, on being fused with potassa, attracts oxygen from the air, and is converted into *manganesic acid*, which unites with the potassa. They suppose that the varieties of colour successively produced, are owing to the

\* If the solution be diluted, or if hot water be used, these changes take place more rapidly. The *cameleon mineral* has lately been applied on the continent to the purposes of dying and marking linen.

† *Annales de Chimie et de Physique*.



acid combining with the alkali in different proportions.

*This theory certainly appears very consistent; but how do they prove the existence of the acid alluded to?*

They obtained a *manganesiate of potassa* by evaporating the red solution rapidly. This salt is in the form of small, purple, prismatic crystals.

*Is there any thing remarkable as regards this salt?*

It affords oxygen very readily to combustible bodies, and detonates powerfully with phosphorus.

*But some mention has just been made of MANGANESEOUS ACID; how is that obtained?*

From certain inquiries which have been instituted by Dr. Forchhammer, it is supposed that the red colour is produced by the manganesic acid; but that the green colour of the solution is occasioned by quite a different acid, which has been called the *manganeseous*.\*

*As chlorine has so great an affinity for metals, I suppose it will form a definite compound with manganese?*

Yes. The chloride of manganese may be

\* In the 16th volume of the *Annals of Philosophy*, the manner in which Dr. Forchhammer succeeded in obtaining the manganesic acid is related to the following effect:—Nitrate of baryta was heated with peroxide of manganese, and manganesite of baryta was thus formed. To this salt, well washed with water, he added as much dilute sulphuric acid as was sufficient for exactly abstracting the whole of its base. By this method, the manganeseous acid was set free, and instantly converted into manganesic acid and deutoxide of manganese; the former dissolving in the water, afforded a beautiful red solution. From the analyses of these compounds, Dr. Forchhammer states as his opinion, that the manganeseous acid contains 3 atoms of oxygen, and the manganesic 4 to 1 atom of manganese.



formed by burning the metal in chlorine, or by exposing the residue, obtained by slowly evaporating a solution of muriate of manganese to dryness, to a red heat in a glass tube, while muriatic acid gas is passed through it.\*

*What are the properties of this compound?*

It is fused with facility at a red heat, and on cooling a lamellated pink coloured substance remains. It is deliquescent, and as it dissolves in water, muriate of manganese is formed, much heat at the same time being liberated.†

*But is there not another compound of chlorine and manganese besides the one just described?*

Yes, another chloride of manganese has lately been discovered by M. Dumas.‡

*Is there any thing remarkable in its nature?*

It is distinguished by its volatility. When first formed it is a copper coloured vapour; but by being passed through a glass tube cooled to  $5^{\circ}$  or  $-4^{\circ}$  F. it condenses into a greenish brown coloured liquid.§

\* The heat of a spirit lamp will be sufficient.

† Chloride of manganese consists of one atom of each of its elements.

‡ The new chloride is directed to be obtained as follows:—Put a solution of manganic acid into strong sulphuric acid, and then add fused sea-salt; muriatic acid thus becomes formed, and mutual decomposition takes place between it and the manganic acid. Water and perchloride of manganese are generated, the latter escaping as vapour. The best way is to form the common green mineral, and then to convert it into red by the addition of sulphuric acid. The solution leaves a residue of sulphate and manganate of potassa by evaporation; and this mixture, by the addition of strong sulphuric acid, yields a solution of manganic acid, to which small fragments of sea-salt are to be added, as long as any coloured vapour is given off.

§ If formed in a capacious tube, its vapour displaces the air until it at last fills the tube. If it be then poured into a large flask, the sides of which



*Is manganese known to unite with any other simple non-metallic body?*

It combines with sulphur, and M. Dumas and Dr. Wöhler have lately observed the combination of manganese with fluorine.

*How is the sulphuret obtained?*

According to Berthier, by igniting the sulphate with  $\frac{1}{6}$ th of its weight of charcoal powder. Arfwedson directs it to be made by acting on the protosulphate of the metal, at a red heat, with sulphuretted hydrogen.\*

*How is the FLUORIDE procured, and what are its properties?*

M. Dumas and Dr. Wöhler's method of forming it will be seen below.† It is a vapour of a greenish yellow colour, deeper than that of chlorine. If it be mixed with atmospheric air it immediately becomes of a beautiful purple-red colour: it also gives the same tint to water when taken up by that fluid, it being rapidly absorbed

are damp, its colour will become changed the instant it comes in contact with the moisture, a dense smoke of a beautiful rose tint appears, and muriatic and manganetic acids are formed. This new chloride is, therefore, evidently equivalent to manganetic acid; or, in other words, when its chlorine combines with hydrogen, the oxygen necessary to form water with that hydrogen is exactly sufficient to form manganetic acid with the manganese, so that it is supposed to consist of

$$\begin{array}{rcl} 1 \text{ atom manganese} & = & 28 \\ 4 \text{ atoms chlorine} & = & 144 \\ \hline & & 172 \end{array}$$

\* Sulphuret of manganese is met with native in Cornwall, and at Nagyag in Transylvania.

† It is best obtained by mixing common mineral cameleon with half its weight of fluor-spar, and afterwards decomposing the mixture in a platinum vessel by fuming sulphuric acid. The vapour thus liberated has the properties enumerated in the text.



by water. It acts immediately on glass, and fluosilicic acid gas is formed, and a brown matter at the same time deposited, which becomes of a deep purple-red tint when water is added.\* Its acting so powerfully on glass prevents its other properties from being properly ascertained.

*In what state does nature present us with ZINC?*

In the form of oxide or sulphuret.†

*Is SPELTRE, the zinc of commerce, the metal in a pure state? ‡*

No. But pure zinc may be obtained from it, by dissolving it in dilute sulphuric acid, and immersing a plate of zinc in the solution for some hours; by this mode of proceeding, any foreign metals which may happen to be present become precipitated. The solution is then to be filtered, and decomposed by carbonate of potassa, and

\* It would appear that on being mixed with water, that fluid, and the fluoride of manganese, are both decomposed, and hydrofluoric and manganic acids are generated and dissolved. The change which takes place when the vapour is exposed to atmospheric air may be similarly explained, on account of the moisture which is then present. Its action depends upon fluosilicic acid gas being produced, and anhydrous manganic acid being deposited.

This new compound is supposed to consist of 1 atom of manganese and 4 atoms of fluorine.

† There are mines of zinc in Alsace, in Normandy, near Aix-la-Chapelle, in Brigshaw, in Carinthia, in Somersetshire, and in many other places. Calamine, the native carbonate of zinc, according to Werner, is not found in primitive rocks. It often occurs sulphuretted, and then the vulgar name of it is Pseudo-galena, or blende. This mineral is scattered over Sweden, Norway, Saxony, and Bohemia, and we may say almost everywhere. It generally accompanies galena, or sulphuret of lead. It is often mixed with iron, gold, and silver. The metal that is brought from India, under the name of *teutenag*, is, according to Bergman, zinc in a state of purity.—*Malte-Brun*.

‡ Speltre is obtained either from calamine, or from the native sulphuret called by mineralogists *zinc blende*



the precipitate afterwards ignited with charcoal in an iron or earthen retort; this will separate the oxygen from the oxide and leave the pure metal.\*

*What are the distinguishing properties of zinc?*

It is a bluish-white metal, of a lamellated texture. Its specific gravity is about 7. It is a hard brittle metal. Its brittleness varies with its temperature, for it possesses this property both at high and low temperatures; but at a medium temperature of about 210° to 300° F. it is malleable and ductile, so that it may be formed into very thin sheets.† It fuses at 680° F. and assumes a regular crystalline form on cooling.

*What action have air and moisture upon it?*

They do not much affect it at ordinary temperatures; but if fused in open vessels it absorbs oxygen and is changed into oxide, and if the vapour of water be brought in contact with it when ignited, it decomposes that fluid very rapidly, and become oxidized as before.‡

*How many oxides of zinc are there?*

\* Zinc may likewise be freed from its impurities by distillation in an earthen retort, the beak of which should terminate in a receiver full of water. A white heat will be requisite to carry on the process.

Its impurities are lead, copper, iron, traces of arsenic and manganese, and a small quantity of plumbago. When the metal is dissolved in dilute sulphuric acid, these remain in the form of a black powder.

† It is considered as a connecting medium between the ductile metals and those which are not so.

‡ When air is admitted to zinc after it has been brought to a white heat, it burns with a most dazzling splendour, almost more than the eye can support. This property seems to distinguish zinc from other metals and combustible bodies.



Only one. It consists of 1 atom of oxygen and 1 atom of zinc.\* It is formed by burning the metal in contact with air or oxygen gas. The oxide thus formed was formerly called *flowers of zinc*, *pompholiæ nihil album*, and *philosopher's wool*; but as thus procured it contains particles of the metal, which seem to be carried up with it mechanically as it sublimes, on which account it is gritty and impure.

*Which is the best mode of obtaining it in a purer state?*

By precipitating it from the sulphate of zinc in solution, by means of ammonia.†

*Is there no precaution to be observed in thus decomposing the sulphate?*

We must be cautious not to add the ammonia in excess, because it would re-dissolve the oxide which is at first thrown down.

*What are the characters of the oxide of zinc?*

It is without taste or smell, and white at common temperatures, but it becomes yellow on being heated to low redness; on cooling it again becomes gradually white. It remains permanent in the fire, not being capable of sublimation when once deposited after its formation by heat. It is not soluble in water.

*Of what use is the oxide of zinc?*

It is employed in medicine as a tonic, and is

\* The atomic weight of zinc is 34.

† Sulphate of zinc consists of 1 atom sulphuric acid and 1 atom of oxide of zinc, on adding the ammonia it abstracts the sulphuric acid, and the oxide of zinc falls down.



used for painting in oil or water colours, and forms the base of the salts of zinc.

*Is the pure metal applied to any useful purpose?*

It forms alloys with other metals, of which brass, made by uniting it in certain proportions with copper, is the most useful.\* Zinc is also beginning to be applied to other purposes of utility. In a granulated form it is convenient in the laboratory for procuring hydrogen gas by acting upon it with dilute sulphuric acid.†

*What tests are usually employed for detecting the presence of zinc?*

Potassa, soda, and ammonia, throw it down in the state of oxide from its solutions, but re-dissolve it, as just explained, if added in excess. The carbonates of these alkalies precipitate it permanently from its solutions as carbonate of zinc. The hydrosulphuret of ammonia, or potash, or sulphuretted hydrogen, throws down a white precipitate.‡

*What compounds are formed by the union of zinc with the other simple non-metallic bodies?*

It forms with chlorine *chloride of zinc*,§ and

\* See page 300. Zinc forms brittle alloys with potassium and sodium, which are decomposed by air and water.

† Granulated zinc is made by pouring the metal from a ladle, while in a state of fusion, into water. It may be purchased at a copper-smith's.

‡ This precipitate, as formed by the hydrosulphuret employed, is regarded by some as a hydrosulphuret of the oxide of zinc; by others as a hydrated sulphuret of zinc. It is to be remarked, that in the case of applying sulphuretted hydrogen in an uncombined state, or in solution, that the solution containing the zinc must be perfectly neutral, as an excess of acid would prevent the action of the test.

§ The chloride is formed by heating zinc leaf in chlorine gas, or by evaporating muriate of zinc to dryness, and then exposing the mass to a red heat



with sulphur *sulphuret of zinc*.\* Its combinations with other similar bodies have not been much examined by chemists, and therefore we need not dwell upon them.

*By whom was the metal URANIUM first discovered?*

By Klaproth in 1789.

*In what mineral did he meet with it?*

In *pechblende*, a mineral which derived its name from its black colour.

*But if such a mineral was known, how did it happen that the metal in question was not earlier discovered?*

Because *pechblende*, or *pitchblende*, was always

in a glass tube. It is a fusible compound, decomposes water, and is very deliquescent, in the latter cases it becomes a muriate after the manner of chlorides in general.

\* *Sulphuret of zinc* is found native. It is called *blende*, and is known by the miners of this country under the name of *black jack*. It may be formed artificially by fusing the oxide of zinc with sulphur, by heating the sulphate of zinc with charcoal, or simply by drying the precipitate which is obtained by adding the hydrosulphurets, as above mentioned, to a solution of any of the salts of zinc. This compound is composed of 1 atom of zinc and 1 atom of sulphur.

Blende is a brittle, soft mineral, of different shades of brown and black, and is also frequently yellow and red. It is of a lamellated structure, of an adamantine lustre, and its crystals are of the rhomboidal dodecahedral form. It generally contains traces of iron and lead. This mineral being found in great plenty is one of the sources of the metal of commerce (*speltre*), to obtain which it is treated in the following manner:—after the ore has been picked and broken into small pieces, it is placed in a reverberatory furnace, and submitted to the action of a dull red heat, which drives off its sulphur. It is next washed, ground, and well mixed with about  $\frac{1}{3}$  of its weight of powdered charcoal, and the mixture is placed in large earthen pots, of a similar shape to that of oil jars, six of which are generally placed in a circular furnace. From the lower part of each pot proceeds an iron tube, which passing through the floor of the furnace, eventually terminates in water. The heat which is employed causes the metal to distil through the tube into the water beneath. It is afterwards melted and cast into cakes as we find it in the market.



considered as an ore of zinc, until Klaproth made known its real nature.\*

*How is the metal separated from the ore?*

The latter is to be heated to redness, then to be reduced to a fine powder, and digested in nitric acid diluted with three or four parts of water. In doing this, let there be more of the ore than the nitric acid will dissolve. The protoxide of uranium in the ore thus becomes changed into peroxide, and unites with the nitric acid, without the latter having scarcely any action on the oxide of iron. To separate the lead and copper from the solution, pass through it sulphuretted hydrogen gas, and then boil it to drive off the excess of sulphuretted hydrogen. Next evaporate and set it aside to crystallize; the nitrate of uranium separates in flattened four-sided prisms, which are of a beautiful lemon-yellow colour. These may be decomposed by heat, and the peroxide remaining being mixed with oil or powdered charcoal, will yield uranium in a metallic state by the application of a very intense heat.†

*What are the properties of this metal?*

As far as it has been examined it appears to be of a reddish-brown colour internally, and exter-

\* *Pechblende* consists of the protoxide of uranium and oxide of iron, and the sulphurets of copper and lead. It is erroneously described in some chemical works as containing the uranium in the state of *sulphuret*.

† Arfwedson obtained metallic uranium by conducting hydrogen gas over the protoxide of uranium submitted to the action of heat in a glass tube.



nally of a grey colour, possessing metallic lustre. It is very difficult of fusion. At ordinary temperatures it is not changed by exposure to air; but if strongly heated it takes fire, and is changed into protoxide. Its specific gravity is stated at 9.

*How many oxides of uranium are there?*

Two,\* the *protoxide* and *peroxide*.

*How are they distinguished?*

The first is of a very deep green colour, approaching to black. It is very infusible, and the highest temperatures to which it can be submitted do not reduce it. It unites with acids, and the salts thus formed are of a green colour. The peroxide is of an orange colour, and the salts which it forms with acids are of the same complexion.† It is decomposed by a strong heat, becoming protoxide. It is not easily obtained pure, on account of the affinity which it has for alkalies, as explained below.

*Are the oxides of uranium capable of being appropriated to any particular use?*

\* Arfwedson and Berzelius make the atomic weight of uranium 216, and its oxides are stated to contain 1 and  $1\frac{1}{2}$  of oxygen to 1 of base.

Dr. Thomson fixes the atomic weight of uranium at 208, and considers the protoxide to contain 1 atom, and the peroxide 2 atoms of oxygen to 1 atom of uranium. The opinion of Dr. Thomson is perhaps nearest the truth.

† Arfwedson has observed that this oxide not only unites with acids to form salts, but also with alkalies. Pure alkalies added to its acid solutions throw it down as a hydrate, but a portion of the alkali remains in combination with it. The alkaline carbonates precipitate it; but added in excess, (especially the carbonate of ammonia,) it is re-dissolved. Sulphuretted hydrogen does not affect its solutions; but ferrocyanate of potash throws down a brownish red precipitate, which is peculiarly characteristic.



Yes. The protoxide is used for giving a black, and the peroxide an orange colour to china.

*From what was CERIUM first obtained? \**

From a mineral found at Bastnas in Sweden, which was considered an ore of tungsten. It has also been discovered in a mineral from Greenland, now known by the name of *Allanite*, in honour of Mr. T. Allen, of Edinburgh, who first recognized it as a peculiar species.†

*Is the metal readily obtained in a pure state?*

No. It has only been procured by Vauquelin, (in his attempts to reduce the oxide obtained from the mineral,) in very minute quantities, the globules not exceeding the size of a pin's head. Mr. Children succeeded in fusing the oxide by means of his powerful Voltaic battery, and when intensely heated, it burned with a vivid flame and was partly volatilized.

*What characters has it been possible to distinguish in the metal thus obtained?*

It is said not to be acted upon by any of the simple acids; but is dissolved slowly by nitromuriatic acid. The solution obtained was reddish, and contained traces of iron. The metallic

\* *Cerium* was first discovered by Hisinger and Berzelius in 1803. Klaproth also about the same time became acquainted with it, Vauquelin has since confirmed the truth of the experiments of the original discoverers of Cerium.

It derives its name from the planet *Ceres*, which was discovered about the same time as the metal. The mineral from which it was first obtained has been since called *cerite*.

† The latter mineral, as Dr. Thomson states, contains about 40 per cent. of cerium.



globule appeared to be harder, whiter, and more brittle and scaly in its fracture than cast iron.

*How many oxides does it exhibit?*

Two. The nature of which have been particularly investigated by Hisinger and Dr. Thomson. It appears from the data arising from their experiments, that the atomic weight of the metal is 50; and that the oxygen in the two oxides is as 8 and 12, or as 1 and  $1\frac{1}{2}$ .

*What are the properties which distinguish these oxides?*

The protoxide is in form of a white powder, and is insoluble in water. The soluble salts which it forms with acids turn vegetable blues red. Air does not act upon it without heat; but when exposed to the action of the latter in open vessels, it is converted into the peroxide. The peroxide of cerium is of a reddish-brown colour. It also forms salts with several acids like the preceding.

*How are these oxides obtained?*

To obtain the oxide from the ore, the latter is to be calcined, pulverized, and dissolved in nitro-muriatic acid; the filtered solution is then treated with pure potash to neutralize any excess of acid, and afterwards precipitated by adding tartrate of potash or oxalic acid.\* The preci-

\* Laugier recommends the latter. His mode of proceeding is to evaporate the nitro-muriatic solution to perfect dryness, and after the soluble parts of the mass thus obtained, are re-dissolved in water, an excess of ammonia is to be added. The precipitate thus formed contains the oxides of cerium and iron, and is to be digested in a solution of oxalic acid, which dissolves the iron, but forms an insoluble oxalate with the cerium.



pitate dried and ignited is the peroxide of cerium.

*What are the characters of the salts of cerium?*

They are either white or yellow, according to their containing the protoxide or the peroxide. Their neutral solutions have a sweet taste. The protoxide is separated from them as a white hydrate by pure alkalies, and carbonated alkalies throw it down as a carbonate, which they redissolve if added in excess. Oxalate of ammonia precipitates oxalate of cerium. Solutions of cerium are not affected by gallic acid,\* nor by sulphuretted hydrogen.

*I suppose not much is known at present respecting the combination of cerium with other bodies?*

No. Two sulphurets have been described by Dr. Mosander.†

*What kind of a metal is TITANIUM?*

It is of a copper colour. It conducts electricity. It is met with in crystals of a cubic form, which are attracted slightly by the magnet, but it is supposed to possess the latter property in virtue of the presence of a minute quantity of iron.

*Who first proved the existence of this metal?*

\* Infusion of galls produces in muriate of cerium a yellowish precipitate, not very abundant.—*Henry's Chem.*

† These are described in *Philos. Mag. and Annals of Philos.* One of them is obtained by passing the vapour of sulphuret of carbon over carbonate of cerium at a red heat. The substance thus obtained is light, porous, of a red colour, resembling red lead. Another substance, obtained by fusing oxide of cerium at a white heat with a large excess of sulphuret of potassium, and then removing the soluble portion by water, is in small brilliant scales, of a yellow colour, resembling *aurum musivum*.



Mr. Gregor of Cornwall, whose discovery became confirmed by Klaproth, Vauquelin and Hecht, Lovitz and Lampadius, but its nature was little known before 1822, when Dr. Wollaston was led to examine some minute crystals, of the nature just described, which were met with in a slag at the bottom of a smelting furnace, at the large iron works at Merthyr Tydvil in Wales, and presented to him by Mr. Buckland. These crystals have also been found at other iron works. Their specific gravity is 5.3, and they are so extremely hard as to scratch a polished surface of rock crystal.

*But from what was titanium originally obtained?*

From *menachanite*,\* a mineral found in the bed of a small stream at Menachan in Cornwall. It is also obtained from *red schorl* or *titanite* of Hungary.†

\* The menachanite is a compound of the oxides of titanium, iron, and manganese.

† *Titanite* is nearly pure oxide of titanium. It is of a brown colour, and occurs embedded in the quartz and granite of primitive countries, and sometimes traverses rock crystals in fine hair-like filaments. In this country it occurs at Bedgellert in Caernarvonshire, and near Killin in Scotland. The finest specimens are from the vicinity of Mont Blanc and St. Gothard. The mineral known by the name of *anafase*, *octodrite*, and *oysanite*, is nearly of the same nature as titanite. It is found in Bavaria, Norway, Switzerland, and in the valley of Oysans in France. *Nigrine*, *iserine*, *retelite*, and *sphene*, are also ores of titanium.—*Brande*.

Titanium, another metal of modern discovery, is found in a state of red oxide under the form of a ferruginous stone, and united with silex and lime. Of all the new minerals, it is the one which is most interesting to physical geography: it seems to occupy the same place in relation to iron in the primordial mountains, that manganese holds in those of secondary formation. All the iron which is found in the primitive trapp of Norway, particularly near Arendal, is more or less combined with titanium.—*Matte-Brun*.



*How is the metal obtained from its ores?*

By the method described below.\*

*How many oxides are there of titanium, and how are they procured?*

There are three oxides mentioned by some chemists, their colours being blue, red, and white, while others enumerate but two.† It does not however appear that these oxides are perfect, as the white is the only one whose composition has been well ascertained.‡

*What are the properties of the white or peroxide?*

It is only quite white when perfectly pure. It is exceedingly difficult of fusion and of reduc-

\* The metal may be obtained from titanite by fusion with potassa; the fused mass, washed with water, leaves oxide of titanium, containing a little iron; it is to be dissolved in muriatic acid, and precipitated by oxalic acid.

The oxalate affords the metal by intense ignition with charcoal. It is, however, scarcely possible to obtain it in any state of agglutination: in some trials made in the Royal Institution, nothing like globules of the metal could be procured, and the crucibles were always fused.—*Brande*.

† The protoxide is of a purple colour, and supposed to exist pure in the mineral called *anatase*.

‡ The following method of obtaining the oxide was proposed by Professor Rose, of Berlin:—The mineral is first to be reduced to an exceedingly fine powder, and then fused in a platinum crucible, with three times its weight of carbonate of potash, and the resulting mass is to be washed in water to remove the excess of alkali. The grey mass which then remains consists of potash and oxide of titanium, and is to be dissolved in concentrated muriatic acid. By diluting the solution with water and boiling, the greater part of the oxide of titanium is precipitated, which is then to be collected on a filter, and well washed with very dilute muriatic acid. As thus obtained, the oxide is not quite pure, but contains a little of the oxides of iron and manganese, which exist in the mineral. The best way of separating them is to digest the precipitate, while still moist, with hydrosulphuret of ammonia, by which the oxides of iron and manganese are changed into sulphurets, without the oxide of titanium being acted upon. Dilute muriatic acid will dissolve the two sulphurets, and the oxide of titanium, after being collected on a filter and well washed, as before, is to be dried and heated to redness.—*Annales de Chimie et de Physique*.



tion; and when it has once been ignited, is no longer soluble in acids.

*Is not this oxide possessed of acid properties?*

Yes; this was observed by M. Rose. Its properties in this respect are weak. He observed that it combines readily with alkalies, and says that it is incapable of taking the part of an alkaline base, and has therefore proposed the name of *titanic acid*.\*

*What is the atomic weight of titanium, and the composition of the peroxide?*

From the experiments of Rose and Thomson, the atomic weight of the metal is stated as 32; and the peroxide or titanic acid is said to consist of 1 atom of metal and 2 atoms of oxygen.†

*How is titanium recognized in solutions containing it?*

The peroxide is precipitated from its solution in muriatic acid, merely by boiling.‡ It is thrown down by all the pure and carbonated alkalies. Infusion of galls gives an orange red precipitate in solutions of titanium. Hydrosulphurets throw down precipitates of a dirty dark-green colour, and those produced by prussiate of potash are

\* In the state of hydrate, as it is obtained from muriatic acid by boiling, or when fused with an alkali, it has a remarkable property of passing through the pores of a filter, on being washed thereon with pure water. This may be prevented by adding an acid, alkali, or salt, to the liquid containing it. The hydrofluoric acid is the only acid which will act upon it after it has been heated to redness.

† There is however some doubt about the accuracy of the composition of the peroxide.

‡ This solution is made by igniting the oxide of titanium with carbonate of potassa, previously to adding the muriatic acid in a dilute state.



grass-green. A rod of zinc being placed in the solution, a purple coloured powder is deposited, which has been supposed to be the protoxide. It is gradually changed to the state of peroxide.

*What combinations are there of titanium with other bodies besides oxygen?*

There is a *chloride of titanium* and a *sulphuret*.\*

*What metals are those which are discovered only in the ores of platinum?*

They are PALLADIUM, RHODIUM, IRIDIUM, and OSMIUM.

*How must we proceed to obtain these metals?*

By digesting platinum ore in nitro-muriatic acid: the platinum, palladium, and rhodium are dissolved, and a black powder remains, which consists of iridium and osmium.†

\* Mr. George, of Leeds, first prepared the *chloride of titanium*. He passed dry chlorine gas over metallic titanium at a red heat. Its composition as regards the atomic proportions of its components, is not accurately determined. Chloride of titanium is a transparent colourless fluid, which boils rapidly at rather more than 212° Fahr. and its vapour condenses again without change. Exposed in open vessels to air it attracts moisture, and emits dense white fumes of the odour of chlorine, but less offensive. When a few drops of water are added to it, chlorine is as rapidly disengaged as almost to amount to explosion, and the temperature is much increased. If the water is not added in excess, a solid mass remains which is deliquescent, and consequently soluble in water: the solution in every respect resembles muriate of titanium.

The latter compound mentioned in the text was discovered by M. Rose. It is prepared similarly to the sulphuret of cerium by means of the action of sulphuret of carbon on the peroxide of titanium. It exists in green coloured masses, which on the application of the slightest friction become of a dark yellow, metallic appearance. Heated in the open air it is changed into sulphurous acid and oxide of titanium. It is slowly decomposed by acids. Rose states it to be composed of 1 atom of metal and 2 atoms of sulphur.

† Any iron, lead, and copper, which may be in the ore, are also present in the solution containing the platinum, palladium, and osmium.



*How is the palladium separated from the nitro-muriatic solution?*

By adding solution of cyanuret of mercury, after having neutralized any excess of acid which may exist in the solution containing the ore, a flocculent precipitate of a yellowish white colour will be gradually thrown down, which is *cyanuret of palladium*.\* If heat be applied to it, the cyanogen will be expelled, and pure palladium remains.

*What kind of a metal is PALLADIUM.†*

Its colour and lustre are very similar to those of platinum. It is a great deal harder than platinum, and its specific gravity is stated by its discoverer as varying from 11.3 to 11.8. It is malleable and ductile. Its fusibility is between that of gold and platinum.‡

*Is it attacked by acids?*

The nitro-muriatic acid readily dissolves it, and is its best solvent. The nitric acid also dissolves it. And if heat be applied, it will be dissolved by the sulphuric and muriatic acids.

*How many oxides are there of palladium?*

Only one. It is obtained by adding to solution of palladium pure potash, which throws it down as an orange coloured hydrate, which becomes black after being dried.

\* The palladium may thus be separated either before or after the separation of the platinum by solution of muriate of ammonia. (See *platinum*.)

† It was discovered by Dr. Wollaston in 1803.

‡ Heated powerfully before the oxyhydrogen blow-pipe it is dissipated in sparks.



*What are the properties and composition of oxide of palladium?*

It is decomposed at a red heat, and forms red coloured salts with acids.\* It is represented according to Berzelius to consist of 1 atom of oxygen = 8 + 1 atom of palladium = 56.†

*How is RHODIUM obtained?‡*

By immersing a thin clean iron plate in the solution from which palladium, and the greater part of the platinum have been thrown down, in the manner described under each of those metals, the rhodium is precipitated in a metallic state along with a little platinum, copper and lead. If the precipitate be acted upon by dilute nitric acid, the copper and lead will be removed. The residue, containing the rhodium and platinum, is then dissolved in nitro-muriatic acid, and to the

\* Metallic palladium may be precipitated from its salts by protosulphate of iron, and by all the metals except silver, gold, and platinum. Ferrocyanate of potassa produces an olive-green precipitate, and sulphuretted hydrogen and hydrosulphurets one of a dark brown colour. Muriate of tin is a very delicate test of palladium. It affords a dark orange or brown precipitate from neutralized salts of palladium.

It combines with sulphur, forming a sulphuret which consists of 1 atom of each of its constituents; and it unites with other metals forming alloys.

+ Palladium has the property, in common with platinum, of destroying the colour of gold, even when in a very small proportion. Thus one part of platinum, or palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed.

Dr. Wollaston has furnished an alloy of gold and palladium for the graduation of the magnificent circular instrument constructed by Mr. Troughton, for the Greenwich observatory. It has the appearance of platinum, and a degree of hardness, which peculiarly fits it for receiving the graduations.—*Henry's Chemistry*, vol. ii. p. 166.

‡ Rhodium was discovered by Dr. Wollaston at the time he was investigating the nature of palladium.



solution, muriate of soda is added, and the whole evaporated to dryness. The dry mass contains the soda-muriates of platinum and rhodium. The first of these triple salts is soluble, and the latter insoluble in alcohol. After separating the two salts by solution and filtration, the salt containing the rhodium is to be dissolved in water, and by placing a rod of zinc in the solution, the rhodium will be precipitated.

*What are the characters of rhodium?*

When obtained as we have just described, it is in the form of a black powder, which is only capable of fusion at a most intense heat. Its specific gravity is 11. It is a white brittle metal.

*What action have the acids upon rhodium?*

If it be in a pure state they have not the power to dissolve it; but if it be united with some other metals it is capable of being oxidized and dissolved by nitro-muriatic acid.\* It may likewise be oxidized by ignition with nitre.

*How many oxides are there of this metal?*

Berzelius describes three; Dr. Thomson two, the protoxide, of a black, and the peroxide, of a yellow colour. The same chemist fixes the

\* When an alloy of silver or gold with rhodium is digested in nitric or nitromuriatic acid, the rhodium remains untouched; but when alloyed with three times its weight of bismuth, copper, or lead, each of these alloys may be dissolved completely, in a mixture, by measure, of two parts of muriatic with one of nitric acid. Lead appears preferable, as it forms by evaporation an insoluble chloride. The chloride of rhodium then exhibits the rose colour, from which the name of the metal has been derived (*rose* a rose).—*Henry's Chemistry*.



atomic weight of the metal at 44, and described the oxygen in the oxides to be as 1.2.\*

*How is rhodium acted upon by re-agents?*

Its solutions are not affected by the addition of ferrocyanate of potash, muriate of ammonia, the hydrosulphurets, or carbonated alkalies; but the pure alkalies precipitate the peroxide.†

*By what is OSMIUM distinguished? ‡*

It is of a dark grey colour, and not volatile if heated in close vessels; but when heated in air it absorbs oxygen, and is converted into a volatile oxide. It has never been fused. It has the power of resisting the action of all the acids after having been exposed to heat. §

\* The additional oxide of Berzelius is described to be of a brown colour, but its composition has not been defined so as to give it a place with the two described in the text.

† Rhodium forms malleable alloys with malleable metals, and several of these have been examined by Dr. Wollaston.—*Philos. Trans.* for 1804.

With steel rhodium forms an alloy, which probably would be very useful in the arts, were it not for the scarcity of the latter metal; 1 to 2 per cent. of rhodium gives steel great hardness, and yet there is sufficient tenacity to prevent cracking either in forging or hammering.—*Quarterly Journal*, ix.

‡ Osmium was discovered by Mr. Smithson Tennant in the year 1803, and may be obtained as follows:—The black powder alluded to (p. 406) is to be fused with potash, and washed; by which means an alkaline solution of oxide of osmium is obtained, which is of a yellow colour. The alkali of the solution is then to be saturated with sulphuric acid, and the whole placed in a retort. By distillation a colourless solution of the *oxide of osmium* passes into the receiver. If this solution be shaken with mercury, an amalgam is obtained, which is decomposed by distillation in close vessels, and pure osmium is left.

§ Its oxide above described has never been obtained free from water. The solution is colourless, and has a pungent and peculiar odour, which is compared by some to the smell of new bread, by others to that of chlorine. This oxide is distinguished particularly by infusion of galls, affording a purple colour to solutions containing it, which afterwards changes to a deep blue.



*Describe the characters of iridium?\**

It is the most infusible of all the metals. Mr. Children succeeded in fusing it by means of his large galvanic battery. He states its specific gravity at 18.68. It is a white metal of a brilliant lustre. It is extremely insoluble in the acids, and aqua regia acts upon it with difficulty. It may, however, be oxidized by heating it with nitre. Its muriate forms a red solution in water, the colour of which is destroyed by pure alkalis, alkaline earths, sulphuretted hydrogen, ferrocyanate of potash, and infusion of galls.

*How is the IRON of commerce obtained?*

Iron, in a pure state, is seldom or ever found native,† but is obtained by a chemical process from some species of earths or stones, which are usually called *iron ores*,‡ in which it exists in the state of oxide.§

\* As iridium is not acted upon by the potassa employed to dissolve the osmium, it remains after that metal is separated from the black powder mentioned at p. 406, as that from which osmium is obtained. Therefore, to procure iridium, it is to be put in muriatic acid; the solution thus obtained becomes blue, next olive green, and lastly red. By depriving the resulting muriate of iridium of its excess of acid by heat, and evaporating the solution, crystals of muriate of iridium are obtained. Iridium is separated in a pure state by immersing a plate of zinc in a solution of the muriate, or by heating its crystals to redness.

The muriate of iridium is decomposed by almost all the metals; gold and platinum form exceptions.

† A few large masses of native iron have been found nearly pure in Siberia and South America, which appear to be of meteoric origin.

‡ The purest iron is made from an ore called hæmatites.

§ The first step, in order to extract iron from those ores in which it is most generally found, is to roast them. This is done by laying the ore, broken into pieces, in a kiln, mixed with small coals; or simply by laying the iron stones, mixed with coals, in alternate strata, in a heap, and then the coal is burnt till all the fuel is consumed, as is the practice in making



*Is it an abundant production of nature?*

It is the most abundant as well as the most useful of all metallic substances.\* There are few mineral bodies, stones, sands, clays, or waters, that are quite free from it. The parts of animal

lime. This separates the volatile parts (both sulphureous and arsenical) with which the ore may be combined, and the stones are much more easily broken. The iron stone is found, after this process, to consist principally of oxide of iron and clay; and when iron ores are found native, in the state of pure oxide, as is the case with the rich ores of Cumberland, this first part of the process is not requisite. After this, it is melted in large furnaces, from 16 to 30 feet high, of various shapes. Near the bottom of these furnaces is a hole for the nozzle of a large pair of bellows, which are worked either by steam or water, and keep up a constant blast. The furnace is open at top, and has more than one hole at different parts, which can be opened at pleasure to draw off the metal, or to remove the earthy substances which are to be separated from it. Charcoal or coke, with lighted brushwood, is first thrown into the furnace, and when the whole has got heated, baskets of ore and of fuel, either coal or coke, are thrown alternately into the furnace. At the same time, a portion of limestone is commonly thrown in as a *flux*. The reason for adding this is, that, in most cases, the earth mixed with the iron is alumina or clay, which of itself cannot be melted, but which is easily fused when mixed with a certain portion of lime. By adding the lime-stone, therefore, in proportions which the eye and hand of the workman generally determines, the two earths melt, and form a sort of glass, separating from the metal, the oxygen of which, at the same moment, combines with the charcoal or coke employed, and flies off as carbonic acid gas: while the metal, by reason of its greater weight, sinks, in a melted state, to the lowest part of the furnace, and is drawn off into moulds prepared for its reception. This process, after being once commenced, is carried on for years without interruption, the fires being never extinguished, and the furnaces being never allowed to cool. There is an incessant addition of the material, and an incessant production of iron. The quantities and proportions of fuel, of ore, and the nature of the flux which must be employed, are all regulated in practice, according to the nature of the ore, and the qualities of the iron to be obtained; and depend on circumstances, which are always acted on with success, though not easily described. Iron in this state is called *cast-iron*.

\* Iron has been known from the remotest antiquity. It was used in the time of the illustrious Jewish lawgiver, Moses, for the manufacture of swords, knives, and axes. It is referred to in the *Iliad* and the *Odyssey* of Homer. A ball of iron was one of the prizes offered by Achilles at the funeral rites of Patroclus.



and vegetable bodies likewise afford iron in the residues they leave after incineration.

*What are the PROPERTIES OF IRON?*

It is a metal of a blueish-white colour, which admits of a high polish, and is extremely malleable, ductile, and tenacious.\* It is one of the most infusible of the metals. Its specific gravity is 7.7. It burns with great splendour in oxygen gas. It is easily oxidized. When exposed to the atmosphere it slowly combines with oxygen and carbonic acid, and its surface becomes covered with a yellowish substance well known by the name of *rust*.†

*What is meant by the WELDING of iron?*

It is the perfect union of two pieces of the same metal, and is a singular and advantageous property that is found in no other metal except platinum. At a white heat, iron appears as if covered with a kind of varnish; and in this state, if two pieces be applied together, they will adhere, and may be perfectly united by forging.

*What is the difference between CAST IRON and BAR IRON?*

*Cast iron* is the impure sort of iron obtained from the smelting furnaces, that is, as it exists when first drawn off from the furnace in which it is extracted from the iron ore. *Bar iron* (sometimes called *sheet iron*) is cast iron purified and

\* See page 288.

† It slowly decomposes water at common temperatures; hydrogen gas is evolved, and oxygen combines with the metal. If the iron be heated, this effect is produced rapidly.



rendered malleable by being melted in a refining furnace, whence it is then withdrawn, and repeatedly hammered and rolled.\*

*With what substances does iron combine?*

Its chief COMBINATIONS are WITH OXYGEN, CHLORINE, and CARBON.†

*In what proportions does it unite with oxygen?*

In two proportions, forming the *black* or *prot-*

\* The cake of metal (cast-iron), after being run out of the refining furnace, is broken in pieces, and introduced into what is called the puddling furnace, where it is exposed, at the same time, to the action of flame and of blasts of air. As soon as it is again melted, a man called a *puddler* begins to rake it about, and a more terrific task cannot well be conceived; at the same time, he occasionally throws water upon it with a small iron dish. The water is decomposed by the melted mass, the hydrogen escapes, and the oxygen unites with a portion of the iron. As the metal is agitated, it gradually loses its carbon, its fusibility diminishes, it loses all cohesion, and becomes a loose, granulated mass. As this change is going on, bubbles of gas, which are carbonic oxide, burst from it with a blue flame. After this, the heat is raised, and the loose mass becomes a number of balls of an irregular shape, which consist of iron united with the vitreous oxide. When it has thus become solid, it is removed from the furnace, and is beat by means of hammers driven by machinery, or it is passed through heavy rollers. It has now acquired a certain degree of malleability, but is yet very brittle when cold. It is again heated, and again hammered or rolled; and every time this process is repeated the iron is improved. Hereby the particles are made to approach nearer each other, and several impurities got rid of. After having repeatedly undergone such hammerings, it is what is called *bar* or *sheet* iron, and is supposed by chemists to be iron nearly in a state of purity.

† It combines likewise with *iodine*, *phosphorus*, and *sulphur*. There are two well known sulphurets of iron, and they are both found in nature. One is formed by heating iron filings and sulphur together out of the contact of air, when they combine with great energy. It has a metallic splendour, and a dull yellow colour. It is magnetic, and has been called *magnetic pyrites*. The other sulphuret of iron is a *super-sulphuret*. It has not yet been made artificially; but is found abundantly in metallic veins, forming the common *iron pyrites*. It is of a bright yellow colour, and often crystallized in cubes.



*oxide*, and the *red* or *peroxide*.\* The *protoxide* of iron is formed by the rapid combustion of iron in oxygen gas, or by digesting it in diluted sulphuric acid. It is composed of 1 atom of iron = 28 + 1 atom of oxygen = 8. Its atomic weight is therefore 36. The *peroxide* of iron is formed by dissolving the protoxide, or iron itself, in nitric acid, then boiling it for some time, and after precipitating it by ammonia, washing, drying, and calcining it in a low red heat. It is supposed to consist of 28 parts or 1 atom of iron, and 12 parts or  $1\frac{1}{2}$  atom of oxygen.†

*What is the best test of the presence of peroxide of iron?*

Ferrocyanate or sulphocyanate of potassa. Either of these substances will detect it although it may exist in very minute quantities. With the former it forms *Prussian blue*, and the latter strikes with it a deep blood-red colour.‡

IRON AND CARBON UNITE in various propor-

\* Both these oxides are soluble in the common acids, and form salts. The black produces pale green solutions; the red, deep yellow solutions. The solutions of triple prussiate of potassa, precipitate the solutions of the black oxide white; those of the red bright blue. When solutions of these oxides are acted upon by solutions of pure alkalies, a white precipitate, having a tint of green or olive, is thrown down from the solution containing the black oxide; and an orange-coloured precipitate from the solution containing the red-brown oxide; and both these precipitates Sir H. Davy found to be hydrates—the oxides combined with water.

† Although it is generally stated that there are but two oxides of iron, Dr. Ure says “there are three, probably four.” The oxides of iron are not well understood.

‡ Infusion of gall-nuts is another excellent test of iron, affording a black colour.



tions :\* *What is the principal compound which these substances form, and how is it made?*

It is STEEL, which is usually made by a process called *cementation*, which consists in keeping bars of iron in contact with powdered charcoal in a state of ignition for ten or twelve days, in earthen troughs, in crucibles, the mouths of which are closed with clay.† Cemented steel is made into the substance called *cast steel*, by being fused in a close crucible with a mixture of powdered glass and charcoal.‡

WOOTZ is a peculiar and most valuable kind of steel imported from India, and therefore sometimes called INDIAN STEEL: *Do you know what its superiority is owing to?*

\* There are two *chlorides of iron*, which were discovered by Dr. John Davy in 1812.

† In this state it is called *blistered steel*. This, when drawn down into smaller bars and beaten, forms *tilted steel*; and this broken up, heated, welded, and again drawn out into bars, forms *shear steel*.

‡ Although iron and steel differ so greatly in their external and physical characters, their chemical composition varies very little, steel owing its properties to not more than  $\frac{1}{60}$ th to  $\frac{1}{140}$ th of its weight of carbon. This appears to be the only addition necessary to convert iron into steel.

Steel is possessed of the very useful property of receiving different degrees of hardness by different applications of heat and cold. In its manufacture the hardness produced is greater in proportion as the steel is hotter, and the water into which it is plunged, colder. The colours which appear on the surface of steel slowly heated, are yellowish-white, yellow, gold colour, purple, violet, deep blue. After which the ignition takes place. These signs direct the artist in tempering or reducing the hardness of steel to any determinate standard. If steel be too hard, it will not be proper for tools which are intended to have a fine edge, because it will be so brittle, that the edge will soon become notched; if it be too soft, it is evident that the edge will bend or turn.

Cast iron is a compound of iron and carbon, it containing more carbon than steel.



Its excellence appears to be owing to a combination with a minute portion of the earths alumina and silica, or with the bases of those earths.\*

*What are the USES OF IRON ?*†

Iron is well known to be of all metals the most important in its applications to the purposes of mankind. We can only hint at its various uses here. By means of it the earth is cultivated, and without it houses, cities, and ships could not be built. It is subservient both to the common and the refined arts, and forms the machinery by which the most important mechanical powers are generated and applied. It is a very useful substance to the dyer,‡ and is of great use in medicine.§

\* Whether the earths are formed in the ore, or are furnished by the crucible used in making the steel, is not certainly known; nor is the Indian steel-maker probably aware of their presence. It is highly probable that the much admired sabres of Damascus are made from this steel.

† Iron is capable of combining with many of the metals, as sodium, potassium, manganese, tin, &c. The formation of *tin plate* depends upon the chemical attraction between tin and iron. Tin plate is formed by dipping thin plates of iron, previously well cleaned by a dilute acid, into melted tin. It is usual to add  $\frac{1}{10}$ th of copper to the tin to prevent it from forming too thick a coat.

‡ Iron is one of the principal ingredients for dyeing black. The stuff is first prepared with a bath of galls and logwood, then with a similar bath to which verdigris is added, and lastly dyed in a similar bath, with the addition of sulphate of iron. If it be wished that the colour should be particularly fine, the stuff should previously be dyed of a deep blue: otherwise a brown may be first given with the green husks of walnuts. Silk however must not be previously blued with indigo, and sumach may be substituted instead of galls. Leather, prepared by tanning with oak bark, is blackened by a solution of sulphate of iron.

§ Iron in different states of oxidation, forms the colouring matter of many precious stones, as the cornelian, ruby, sapphire, &c.

Of all minerals it is the most friendly to the human constitution. For an account of its great use in the relief and cure of diseases, I beg to refer the reader to my *Modern Domestic Medicine*.



*Is not BLACK LEAD or PLUMBAGO a carburet of iron?*

Yes. It contains perhaps about 10 per cent. of iron.\*

*How is TIN procured?*

From the native combinations of the metal with oxygen, by heating them with charcoal or other carbonaceous substances.†

Mr. Malkin gives the following account of the iron-works in South Wales, from which we may judge of their extent and importance.—“Merthyr Tydvill was a very inconsiderable village till the year 1755, when the late Mr. Bacon obtained a lease of the iron and coal mines of a district of at least eight miles long and four wide, for 99 years. Since then, these mines have been leased by him to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The part occupied by Mr. Crawsbay contains now the largest set of iron works in the kingdom. He constantly employs more than two thousand workmen, and pays *weekly* for wages, coal, and other expenses of the works, 25,000 *pounds*. The number of smelting furnaces belonging to the different companies at Merthyr is about sixteen. Around each of these furnaces are erected forges and rolling-mills, for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvill has become the largest town in Wales, and contains more than 12,000 inhabitants.”—*Malkin's Scenery of South Wales*.

What adds to the importance of the iron manufacture to this country, is the fact that it is from the mineral of Great Britain alone it is made, without any foreign ingredient whatever; and, consequently, almost the whole money got for it goes as wages to her artisans.

\* This is the substance used in fabricating pencils, and in covering iron to prevent rust. It is not an uncommon mineral, though rarely found of sufficient purity for the manufacture of pencils. At Borradale in Cumberland, where it occurs particularly pure, it is in imbedded masses in slate and grauwacke: the coarser kinds and the dust, are melted with sulphur for common carpenter's pencils, and crucibles are sometimes made of it. Plumbago is infusible, and burns with great difficulty.

† The metal obtained from these ores is not pure. To obtain it in a state of purity, metallic tin should be boiled for some time in solution of nitric acid; the white powder formed, should be well washed in pure water, and heated strongly in contact with about  $\frac{1}{4}$ th of its weight of charcoal powder in a covered crucible for about half an hour: a button of pure tin will be found at the bottom of the crucible.



*What are the properties of tin?*

It is a metal of a silvery-white colour, very malleable, but possessing little ductility or tenacity. It may be extended into extremely thin leaves, tin-foil being about the  $\frac{1}{1000}$ th part of an inch thick.\* Its hardness is greater than that of lead, and less than that of zinc. Its specific gravity is 7.29. It is flexible, has a slight taste, and when rubbed emits a peculiar smell. It melts at 442° Fahr., and by a continuance of the heat is slowly converted into a white powder by oxidation. It acquires a slight tarnish by exposure to the atmosphere, but undergoes no further change.†

*How many OXIDES OF TIN are there?*

Two. The first, which may be called the *protoxide*, is grey; the second, or *peroxide*, is white. The first is formed by heating tin in the air, or by dissolving tin in muriatic acid, and precipitating the solution whilst recent, and before it has been exposed to the air, by solution of potassa, not added in excess. This substance, after being

Tin is not a very abundant production of nature, and is found but in few places, as in Cornwall, in Saxony, in the province of Gallicia in Spain, in Brittany in France, and in Bohemia.

\* The process for making tin-foil consists simply in hammering out a number of plates of this metal, laid together upon a smooth block or plate of iron. The smallest sheets are the thinnest.

† It is not affected by water at common temperatures, but when steam is passed over red-hot tin it is decomposed, oxide of tin is formed, and hydrogen gas is evolved. The oxide of tin resists fusion more strongly than that of any other metal; from which property it is useful to form an opaque white enamel (such as is used, for example, to form the faces of watches,) when mixed with pure glass in fusion.



heated to whiteness, is the protoxide of tin; and it is converted into the peroxide by being boiled with diluted nitric acid, dried by evaporation, and heated to redness. The protoxide is considered to contain one, and the peroxide two proportions of oxygen.\*

*With what other substances does tin combine?*

With chlorine, sulphur, phosphorus, and with several of the other metals. There are *two chlorides of tin*, the protochloride and bichloride; the former of which consists of 1 proportion of chlorine and 1 of tin, the latter of 1 proportion of chlorine and 2 of tin.† There are also *two sulphurets of tin*, the protosulphuret and bisulphuret. The former is made by fusing tin and sulphur together: it is of a bluish colour, and lamellated texture, and contains 1 proportion of each ingredient. The bisulphuret of tin is what is sometimes called *mosaic gold*, which is used as a

\* These oxides form salts by uniting with acids. They are likewise capable of combining with alkalies, so that they have in a certain degree, the properties of acids. Their affinities for the bases are, however, feeble.

The *protoxide* of tin is remarkable for its powerful affinity for oxygen. Therefore its salts not only attract oxygen from the air, but act as powerful deoxidizing agents.

† *Protochloride of tin* is procured by heating together an amalgam of tin and calomel. It is a grey semi-transparent crystalline solid, which dissolves in water, and forms a solution that rapidly absorbs oxygen from the air, depositing peroxide of tin. *Bichloride of tin* may be formed by heating together tin-filings and corrosive sublimate, or an amalgam of tin and corrosive sublimate. It is a very volatile clear liquor, which emits copious white fumes when exposed to the atmosphere, and was formerly called the *fuming liquor of Libavius*, from its discoverer Libavius. It has a very strong attraction for water, and when mixed with a little of that fluid, becomes a solid crystalline substance, a true muriate of tin, containing the peroxide of the metal—therefore a *permuriate*.



pigment for giving a golden colour to small statue or plaster figures, &c.\* It is made by heating together the peroxide of tin and sulphur. It is of a beautiful gold colour, and appears in fine flakes. It consists of 1 proportion of tin and 2 proportions of sulphur.

*What are the USES OF TIN?*

They are very numerous. As already remarked, it is an important ingredient in pewter, bell-metal and bronze, and is usefully employed in covering iron and copper. It is also useful in the silvering of looking glasses. Some of its salts are of great use in *dyeing*, particularly the nitromuriate of tin, which is essential to the production of a fine bright scarlet, when cochineal, lac-dye, &c. are employed in the dyeing of woollens.†

*What are the distinguishing CHARACTERS OF COPPER? ‡*

Copper is a metal of a red colour; it is a little harder than silver; its specific gravity is about 8.8; it is very malleable, has considerable ductility, and in tenacity is superior to all the metals

\* It has been often called *Aurum Musivum* or *Mosaicum*, and is sometimes mixed with melted glass to imitate lapis lazuli.

† Before the use of nitro-muriate of tin in dyeing was discovered, cochineal and the other red dyes, could be made to produce only a dull *crimson*, but now, they by its agency afford a permanent *bright scarlet*. The nitro-muriate of tin is likewise used in making the best red ink.

‡ The copper of commerce is procured from the native combinations of this metal with sulphur, oxygen, and certain acids, by roasting and fusion, either alone or with lime and carbonaceous substances; it is not, however, quite pure. To obtain it in a state of purity;—Dissolve copper in strong muriatic acid, dilute the solution with water, and put into it a polished plate of iron, the copper will be precipitated in its metallic state: it should be washed in dilute muriatic acid and then with pure water.



except iron. When rubbed it emits an unpleasant smell, and it fuses at a low white heat. By exposure to the air it becomes tarnished, and after some time is coated with a green crust, which consists of the metal in union with oxygen and carbonic acid.\* It is not at all attacked by vegetable acids, if atmospheric air be excluded,† and with difficulty by muriatic and sulphuric acids. Its atomic weight is 64.

*How many OXIDES OF COPPER are there?*

Two; the *protoxide* which is *red*, and the *peroxide* which is *black*.‡ The former consists of 1 atom of oxygen and 1 of base; the latter of 2 atoms of oxygen and 1 of base.§

*Does not copper combine also with chlorine, sulphur, phosphorus, and many of the metals.*

Yes. There are two *chlorides of copper*. The *protochloride* is a fixed, easily fusible substance, like rosin in its exterior characters, and consists of 1 atom of each ingredient; the *deutochloride*

\* This is the carbonate of the peroxide of copper. It is sometimes called *verdigris*, which is an improper term, for *verdigris* is an acetate of copper.

† If there is a free access of air, the metal absorbs oxygen with rapidity under such circumstances.

‡ It varies in colour from a dark brown to a bluish-black, according to the mode of formation.

§ The *protoxide of copper* is found native in Cornwall, and elsewhere, and is the *ruby copper ore*. It occurs in octahedrons of considerable lustre; its powder is dull orange red. It may be made artificially by mixing 64 parts of metallic copper in a state of fine powder, with 80 parts of the peroxide, and heating the mixture to redness in a close vessel.

The *peroxide of copper*, the *copper black* of mineralogists, is formed in the combustion of copper, or by heating the precipitate from a nitrous solution of copper by potassa to redness. Both these oxides combine with many of the acids, forming respectively *proto* and *per* salts.



is a yellow pulverulent sublimate, and is composed of 1 atom of copper and 2 atoms of chlorine.\*

*What sort of a metal is NICKEL?*

It is a metal of great hardness, of an uniform texture, and of a colour between silver and tin; very difficult to be purified, and magnetical. It even acquires polarity by the touch. It is malleable, both cold and red hot. It combines with oxygen; and its oxides, when pure, are reducible by a sufficient heat without combustibile matter; and it is little more tarnished by heating in contact with air, than platinum, gold, and silver.† It is usually obtained from its sulphuret, the *kupfer-nickel* of the Germans.‡

*With what substances does it combine?*

With oxygen, chlorine, sulphur, and some of the metals, but these compounds are not worthy of particular notice here.

\* There are two *sulphurets of copper*. The protosulphuret is a natural production, well known to mineralogists under the name of *copper glance*; and in combination with sulphuret of iron, it is a constituent of the variegated copper ore. The bisulphuret of copper is a constituent of copper pyrites, in which it is combined with protosulphuret of iron.

The principal *uses of copper* have already been noticed. Its alloys are of great importance in the arts (see page 301). In early ages the alloys of copper formed the principal arms, offensive and defensive. Sir H. Davy examined an ancient Attican helmet, which consisted of an alloy of copper and tin. The swords and spear-heads of the early inhabitants of Greece and Italy seem to have been composed of the same materials.

† It is very infusible. Its specific gravity, when cast, is 8.279; when forged, 8.666. It was discovered by Cronstadt in 1751; and, as we before remarked, is a pretty constant ingredient of meteoric stones.

‡ It is procured from this ore by roasting and ignition with charcoal; but in this case it is far from being pure. For the method of purifying it, see *Davy's Chem. Philos.* p. 421; or *Dr. Ure's Dict.* p. 616.



*How is the metal BISMUTH procured?*

From its ores, which usually contain it in the metallic state, or combined with sulphur, by roasting, and ignition with charcoal. It is easily separable, in the dry way, from its ores, on account of its great fusibility.\*

*What are the CHARACTERS OF BISMUTH?*

It is a brittle metal, of a white colour, with a slight tint of red, and is composed of broad brilliant plates adhering to each other. Its specific gravity is 9.822, which is increased by hammering. It is one of the most fusible metals, melting at 476° Fahr. and it forms, more readily than most other metals, distinct crystals by slow cooling. If it is exposed to a strong heat in close vessels it sublimes unaltered. It acquires only a superficial tarnish by exposure to the air.† It combines with oxygen, and also with chlorine, in one proportion, forming an *oxide* and *chloride* of

\* The metal may be obtained in a state of purity by dissolving the ore in strong nitric acid, and adding water to the solution, when a white precipitate will appear, which is to be washed, dried, and heated to a dull red for about 20 minutes, with a little oil, and some black flux; a globule of metal will thus be procured.

The ores of bismuth were first described by Agricola prior to 1530, but the proportions of the pure metal were not known before the middle of the last century.

† It is a less perfect conductor of heat than most other metals.

The sulphuric acid has a slight action upon bismuth, when it is concentrated and boiling; but the nitric acid dissolves it with the greatest rapidity and violence. When the *nitrate of bismuth* is put into water, a copious precipitate, the *subnitrate*, of a beautifully white colour subsides, which was formerly called *magistery of bismuth*. It is employed in medicine as a tonic and anodyne, and, when properly prepared, is often of superior efficacy in relieving chronic pain in the stomach and bowels. Some ladies also frequently make use of it as a white paint, to improve the colour of the complexion.



*bismuth*; both of which compounds contain one atom of each of their elements.\*

*What are the distinguishing* CHARACTERS OF ANTIMONY?†

It is a metal of a brilliant white colour, with a shade of blue, very brittle, and of a plated or scaly texture. Its specific gravity is about 6.8. It has little tenacity, and fuses at about 810° Fahr. On cooling it crystallizes, and its laminated structure is owing to the new arrangement of its parts.‡

*What are the principal compounds which it forms by uniting with other substances?*

Those resulting from its union with oxygen, chlorine, and sulphur. Chemists differ with respect to the number of oxides of antimony existing. It is generally considered that there are

\* The *oxide of bismuth* is formed during the combustion of the metal in open vessels. When bismuth, in fine powder, is thrown into chlorine gas, it takes fire, and burns with a pale blue light, and a *chloride of bismuth*, formerly called *butter of bismuth*, is formed.

Bismuth is not much used in the arts. Its alloys have been already noticed.

† The word *antimony* is used in commerce to denote a metallic ore, which is the sulphuret of that metal. Sometimes this ore is called *crude antimony*, to distinguish it from the pure metal, or *Regulus*, as it was formerly termed. Metallic antimony may be obtained by fusing two parts of the sulphuret with one of iron filings in a covered crucible; to which, when in fusion, half a part of nitre may be added. In this case, the sulphur quits the antimony and unites with the iron. The metal, however, being still contaminated with foreign matter, must be dissolved in nitromuriatic acid, and the solution poured into water; when a white precipitate will take place, which, if dried, and mixed with twice its weight of crude tartar, and then fused, will surrender the metal in a state of absolute purity.

‡ It is but little affected by exposure to air or water at common temperatures; but when the vapour of water is passed over red-hot antimony, it acts so powerfully upon the water, as to decompose it with explosions.



but three fully ascertained, but some chemists say there are four, or more.\*

*What is KERMES MINERAL?*

It is an *hydrosulphuretted oxide of antimony*, and is prepared by boiling the native sulphuret, in powder, in a solution of potassa. *Kermesmineral* is a powder of a beautiful deep orange colour. On the addition of a dilute acid to the cold solution just mentioned, a precipitate of a brighter colour ensues, and this is the preparation of the Pharmacopœia called *antimonii sulphuretum præcipitatum*.†

\* The oxides of antimony, as they are usually considered to exist, are as follows:—

Protoxide consisting of 1 atom of antimony, and 1 atom of oxygen.

Deutoxide	..	1	..	1½ atom	..
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Peroxide	..	1	..	2 atoms	..
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The *protoxide of antimony* may be procured by pouring muriate of antimony into water; washing the precipitate, first with a very weak solution of potassa, and afterwards with water, and then drying it; or, by boiling 50 parts of powdered metallic antimony with 200 parts of concentrated sulphuric acid; washing the residuum first with a weak solution of potassa, and then with hot water, and drying.

The *deutoxide* may be obtained by the action of nitric acid on the metal; and the *peroxide* by acting for a considerable time upon the powdered metal, by excess of hot nitric acid, and exposing the product to a red heat. The deutoxide and peroxide of antimony possess acid properties, and form salts with salifiable bases; the former has therefore been called *antimonious*, and the latter *antimonic acid*.

*Chloride of antimony* was formerly called *butter of antimony*. It is prepared by throwing powdered antimony into chlorine gas. It is a soft semi-transparent substance, of a yellowish-white colour, very fusible, and volatile at a moderate degree of heat. It crystallizes in parallelopipeds. It is a very caustic and corrosive substance, and acts with great energy upon water. It is a *bichloride*, consisting of 2 atoms of chlorine and 1 atom of antimony.

† The *sulphuret of antimony*, as above stated, constitutes the crude antimony of commerce; it may also be prepared artificially by fusing the metal with sulphur. It consists of 1 atom of each of its constituents.



MERCURY is a metal of great use, more especially in medicine :\* How is it obtained ?

Mercury has been known from the earliest ages of the world, and is found native in small quantities in Peru, but it is usually obtained from the mercurial ore called *cinnabar*, which is a

\* Mercury is found in Spain, Germany, and Hungary, Siberia, the Philippines, China, and Peru. The most productive mines are those of Idria, of Almaden, near Cordova, in Spain, and of Guanica Velica, near Potosi, in Peru. The Cinnabar mine of Almaden is the oldest and richest in Europe, and was wrought by the Romans two thousand years ago. It yields about 6,000 quintals of fluid mercury annually. Indeed it is so prolific, that more of the metal has sometimes been obtained than could be sold.

The mines of Guanica Velica, in Peru, were discovered in 1566 and 1567, by Henry Garces, a Portugese, who was a native of Porto, and went to Peru in the Spanish service. Examining one day the red earth which the Indians used as paint, and called *limpi*, he observed it was native cinnabar ; and knowing that mercury was extracted from cinnabar in Europe, he began to work the Peruvian mines. One of the mines of Guanica Velica is 480 fathoms deep, and of such extent as to have whole streets formed in it, as well as chapels, where the religious ceremonies of the papists are celebrated—formerly the only consolation of the thousand naked Indians who were annually driven into the mine to perish by the most miserable of deaths. Those who are obliged to live there are speedily affected by convulsions, and other distressing symptoms, which the inhalation and frequent contact of mercury never fails to produce ; and thousands, perhaps millions, of poor Indians fell a prey to the ruthless avarice of the Spaniards. The Almighty has evidently visited Spain with a severe chastisement for these and other enormities of which she has been guilty towards the native inhabitants, and sole rightful owners, of the now important continent of South America. The guilty country, once amongst the richest and most powerful in Europe, is now reduced to a state of manifest wretchedness, and is without money, resources, power, or honour !

In the management of the Spanish mines things are somewhat better now ; but the manner in which the United States of America have outstripped the Spanish colonies in the same country, though blessed with a better soil, is a triumphant proof of the *utility of justice*, and one of the strongest recommendations on record for men to seek wealth by their own industry, and to abstain from oppressing their fellow men.



sulphuret of mercury, from which it is separated by distillation with quicklime.\*

*What are the CHARACTERS OF MERCURY?*

Pure mercury is inodorous, insipid, and of a bright white colour like silver, hence its name of *quicksilver*. It is distinguished from all other metals by its extreme fusibility, which is so great, that while other metals require the strongest heat of our best furnaces to liquefy them, mercury is always fluid at the common temperature of even the coldest climates which man can well inhabit.† It becomes a solid at  $39^{\circ}$  below zero of Fahrenheit's thermometer: at about  $656^{\circ}$  it boils rapidly, and rises copiously in fumes.‡ Its specific gravity is 13.6. It is not perceptibly altered by mere exposure to the air, but by long agitation, with access of air, it becomes converted into a black powder or oxide. Its atomic weight is 200.

*With what substances does it combine?*

Its principal combinations are with *oxygen*,

\* To obtain the metal, the ore, after being sorted, is reduced to powder, and mingled with about one-fourth of quicklime in powder. This mixture is put into large iron retorts, which are placed in a long furnace, and glass receivers adapted to each, but not luted until all the moisture it contains be driven off; the joinings of the vessels are then closely stopped with well-tempered clay, and a full red heat kept up for 7 or 8 hours, in which time the mercury is volatilized, and condensed in the receiver. About 10 ounces of mercury are usually obtained from 100lbs. of the ore.

† This circumstance, combined with that of its extension by heat being very equable, renders it one of the best known materials for measuring temperature. Hence it is generally employed in the construction of thermometers, as we have already noticed at page 68.

‡ From this volatility of mercury, it is commonly purified by distillation.



*chlorine*, and *sulphur*.\* There are two oxides of mercury, the *black* or *protoxide*, and the *red* or *peroxide*. The black oxide of mercury may be formed by acting on calomel by solution of potassa; and the red oxide by treating corrosive sublimate in the same way.†

*What is the BLUE PILL,—that mercurial of which we have lately heard so much?*

Its basis is the protoxide of mercury, which, indeed, is the basis of all the mild mercurial medicines. The *blue pill* is made by triturating metallic mercury with confection of red roses and liquorice powder.‡

*What is CALOMEL?*

It is a *protochloride* of mercury, formed by the union of chlorine with metallic mercury. Its constituents are an atom of mercury = 200, and an atom of chlorine = 36; its atomic weight is therefore 236.

*What are the PROPERTIES OF CALOMEL?*§

\* It unites also with *iodine*, forming an *iodide of mercury*, with *cyanogen*, the result of which is a *cyanuret of mercury*, and with most of the metals, forming *amalgams*.

† The *black* oxide of mercury was formerly called *Ethiop's per se*, and the *red* oxide, *precipitate per se*. The latter is the common *red precipitate* of the shops.

Besides the method described above, the red oxide may be obtained by exposing mercury to such a heat as may cause it to rise quickly in the vaporous form (about 600°,) when it gradually becomes converted into the red oxide. The black oxide may be formed by trituration, as already remarked. The following are the constituents of these oxides:—

Protoxide of mercury consists of 1 atom of mercury + 1 atom of oxygen.  
 Peroxide .. .. 1 atom .. .. + 2 atoms ..

‡ Metallic mercury does not act on the animal system. In order to its exerting any action, good or bad, it must be oxidized.

§ *Calomel* is usually prepared by triturating four parts of corrosive rub-



When formed by precipitation it is a white powder; but when obtained by sublimation, it is in semi-transparent crystalline cakes. It is tasteless, nearly insoluble, and very heavy, its specific gravity being 7.2. Exposure to air darkens its surface. It is decomposed by the alkalies and lime, but very imperfectly by their carbonates. By nitric acid it is dissolved, and converted into corrosive sublimate.\*

*What is CORROSIVE SUBLIMATE? †*

limate with three of quicksilver, till the globules disappear, and subjecting the mixture to a subliming heat. By subsequent washing and edulcorating the sublimed cake, the portion of soluble corrosive sublimate which had escaped decomposition is removed. It may likewise be made by adding solution of proto-nitrate of mercury to solution of muriate of soda (common salt.)

\* Its medicinal properties are of the first importance. It is probably, without exception, the most valuable of all medicines, having a greater power than any other known remedy of correcting the disordered actions of the human system. This opinion, of course, refers only to its correct use, (and for the most part to its employment in conjunction with other remedies,) for by its *abuse* it has proved, and still proves, the source of great misery to thousands. So clearly am I convinced that the practice of unprofessional persons in frequently taking free doses of calomel, say two or three grains, or giving them to others, is one fraught with great and lasting mischief, that I should fail in my duty if I allowed any opportunity to pass without cautioning the public on the subject. I believe I have been sufficiently explicit on this point in my publication on practical medicine, (*Modern Domestic Medicine*,) but would here again say, that calomel is a medicine no unprofessional person ought ever to administer frequently, on his own opinion.

† *Corrosive sublimate* is prepared by heating mercury in chlorine gas; it burns with a pale red flame, and the salt is formed. It may also be prepared by mixing together equal parts of dry bideutosulphate of mercury and common salt, and subliming. The corrosive sublimate rises, and incrusts the top of the vessel, in the form of a beautiful white semi-transparent mass, composed of very small prismatic needles. Mr. Brande gives the following directions:—50 pounds of mercury are boiled to dryness in a cast iron pan with 70 pounds of sulphuric acid; 73 pounds of super-sulphate of mercury are thus formed, which being perfectly mixed with 120lbs. of common salt and sublimed, yield from 63 to 65lbs. of corrosive sublimate.



A *bichloride* or *deutochloride of mercury*. Its constituents are 1 atom of mercury = 200, and 2 atoms of chlorine = 72; its atomic weight is therefore 272.

*What are the PROPERTIES OF CORROSIVE SUBLIMATE?*

It is a white semi-transparent crystalline substance, of an acrid and disagreeable metallic taste; dissolving in twenty parts of cold water, and less than one of boiling water. Its specific gravity is 5.2. It sublimes at a red heat without change. Light has no action upon it in its solid state, but partially decomposes its solution, and *calomel* is formed. It is a deadly poison. From these characters it is evident, that corrosive sublimate is readily distinguished from calomel by its solubility in water, and its acrid metallic taste; for calomel is insoluble, and nearly tasteless.\*

*As corrosive sublimate is an active poison, what would you administer if called to a person who had taken it in too large doses?*

The *white of egg*. The white of four or five eggs should be beaten up, and given instantly, repeating them quickly to the second or third time, or oftener if necessary. *Sulphuretted hydrogen water*, (page 267,) is also an effectual anti-

\* It is not soluble in nitric or sulphuric acid. It is capable of uniting, and forming a double salt, with muriate of ammonia, potassa, soda, baryta, and magnesia, all of which greatly increase its solubility. All fixed alkalies throw down from a solution of corrosive sublimate, a yellow precipitate, becoming brick-red—this is the peroxide of mercury.



dote. The white of egg converts it into calomel.

*What is VERMILION?*

It is a *bisulphuret of mercury*, and is the most perfect red pigment yet discovered. It is formed by fusing sulphur with about six times its weight of mercury, and subliming in close vessels.\*

*What are the PROPERTIES OF SILVER?* †

Silver is the whitest of all metals, and admits of receiving a degree of lustre, inferior only to that of polished steel. In malleability and ductility it exceeds all the metals, except gold, and

\* In this state it is called *factitious cinnabar*. By being reduced to powder its tint is greatly improved, and it then forms *vermilion*.

There are two *sulphurets of mercury*, the bisulphuret just mentioned (*cinnabar*), which is red, and the protosulphuret, or *Ethiops mineral*, which is black. The latter is formed by heating mercury and sulphur together strongly, but not to sublimation; or by adding a hydrosulphuret of an alkali to a mercurial alkaline solution. The sulphuret is composed of 1 atom of mercury and 1 of sulphur, and the bisulphuret of 1 atom of mercury and 2 atoms of sulphur.

I have already noticed the chief *uses of mercury*, namely, water-gilding, the making of vermilion, the silvering of looking-glasses, the formation of barometers and thermometers, and the preparation of several powerful medicines.

† This metal is found in many countries, and was formerly procured to a considerable extent in several parts of Europe. The discovery of mines in America, in which it is much more abundant, and can be worked at much less expense than in the silver mines of Europe, made it cease to be advantageous to work the latter, and many of them were therefore abandoned. Silver is, however, still obtained in various parts of the Continent; and a small quantity even is got from working lead mines in both Ireland and England. America, however, is the great store-house of this metal at present; and Humboldt says, that the mines in three centuries have afforded 316,023,883lbs. troy of pure silver, which would form a solid globe, 91,206 feet in diameter. The following is given by M. Brogniart, a French mineralogist of considerable celebrity, as the average annual quantity of silver supplied from the under-mentioned places, between the years 1790 and 1802:—



its tenacity is considerable. Its specific gravity is 10.4. When pure, it does not rust by exposure to air and moisture, and the heat of common furnaces is insufficient to oxidize it. It has been partly oxidized by *twenty successive* exposures to the heat of the porcelain furnace at Sevres. A fine silver wire burns under the influence of the oxy-hydrogen blow-pipe.\* It fuses at 22° of Wedgwood's pyrometer.

*With what substances does it combine?*

*Old World.*

Asia—	
Siberia .....	40.200lbs. troy.
Europe—	
Hungary .....	46.000
Austrian dominions.....	11.000
Hartz and Hesse .....	11.000
Saxony .....	22.000
Norway .....	22.000
Sweden	}..... 11.000
France	
Spain	
<hr/>	
Total, Old World.....	163.200lbs. a year.

*New World.*

North America .....	1.400.000
South America .....	885.000
<hr/> Total, New World .....	
<hr/>	
2.285.000lbs. a year.	

The labour and trouble both of procuring silver ore, and separating the metal from the substances with which it is associated, are very great. The process is called amalgamation, from being effected by mercury.

\* Nitric acid is its proper solvent. Sulphuric acid also acts upon it when heated.

Although the air scarcely alters it, yet it is tarnished by the sulphureous vapours which are emitted from animal substances, drains, or putrefying matters. This coating, after a long series of years, has been observed to scale off from images of silver exposed in churches; and was found, on examination, to consist of silver united with sulphur.



With oxygen, chlorine, iodine, sulphur, and with most of the other metals.\* There is *one oxide*,† and *one chloride of silver*. The latter is a whitish semi-transparent substance, cuts like horn, is insoluble in water, and has been long known by the name of *luna-cornea*, or *horn silver*. It may be formed by heating the metal in contact with the gas. It contains one proportion of each of its constituents.‡

GOLD is always found native, or in its metallic state,§ and sometimes alloyed with copper or silver,

\* When alloyed with copper it becomes harder, and is better adapted to receive a fine impression.  $12\frac{1}{2}$  parts of silver, alloyed with one of copper, form *standard silver*, of which the silver coins in use are made.

† The oxide is formed by adding a solution of caustic barytes to one of nitrate of silver, and heating the precipitate to dull redness.

‡ The *sulphuret of silver* is a brittle substance, of a black colour and metallic lustre. It is made by heating to redness thin plates of silver stratified with sulphur. It consists of 1 atom of silver + 2 atoms of sulphur.

“*Fulminating silver* is formed by pouring lime water into the pure nitrate, and filtering, washing the precipitate, and then digesting on it liquid ammonia in a little open capsule. In 12 hours, the ammonia must be cautiously decanted from the black powder, which is to be dried in minute portions, and with extreme circumspection, on bits of filtering paper or card. If struck, in even its moist state, with a hard body, it explodes; and if in any quantity, when dry, the fulmination is tremendous.”—*Dr. Ure's Dict.* p. 721.

§ The most usual forms in which metallic gold is found, are grains, leaves, and small crystals. It is contained in the sands of many rivers, both in Africa and Europe, and is found abundantly in South America and India. France, Sweden, Norway, and Ireland all possess gold. Spain was formerly celebrated for its mines, but the principal places where this metal is now produced are South America, Hungary, and Germany. Though by no means so abundant as iron, nor so easily procured, it is, perhaps, almost as widely scattered through the mineral kingdom, and has been certainly as long, if not longer, known.

When gold is found in the sand of rivers, no other process is employed than to wash the sand well with a quantity of water, so that all the lighter particles are carried off. In general, the quantity of metal contained in the sand



*and occasionally with tellurium: What are ITS PROPERTIES?*

It is of a fine reddish-yellow colour, and may be made to assume a degree of lustre inferior only to that of steel, platinum, silver, and mercury. Its specific gravity is 19.3. In malleability and ductility it is superior to all the other metals,\* and its tenacity is considerable;—a wire of  $\frac{1}{1000}$ th of an inch in diameter will support a weight of 150lbs. It fuses at about 1300° Fahr., and it is not altered by exposure to air or water. The only acids which act on it are *aqua regia*, (a mixture of muriatic and nitric acids,) and muriatic acid mixed with chromic acid: aqueous chlorine also dissolves it.† Its atomic weight is 200.

is so small that this process, though there seems nothing costly in it, requires so much time and labour, as, in fact, to be very expensive. Gold has, indeed, occasionally been found so plentiful, that the Spaniards on one occasion, collected in a few hours upwards of £30.000 worth. One piece weighed 132 ounces, and was worth £500.; but such mines are like hidden treasures; and if they were frequent, and could be worked at pleasure, would reduce the value of the metal as low as that of copper. When gold is found alloyed with silver, and mixed with earthy matter, it is separated by amalgamation with mercury, a process which I need not describe here.

\* The method of extending gold used by the gold beaters, consists in hammering a number of thin rolled plates between skins or animal membranes. By the weight and measure of the best wrought gold leaf, it is found, that one grain is made to cover  $56\frac{3}{4}$  square inches; and from the specific gravity of the metal, together with this admeasurement, it follows, that the leaf itself is  $\frac{1}{282000}$ th part of an inch thick. This, however, is not the limit of the malleability of gold; for the gold-beaters find it necessary to add three grains of copper in the ounce to harden the gold, which otherwise would pass round the irregularities of the newest skins, and not over them; and in using the old skins, which are not so perfect and smooth, they proceed so far as to add twelve grains.

† Gold is precipitated from its solution in *aqua regia*, by a great number of substances. Lime and magnesia precipitate it in the form of a yellowish



*With what substances does it combine?*

It combines with oxygen forming an *oxide of gold*, with chlorine, forming a *chloride*, and also with sulphur, &c. A purple oxide is formed when gold leaf is burnt by electricity, or gold wire by the Voltaic battery, but its composition has not been ascertained.\* Gold forms alloys with the other metals.†

*The ores of PLATINUM are rare, and have been found chiefly in South America and Spain.‡*

powder. Alkalies exhibit the same appearance; but an excess of alkali re-dissolves the precipitate. Most metallic substances also precipitate it: lead, iron, and silver, throw it down of a deep and dull purple colour; copper and iron in its metallic state; bismuth, zinc, and mercury, likewise precipitate it. A plate of tin, immersed in a solution of gold, affords a purple powder, called the *purple powder of Cassius*, which is used to paint in enamel, and for colouring glass and porcelain.

*Fulminating gold* is formed by precipitating the solution of gold in aqua regia by ammonia. This precipitate, which is of a brown, yellow, or orange colour, possesses the property of detonating with a very considerable noise when gently heated. Much caution is necessary in preparing this substance. It ought not to be dried but in the open air, at a distance from a fire, because a very gentle heat may cause it to explode.

\* According to Pelletier, there are *two chlorides of gold*, but they are not worthy of particular notice.

† When alloyed with bismuth, it presents the remarkable fact of the gold becoming brittle by the addition of the smallest quantity of that metal. Copper renders gold less ductile, harder, more fusible, and of a deeper colour. This is the usual addition in coin, and ornamental articles of gold. The gold coins of Great Britain contain eleven parts of gold, and one of copper. With iron, gold forms a grey mixture, which obeys the magnet. This alloy is very hard, and is said to be much superior to steel for the fabrication of cutting instruments.

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

‡ It was first discovered to be a distinct metal about the year 1750. It was first found at Choco in Peru, and in the mine of Santa Fè near Cartha-



*They always consist of small roundish flattened grains or scales. What are the properties of platinum?*

It is a metal of a white colour, resembling silver but much less brilliant. It is by much the heaviest body in nature, its specific gravity being about 21.5.\* It is considerably harder than gold or silver, and very malleable and ductile. It is extremely difficult of fusion, the strongest heat of a smith's forge not affecting it; but a small wire of it may be fused by means of Voltaic electricity, or the oxy-hydrogen blow-pipe. When urged by a white heat, it is capable of being welded like iron. (See page 413). None of the pure acids, even in their most concentrated state, act upon it; but it is speedily corroded by caustic alkalies, and even some neutral salts. Its solvents are *aqua regia* and chlorine.†

gena; and it has since been discovered in the *silver* mine of Guadalcanal in the Province of Estramadura in Spain. It has also been found in the Brazils, and St. Domingo. Very recently, it is said, (*Edinb. Journal of Science*, No. X.) rich mines of gold and platinum have been discovered in the Uralian mountains. In 1814, a mass weighing 1lb. 9oz. 1 drachm, was picked up in Quebrada de Apoto, in the Province of Notiva, government of Choco, in South America. This was considered so great a curiosity, that it was presented by its proprietor, Dr. J. Hurtado, to the King of Spain, and it is now deposited in the Museum at Madrid. The platinum ore always contains four other new metals, palladium, iridium, osmium, and rhodium, which have already been described. It is brought from America in the impure state in which it is found. To purify it the ore is dissolved in *aqua regia*, with as little heat as possible; the solution is poured off the undissolved matter, and the platinum is precipitated by sal ammoniac. The precipitate is then washed, and exposed to a heat raised slowly to redness. By redissolving it, and repeating the process, pure platinum in grains is obtained. They are wrapped in a thin plate of the same substance, heated, and cautiously hammered till they are formed into an ingot.

\* Some place its specific gravity as high as 22. or 23.

† There are two *oxides of platinum*, and a *chloride* of the metal. It com-



*What are the USES OF PLATINUM?*

It is a metal of great value. From its uniting the indestructibility of gold with almost the hardness of iron, it is evidently peculiarly well adapted for a variety of purposes. It is therefore of great use for making crucibles, cups, tongs, and various other chemical vessels.\*

CADMIUM is a new metal first discovered by M. Stromeyer in 1817:† *What are its characters?*

It combines also with sulphur, phosphorus, &c., but these compounds need not be dwelt upon in an elementary work like the present.

Muriate of tin is the most delicate test of the presence of platinum. A solution of platinum so dilute as to be scarcely distinguishable from water, assumes a bright red colour, on the addition of a single drop of the recent solution of tin. Hydriodic acid is likewise a very good test for platinum. When dropped into a weak solution of that metal, it almost instantly produces a deep wine-red colour, or reddish-brown, which on standing becomes very intense. No other metallic solution gives similar results with this acid.

\* Platinum is now worth about 35 shillings per ounce.

A most valuable property of platinum is that of furnishing a light to the miner, when any ordinary lamp would either be extinguished or subject him to an explosion. The moment the common light in the safety-lamp is extinguished by the superabundance of carburetted hydrogen (*see* p. 233), a coil of platinum wire, suspended over it, becomes red-hot, and affords light enough for the men to find their way back from the threatened danger. When they return to where the air contains less than  $\frac{1}{4}$ th of carburetted hydrogen, the lamp is rekindled by the wire.

† M. Stromeyer first discovered it in some carbonate of zinc which he was examining in Hanover. It has been since found in the Derbyshire silicates of zinc. Mr. W. Herepath states, that he has obtained cadmium in abundance from the zinc works near Bristol.—*See Annals of Philos.* vol. iii. p. 435.

Dr. Wollaston's process for procuring cadmium is as follows:—From the solution of the salt of zinc supposed to contain cadmium, precipitate all the other metallic impurities by iron; filter and immerse a cylinder of zinc into the clear solution. If cadmium be present, it will be thrown down in the metallic state, and when redissolved in muriatic acid, will exhibit its peculiar character on the application of the proper tests.

Stromeyer's process for obtaining it, may be seen in *Dr. Ure's Dict.* p. 241.



It is a metal of a white colour, with a slight shade of a bluish-grey similar to that of tin.\* It is ductile and malleable. Its specific gravity before hammering is 8.6040; when hammered, it is 8.6944. It melts, and is volatilized under a red heat. It crystallizes easily in octahedrons, and presents on its surface, when cooling, the appearance of leaves of fern. It is a little altered by exposure to the air as tin, but when heated in the air, it burns like that metal, passing into a smoke, which falls and forms a very fixed oxide, of a yellow or orange colour. Nitric acid readily dissolves it, and is its proper solvent; sulphuric and muriatic acids act upon it less easily.† Its atomic weight is 56.

*With what substances does it combine?*

It combines with oxygen in one proportion. It unites also with sulphur, phosphorus, and the other metals. The oxide of cadmium may be conveniently procured by igniting the carburet. As remarked, it is of an orange colour, and is fixed in the fire. It is insoluble in water, and does not change the colour of violets; but is a powerful salifiable base, forming neutral salts with acids.‡ It is composed of one atom of oxygen and one of base.

\* It resembles tin in lustre and susceptibility of polish.

† Dilute sulphuric, muriatic, and even acetic acids, act feebly on it with the disengagement of hydrogen. The solutions are colourless, and are not precipitated by water.

‡ These salts are almost all colourless, have a sharp metallic taste, and are generally soluble in water.

The sulphuret of cadmium, which occurs native in some kinds of zinc



*From what substance is the metallic LEAD of commerce extracted, and what are its properties?*

Lead is rarely found native. The metal is obtained from the native sulphuret.\* It is of a bluish-white colour, and when recently cut or melted, exhibits considerable lustre, which however, soon tarnishes. It is very soft, flexible, and malleable, but not very tenacious. Its specific gravity is 11.35. It melts at  $512^{\circ}$ . Exposed to a red heat, with free access of air, it fumes and sublimes, and affords a grey oxide, which collects on surrounding bodies. It is slowly oxidized, also, by exposure to the atmosphere at common temperatures; and more rapidly, when exposed alternately to the action of air and water. Its atomic proportion is 104.†

*How many oxides of lead are there?*

It is generally considered that there are three, but the opinion is not fully confirmed. The constitution of these three oxides is as follows:—

	<i>Lead.</i>	<i>Oxygen.</i>
Protoxide of lead consists of	1 atom	+ 1 atom
Deutoxide ..	1 atom	+ $1\frac{1}{2}$ atom
Peroxide ..	1 atom	+ 2 atoms.

blende, is easily procured by the action of sulphuretted hydrogen on a salt of cadmium. It has a yellowish orange colour, and is distinguished from the sulphuret of arsenic by being insoluble in pure potassa, and by sustaining a white heat without subliming.

\* The native sulphuret of lead is the *galena* of mineralogists.

† Most of the acids attack lead, but the nitric is its proper solvent. Sulphuric acid does not act upon it, unless it be concentrated and boiling. Lead is separated from its salts in the metallic state by either iron or zinc. The arborescent brilliant metallic substance (sometimes called the *lead tree*) produced from solution of sugar of lead by suspending in it a piece of zinc, is generally *pure lead*.



The *protoxide* of lead\* has a yellow colour, is tasteless, and insoluble in water, but soluble in potassa and in acids, forming the base of all the salts of lead. In commerce it is known by the name of *massicot*: and when partially fused by heat, it assumes the appearance of yellow scales, and is called *litharge*. The *deutoxide* has a brilliant red colour, and is known in commerce by the name of *minium*, or *red lead*.† The *peroxide* is of a puce colour.‡

*What are the USES OF LEAD?*

As is well known, it is a metal in very extensive use, and many of its uses are too familiar to need mentioning here. The uses of its oxides have been noticed; they are common pigments, and form an important part of flint glass. Some of

\* The protoxide is obtained by heating the carbonate or nitrate to redness in a close vessel. This oxide unites readily with earthy substances, forming with them a transparent colourless glass; which property renders it of great use in the glazing of earthenware and porcelain. It enters largely into the composition of flint glass, which it renders more fusible, transparent, and uniform.

† The deutoxide is formed by exposing the protoxide to heat with a large surface and free access of air. It does not unite with acids. When heated to redness it gives off pure oxygen gas, and is reconverted into the peroxide. *Red lead* is used as a pigment, and in the manufacture of flint glass. As commonly sold, it is very impure, containing the yellow oxide, sulphate of lead, submuriate of lead, and silica.

‡ It is obtained by exposing the red oxide to the action of nitric acid.

Lead also unites with chlorine, iodine, sulphur, and many of the metals. The *chloride* of lead is a semi-transparent, greyish-white mass, somewhat like horn, whence the old name of *plumbum corneum*, or *horn lead*. It is fixed at a red heat in close vessels, but evaporates at that temperature in the open air. The pigment called *mineral*, or *patent yellow*, appears to be a compound of the chloride and protoxide of lead.



its salts are much employed in medicine, and some of its alloys are of great utility.\*

*We have now to speak of the acidifiable metals: What are the characters of TELLURIUM?†*

Tellurium is a metal of a tin-white colour, varying to lead grey, with a high metallic lustre; of a foliated fracture; and very brittle, so as to be easily pulverized. Its specific gravity is 6.115., consequently it is one of the lightest metals, the bases of the alkalies and earths excepted. It melts before ignition, requiring a little higher heat than lead, and less than antimony; and, according to Gmelin, is as volatile as arsenic. It is oxidized when heated in contact with air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. This smoke when condensed, and examined in quantity, is found to be white with a tint of yellow. It is fusible by a strong heat, and volatile at a still higher temperature. It not only unites as a base with acids, but also itself possesses the character of an acid, and forms salts,‡ which may

\* Tin combines very easily with lead, and forms a compound, which is much more fusible than lead by itself, and is, for this reason, used as a solder for lead. Two parts of lead and one of tin form an alloy more fusible than either metal alone: this is the solder of the plumbers.

† It was discovered by Klaproth in an ore from the gold mines of Transylvania. It is a rare metal.

‡ Tellurium forms two distinct compounds with hydrogen, one of which, the *hydruret of tellurium*, is solid, the other, called *telluretted hydrogen*, is



be called *tellurates*. The atomic weight of tellurium is supposed to be 32.

ARSENIC is rarely found in the metallic state,\* the arsenic of commerce being in the state of an oxide. How many oxides of arsenic are there?

There are two known combinations of arsenic and oxygen; both of which are possessed of several of the properties of acids; and are, therefore, now commonly called *arsenious* and *arsenic acids*. The *arsenious acid* is the common white arsenic of the shops, and was formerly called by chemists the white oxide of arsenic. The greater part of the arsenious acid of commerce is brought from Bohemia and Saxony, where it is made in roasting cobalt and iron ores.†

What are the PROPERTIES OF ARSENIUS ACID?

It is met with both in the form of a dense, semi-transparent, solid cake, and as a white powder. It reddens the most sensible vegetable

a gas. The latter is made by igniting hydrate of potassa and oxide of tellurium with charcoal, and then acting on the mixture by dilute sulphuric acid, in a retort connected with a mercurial pneumatic apparatus. This gas possesses very singular properties, and was first discovered by Sir H. Davy in 1809. It is soluble in water, and forms a claret-coloured solution. It combines with the alkalies; burns with a bluish flame, depositing oxide of tellurium; and has a very strong and peculiar smell, not unlike that of sulphuretted hydrogen.

\* By enclosing in a glass tube a very small quantity of the white arsenic of the shops, and a little black flux, and applying the heat of a spirit lamp to the mixture, a portion of metallic arsenic sufficient for examination will sublime into the superior part of the tube. It will appear of a brilliant metallic aspect, not unlike polished steel.

† The roasting is performed in furnaces with long flues, in which the impure oxide is condensed, and this is purified by sublimation.

Fourcroy was the first who distinguished the common white arsenic by the name of arsenious acid.



blues, though it turns the syrup of violets green; it is inodorous, but has an acrid taste, and is highly corrosive and poisonous. Thrown on hot coals, it evaporates in white fumes, with a strong smell of garlic. It is sparingly soluble in water.\* Its specific gravity is 3.7. It combines with the salifiable bases, forming a class of salts called *arsenites*. Its combining proportions have not been accurately determined; Berzelius says they are 1 atom of arsenic = 38 to 3 atoms of oxygen = 24, but according to Thomson, it contains only 2 atoms of oxygen.†

*Arsenious acid is universally known to be a virulent poison: Suppose you were required to determine whether a solution supposed to contain arsenic, did contain it or not, how would you proceed?*

There are several tests used for detecting arsenic, but the best is *sulphuretted hydrogen gas*, which passed through the suspected solution‡ immediately throws down a golden yellow pre-

\* It requires for solution 13 times its weight of boiling water, and 80 times its weight of cold. It is also soluble in oils, pure potassa, and alcohol; the last taking up from 1 to 2 per cent.

† The *arsenic acid* does not require to be dwelt upon. It is made by dissolving arsenious acid in concentrated nitric, mixed with a little muriatic acid, and distilling the solution to perfect dryness. This acid has a sour metallic taste, reddens blue vegetable colours, and unites with alkalies forming neutral salts, called *arseniates*. It is much more soluble in water than arsenious acid, dissolving in 5 or 6 times its weight of cold, and in a still smaller quantity of boiling water. When urged by a very strong red heat it is resolved into oxygen and arsenious acid. It is an active poison.

‡ Sulphuretted hydrogen gas may readily be passed through any liquid by pouring diluted sulphuric acid on sulphuret of iron in a common bottle, from the mouth of which proceeds a bent glass tube terminating in the suspected liquor.



precipitate if arsenic be present, which precipitate is *orpiment*, or sulphuret of arsenic. This is a pretty sure criterion of the existence of arsenic, and will detect it when given in tea, porter, or similar fluids; but in order to render the fact certain, the revival of the metal must be attempted. The water being poured off, the golden yellow precipitate should therefore be dried, and a little of it put, with a small pinch of dry flux, into a narrow glass tube, sealed at one end; after cleansing its sides with a feather, its bottom must be urged with a blow-pipe till it be distinctly red-hot for a minute, when garlic fumes will be smelt, and the steel-lustred coating of *metallic arsenic* will be seen in the tube about one-fourth of an inch above its bottom.\*

\* This is decisive of arsenic being present; but to render the fact still more evident, the steel-lustred coating may be tested with the ammoniacal sulphate of copper. For this purpose, the tube should be cut across where the coating appears, by means of a fine file, and the scale of arsenic detached with the point of a pen-knife. Then put a fragment of it into the bottom of a small wine-glass along with a few drops of ammoniaco-sulphate of copper, (that is, a solution of sulphate of copper having a few drops of aqua ammonia dropped into it,) and triturate them well together for a few minutes with a round-headed glass rod. The mazarine blue colour will soon be changed into a lively grass green (called *Scheele's green*,) while the metallic scale will vanish. Under the concurrence of these signs no one can consistently doubt the presence of arsenic.

Besides sulphuretted hydrogen, there are two other tests which are commonly used in attempts to discover arsenic. They are—

- 1st. The *ammoniaco-sulphate of copper* (alone), which throws down with arsenic, as just observed, a beautiful grass green.
- 2d. The *ammoniaco-nitrate of silver*, which throws down a pale yellow. This is made by dropping ammonia into a solution of lunar caustic till the oxide of silver first thrown down, is nearly all dissolved.



*With what other substances besides oxygen does ARSENIC combine?*

IT COMBINES also WITH CHLORINE, forming a CHLORIDE OF ARSENIC; WITH HYDROGEN, forming ARSENIURETTED HYDROGEN; and WITH SULPHUR, in two proportions, forming SULPHURETS OF ARSENIC.\* The protosulphuret of arsenic is *red*, and is called *realgar*; the persulphuret is of a *rich golden colour*, and is called *orpiment*. Both these compounds are used as pigments. Orpiment is the colouring principle of the paint called *king's yellow*.†

The revival of the metal in the way advised, after the formation of the yellow precipitate by the use of sulphuretted hydrogen gas, is necessary, because this gas causes a yellow precipitate with four other metals, namely, selenium, cadmium, tin, and antimony. This yellow is not, however, so fine a golden yellow as that afforded by arsenic.

\* The *chloride of arsenic* may be formed by throwing the metal, finely powdered into chlorine, when the former inflames, and a whitish deliquescent and volatile compound results, or by distilling a mixture of six parts of corrosive sublimate with one of arsenic. It consists of 1 atom of arsenic, and 2 atoms of chlorine.

The *arseniuretted hydrogen gas* was discovered by Scheele, and may be procured by dissolving an alloy of 14 parts of tin and 1 of arsenic in muriatic acid. This substance has an extremely fetid smell, and burns with a blue flame, when brought near an inflamed taper. It inflames spontaneously when acted upon by chlorine. It is sparingly soluble in water. It is highly poisonous. Its atomic constituents have not been accurately determined.

† Both of these sulphates are found native. They may also be formed artificially, the red by fusing white arsenic with sulphur; the yellow by dissolving white arsenic in muriatic acid, and precipitating by hydrosulphuret of ammonia, or sulphuretted hydrogen gas. The former is said to consist of 1 proportion of each ingredient, and the latter of 1 proportion of arsenic to  $1\frac{1}{2}$  of sulphur.

Orpiment, besides being used as a pigment, is employed in calico-printing to de-oxygenate indigo, which thus becomes capable of attaching itself to the cloth. M. Braconnot recommends *realgar* for dyeing wool, silk, or cotton, of a fine yellow colour. Having mixed 1 part of sulphur, 2 parts of white arsenic, and 5 of potash of commerce, melt them in a crucible at a heat near that of redness. The yellow mass thus obtained is to be dis-



Arsenic also unites with phosphorus, and with the other metals.\*

*What are the PROPERTIES of CHROMIUM?*

It is a brittle metal, of a greyish-white colour. It requires an intense heat for its fusion, and is with great difficulty acted on by acids. It does not readily enter into combustion, and has a specific gravity of 5.9. Its atomic weight is 28.†

*How many oxides of chromium are there?*

It is generally supposed to combine with chromium in three proportions, forming a *protoxide* and *deutoxide of chromium*,‡ and *chromic acid*. Their constituents are as follows—

solved in hot water, and filtered. It is then to be diluted, and sulphuric acid poured into it, of such a strength as to produce a fleecy precipitate of a superb yellow colour. This dissolves with facility in ammonia, and gives a yellowish liquor, into which is to be poured an excess of ammonia for the purpose of discolouring it entirely. Goods plunged into this solution come out colourless, but they assume a fine yellow as the ammonia evaporates. The colour is durable, and resists acids but not alkalies.—*Annal. de Chim. et de Phys.* tom. xii.

\* Arsenic is used in a variety of arts. Besides the uses already assigned to it, it enters into metallic combinations, wherein a white colour is required, and is employed by glass manufacturers.

† There are two *ores* from which chromium may be procured; one is the red lead ore of Siberia, the *chromate of lead*; the other is the *chromate of iron*, which has been found in France, North America, and in Shetland. The latter is the cheapest and most abundant.

There are several processes recommended for extracting chromium from the ore. This metal was discovered by Vauquelin in 1797, in the red lead ore of Siberia. To obtain it, this ore, in fine powder, is boiled with twice its weight of carbonate of potassa. An orange-yellow solution, composed of potassa and chromic acid, is thus obtained; and when to this a mineral acid is added, and the liquor is evaporated, we obtain, 1. the chromate of potassa; and 2. the chromic acid in long ruby-coloured prisms. From this acid the chromium may be obtained by igniting it with charcoal.

‡ The *protoxide* is of a green colour, infusible, indecomposable by heat, reducible by voltaic electricity, and not acted on by oxygen or air. Dr. Thomson obtained this oxide by dissolving a quantity of chromate of po-



	Chromium.	Oxygen.	Atom.Weight.
Protoxide of Chromium	1 atom . . . . .	1 atom =	36
Deutoxide . . . . .	1 atom . . . . .	2 atoms =	44
Chromic Acid . . . . .	1 atom . . . . .	3 atoms =	52

*How is CHROMIC ACID procured, and what are its properties?*

It may be obtained by mixing nitrate of baryta with chromate of potassa,\* when chromate of baryta is formed, and may be decomposed by adding its equivalent of sulphuric acid, which precipitates the baryta, leaving the chromic acid in solution. By cooling and evaporation, the acid crystallizes in long prisms of a ruby red. Its taste is acrid and styptic, and it powerfully reddens the tincture of turnsole. Its specific gravity is not exactly known, but it always exceeds that

tassa in water, and adding tartaric acid to the solution. The chromic acid was thus changed into a fine green protoxide, which was precipitated by ammonia, then washed, and dried in the air. In this state it is a fine powder, exceedingly light, tasteless, and dissolving with facility in acid. When gradually heated to redness out of the contact of air, it lost a quantity of water, equivalent to 26 atoms, which had been united with 1 atom of protoxide, a proportion of water greatly exceeding that found in any other metallic hydrate.

It is this oxide which gives to the emerald its beautiful green colour, and it is employed to give an artificial green to glass and enamel. Chromic acid is the colouring matter of the spinelle ruby.

The *deutoxide* of chromium is procured by exposing the protonitrate to heat, till the fumes of nitrous gas cease to issue. A brilliant brown powder, insoluble in acids, and scarcely soluble in alkalies, remains. Muriatic acid digested on it exhales chlorine, showing the increased proportion of oxygen in this oxide.

\* "To obtain pure chromic acid, we must distil fluor spar, chromate of lead, and sulphuric acid (anhydrous?) in a leaden retort, when a gaseous mixture of chromic and fluoric acids is evolved, that is readily absorbable by water. This mixed gas affords a thick orange smoke, and on coming in contact with air deposits small red crystals of chromic acid."—*Dr. Ure's Dictionary*, p. 28.



of water. If muriatic acid be distilled with the chromic acid, by a gentle heat, it is converted into chlorine. It likewise imparts to it by mixture the property of dissolving gold; in which the chromic resembles the nitric acid. Chromic acid unites readily with the alkalies and earths, forming *chromates*, and is the only acid that has the property of colouring its salts, whence it derives its name of chromic (from  $\chi\rho\omega\mu\alpha$ , *colour*).\* As already stated, its atomic weight is 52.

*What are the Uses of CHROMIUM?*

Its principal use is in the preparation of the beautiful pigment, chromate of lead, which is used to a great extent in painting, and also in dyeing.

*What kind of a metal is MOLYBDENUM? †*

It is a brittle metal, of a whitish-yellow colour, almost infusible by any heat, and having a specific gravity of 8.611. It has hitherto only been obtained in small quantities. It is readily oxidized when heated in contact with air, and is converted into a white oxide, which is volatilized in small brilliant needle-shaped crystals, and

\* Chromic acid, heated with a powerful acid, becomes chromic oxide; while the latter, heated with the hydrate of an alkali, becomes chromic acid.

Chromic acid combines with potassa in two proportions, forming a *chromate* and *bichromate of potassa*. These salts are noticed in the chapter on *Salts*. The former is of an intense lemon-yellow colour, with a slight shade of orange. Its taste is cooling and disagreeable. The bichromate of potassa is of a beautiful orange red colour, and has a metallic bitter taste. It is less soluble in water than the former salt.

† The common ore of molybdenum was long mistaken for plumbago, or carburet of iron, to which it bears a great resemblance. Hielm first obtained the metal called molybdenum from this ore, in 1782.



possesses acid properties. This is *molybdic acid*. There appears to be only two well ascertained compounds of molybdenum and oxygen; one is the acid just described, the other is *molybdous acid*, which is formed by triturating 2 parts of molybdic acid, with 1 part of the metal, along with boiling water, then filtering, and evaporating the solution at a temperature not exceeding 130° Fahr. It is a fine blue powder.\*

*Describe the* CHARACTERS OF TUNGSTEN. †

It is a metal of a greyish-white colour, with considerable lustre, and very hard and brittle. Its specific gravity is about 17.8; and it requires the strongest heat of a forge for its fusion. It is scarcely affected by exposure to air at common temperatures, but is oxidized by the conjoined action of heat and air. It combines with oxygen in two proportions.‡ Neither this metal nor its oxides have yet been put to any use.

† The compounds of molybdenum and oxygen are very imperfectly known, and therefore different opinions are entertained about them. Berzelius has lately described what he considers two oxides of molybdenum, and he says, that the blue powder described above as molybdous acid, is a bimolybdate of the deutoxide of molybdenum.

The molybdic and molybdous acids, as above described, both change the vegetable blues to red, and form salts with the bases.

† Tungsten is obtained from a mineral called *wolfram*, in which it is united with iron and manganese; and also from another mineral called tungsten, which consists of tungstic acid, united with lime. Tungsten in its metallic form was first procured by MM. D'Elhuyars, in 1782.

‡ The first oxide, procured by the action of heat, is flea brown. This, when heated, burns like tinder, and is converted into the second which is yellow, and is commonly termed *tungstic acid*. This acid is tasteless, insoluble in water, and does not affect vegetable colours; but it unites with the bases, forming *tungstates*.

Tungsten unites with chlorine, sulphur, &c. but the compounds thus formed are not worthy of particular notice here.



*What are the* CHARACTERS OF COLUMBIUM?

This metal was discovered by Mr. Hatchett, in 1802. It has a dark grey colour; and when newly abraded the lustre nearly of iron. Its specific gravity is about 5.61. Neither nitric, muriatic, nor nitro-muriatic acid, produces any change in columbium, though digested on it for several days. It is not a metal of any importance. It unites with oxygen in one proportion, which compound possesses acid properties, and is called *columbic acid*. This acid is in the form of a white powder.\*

SELENIUM is a more interesting and important metal than either of the three preceding metallic substances: *What are its* PROPERTIES?†

When, after being fused, it becomes solid, its surface assumes a metallic brilliancy of a deep brown colour. It is brittle like glass, and its

\* Columbium was discovered by Mr. Hatchett in a mineral deposited in the British Museum, supposed to be brought from Massachusetts in North America. It has also been found in two different fossils, brought from Finland, called *tantalite* and *ytthro-tantalite*. Mr. Ekeberg, a Swedish chemist, who discovered the metal in these fossils, called it *tantalum*, supposing it was a different metal from columbium, but their identity has been established by Dr. Wollaston.

*Columbic acid* is insoluble in nitric and sulphuric acids, but partially in muriatic. Fixed alkalies attack it when fused with it in considerable excess, and dissolve a considerable quantity which may afterwards be precipitated by acids, even by the carbonic.

§ Selenium was discovered in 1818, by Berzelius, in the iron pyrites of Fahlun. Stromeyer has since found it in fuming sulphuric acid from Nordhausen, and also in the volcanic productions of the Lipari islands. It has hitherto been obtained only in very small quantities. For the mode of extracting it from pyrites see Berzelius's *Memoirs* in *Ann. de Chimie et de Phys.* tom. ix., or *Annals of Philosophy*, for June, 1819, *et seq.* Its atomic weight is 40.



fracture is conchoidal, vitreous, of the colour of lead, and perfectly metallic. In powder it has a deep red colour; and in very thin coats is transparent, with a ruby-red colour. When heated it softens; at  $212^{\circ}$  it is semi-liquid, and melts completely at a temperature a few degrees higher. In its softened state, it may be kneaded between the fingers, and drawn out into long threads, which have a great deal of elasticity and transparency. These threads, viewed by transmitted light, are red; but, by reflected light, they are grey, and have the metallic lustre. It is not a good conductor of heat, and is a non-conductor of electricity. Its specific gravity is between 4.3 and 4.32.

*Does it combine with oxygen?*

Yes; it unites with that element in three proportions, forming *oxide of selenium*, and *selenious* and *selenic acids*. If selenium be heated in the open air, and a flame directed on it by the blow-pipe, its edges assume a fine sky-blue colour, and it is volatilized with a strong smell of horseradish.\*—This odorous gas is the oxide of selenium. Selenious acid may be conveniently prepared by digesting selenium in nitric or nitromuriatic acid till it is completely dissolved, when by evaporating the solution to dryness, a white residue is left, which is selenious acid. This acid absorbs a little moisture from the air, and is very

\* This forms a good character of selenium, and by which it may always be detected whether alone or in combination.

The atomic weight of this metal is 40.



soluble both in cold and hot water. It has a pure acid taste, and its salts are called *selenites*.†

† The acid above called *selenious acid*, consists of 1 atom of base and 2 atoms of oxygen, and was formerly called *selenic acid*, no other acid of selenium being supposed to exist, but lately an acid has been discovered consisting of 1 atom of selenium and 3 atoms of oxygen, which must therefore be termed selenic acid. This acid may be obtained by fusing nitrate of potassa or soda with selenium, a metallic seleniuret, or with selenious acid, or any of its salts. It is a colourless liquid, and will bear a heat of 536° F. without being sensibly decomposed; but above that temperature decomposition takes place. At 329° F. its specific gravity is 2.524.; at 512° F. it is 2.60., and at 545° F. it is 2.625, but then a little selenious acid is present. Procured by the above process, it is always combined with water, but it is exceedingly difficult to arrive at the precise proportion. It has a very great affinity for water, and resembles sulphuric acid in not being decomposed by sulphuretted hydrogen, so that this gas may be used for decomposing the seleniates of lead and copper. If it be boiled with muriatic acid, the change is peculiar;—chlorine is set free, selenious acid is generated, and the solution possesses the property of dissolving gold or platinum, like the *aqua regia*. Selenic acid dissolves zinc and iron, hydrogen gas at the same time being liberated; it also dissolves copper, selenious acid being produced. It will likewise dissolve gold, but not platinum. For a further account of its properties, see the *Ann. de Chim. et de Phys.* or *Maugham's Annals of Chem. Philos.* for Dec. 1828.



## CHAPTER XI.

## OF SALTS.

*What is a SALT?*

It is a compound from which an acid and a base\* may be extracted, in definite proportions.† The term has been usually employed to denote a definite compound of an acid with an alkali, earth, or metallic oxide; but this is evidently an incorrect definition, because there are salts which do not contain either an acid, alkali, earth, or metallic oxide.

*Will you name such a salt?*

The very substance that first gave rise to the term salt, namely, COMMON SALT, is such a substance. It is a chloride of sodium, and is therefore a compound of chlorine with a metal.‡

\* A *base* is a term usually applied to alkalies, earths, and metallic oxides, in their relations to the acids and salts. Thus, in sulphate of soda or lime, which are compounds of sulphuric acid with soda or lime, the soda and lime are said to be the bases of those salts. Such bases are often termed *salifiable* bases. The word base is sometimes likewise applied to the particular constituents of an acid or an oxide. For example, in sulphuric acid, which is constituted of sulphur and oxygen, sulphur is called the base; so in oxide of iron, the iron is termed the base.

† This is the best definition of a salt I am acquainted with, as it is applicable to every variety of salts, since an acid and a base may be *extracted* from all of them, although they do not all contain an acid.

‡ In its *dry* state it is a chloride of sodium, but in solution in water it is a muriate of soda, as we have already remarked, p. 321. The same remarks may be made with regard to the salt usually called muriate of lime, which



*How many CLASSES OF SALTS are there?*

THREE; namely, *sub-salts*, *neutral salts*, and *super-salts*. A *sub-salt* is one in which there is an excess of base; a *neutral salt* one in which the proportions of the constituents are so adjusted, that the resulting salt does not affect the colour of infusion of litmus, or red cabbage; and a *super* or *bi-salt* one in which there is a predominance of acid.\*

*Give an example of these three classes of salts.*

*Goulard's extract*, made by boiling litharge in vinegar, is a *subacetate* of lead; *Epsom salt*, or sulphate of magnesia, is a *neutral salt*; and the *acidulous sulphate of potassa* is a *super* or *bi-salt*.

*On what principle are salts now named?*

On that of making its name to afford an immediate insight into the composition or nature of the salt,† that is, of showing the acid and base of which it is constituted; thus, the salt formed of *sulphuric acid* and *magnesia* is called a *sulphate*

in its dry state is a *chloride of calcium*, giving muriate of lime by solution in water.

Sir Humphry Davy remarks, that very few of the substances which have been always considered as neutral salts, really contain, in their dry state, the acids and alkalies, from which they were formed. According to his views, the muriates and fluates must be admitted to contain neither acids nor alkaline bases. Most of the prussiates (or prussides) are shown by M. Gay Lussac to be in the same case. Nitric and sulphuric acids cannot be procured from the nitrates and sulphates, without the intervention of bodies containing hydrogen.

\* Salts are also sometimes divided into the three classes of *alkaline*, *earthy*, and *metallic salts*, according as their bases are alkalies, earths, ordinary metallic oxides, or metals.

† Thus, *chalk* is called *carbonate of lime*, showing it at once to be a compound of carbonic acid with lime; and *salt-petre* is termed *nitrate of potassa*, because it is constituted of nitric acid and potassa.



of *magnesia*; and when the acid is united with two bases, as in a triple salt, the same principle is adhered to, as, for instance, in the compound of *tartaric acid*, *potassa*, and *soda*, which is called a *tartrate of potassa and soda*.\*

*How many salts are there?*

The precise number are not known, but there are above 2000.†

*How does it arise that there are so many different salts?*

Because almost every acid is capable of com-

\* The principle of the present chemical nomenclature has been already explained at p. 133, where other remarks are made on this subject.

† The very large number of these compounds now known is naturally calculated to excite surprise in the mind of the youthful student. About forty years ago only thirty salts in all were known. I may with propriety take this opportunity of observing that, there are few subjects in natural philosophy, the contemplation of which is better calculated to exalt and improve the understanding than the vast and almost inconceivable divisibility of matter. The vegetable and animal kingdoms afford the most wonderful instances of the attenuation of matter. The *Vibrio Undula* found in duck-weed, is computed to be ten thousand million times smaller than a hemp-seed; and the *Monas Gelatinosa*, discovered in ditch-water, appears in the field of a microscope a mere atom endued with vitality, millions of which are seen playing, like the sun-beams, in a single drop of liquid. It has been calculated, that the skin is perforated by a thousand holes in the length of an inch; and if we estimate the whole surface of the body of a middle-sized man to be sixteen square feet; it must contain not less than two millions three hundred and four thousand pores. These pores are the mouths of so many excretory vessels, which perform the important function of *insensible perspiration*. The lungs discharge, every minute, six grains, and the surface of the skin from three to twenty grains, the average over the whole body being about fifteen grains of lymph, which consists of water, with a very minute admixture of salt, acetic acid, and a trace of iron. See *Elem. of Nat. Philos. by Professor Leslie*.

A correct idea may be formed from the above remarks, of the great importance of keeping the insensible perspiration unchecked and unimpaired; and for further proofs of the extraordinary influence of this discharge on the health and happiness of mankind, I beg leave to refer the reader to my *Treatise on the Art of prolonging Life*, p. 183.



binning with every alkaline base. The salts must therefore form a very numerous class of bodies.

*What is the most important general habitude of salts?*

Their solubility in water.\* Some dissolve in less than their weight of water; while others require several hundred times their weight of this liquid for solution, and others are quite insoluble.

*On what does this difference depend?*

On two circumstances, namely, on the degree of their affinity for water, and on their cohesion; their solubility being in direct ratio with the first, and in inverse ratio with the second.†

*What happens when saline solutions are evaporated?*

They crystallize more or less regularly. In other words, the particles of the salt arrange themselves into determinate forms, which process is termed CRYSTALLIZATION; the regular bodies so produced being called CRYSTALS.‡

*What circumstances are necessary, in the case of saline solutions, to perfect crystallization?*

The three most essential circumstances are

\* In this menstruum they are usually crystallized; and by its agency they are purified and separated from one another, in the inverse order of their solubility.

† It should be observed, however, that one salt may have a greater affinity for water than another, and yet be less soluble; an effect which may depend on the cohesive power of the salt which has the stronger attraction for water, being greater than that of the salt which has a less powerful affinity for that liquid.

‡ The form which salts assume in crystallizing is constant under the same circumstances, and constitutes an excellent character by which they may be distinguished from one another.



*time, space, and repose.* By allowing sufficient time, the superabundant fluid is slowly dissipated, so as to allow the particles of the salt to approach each other by insensible degrees, and without any sudden shock, in which case they unite according to their constant laws, and form a regular crystal.\* Space, or sufficient latitude for motion, is also a very necessary condition; for, if Nature be restrained in her operations, the products of her labour will exhibit marks of constraint. A state of repose in the fluid is absolutely necessary for obtaining regular crystals.†

*What is meant by WATER OF CRYSTALLIZATION?*

The crystals of most salts, in separating from the water in which they were dissolved, carry with

\* Indeed it is a general rule, that the slower the formation of a crystal is the more perfect will be its form; the larger, its size; and the harder and more transparent, its texture; while, on the contrary, too speedy an abstraction of the separating fluid will force the particles to come together suddenly, and, as it were, by the first faces that offer; in which case the crystallization is irregular, and the figure of the crystal indeterminate; and, if the abstraction be altogether sudden, the body will ever form a concrete mass with scarcely a vestige of crystalline appearance.

† All symmetrical arrangement is opposed by agitation, and a crop of crystals obtained under such circumstances would necessarily be confused and irregular.

If a concentrated saline solution, composed, for example, of about three parts of sulphate of soda in crystals to two of water, is made to boil briskly, and the flask which contains it is then tightly corked, while its upper part is full of vapour, the solution will cool down to the temperature of the air without crystallizing, and may in that state be preserved for months without change. Before removal of the cork, the liquid may often be briskly agitated without losing its fluidity; but on re-admitting the air, crystallization commonly commences, and the whole becomes solid in the course of a few seconds. The admission of the air sometimes, indeed, fails in causing the effect; but it may be produced with certainty by agitation or the introduction of a solid body, which acts as a nucleus. This phenomenon has been attributed to the influence of atmospheric pressure, but this seems doubtful, and its theory is not well understood.



them a quantity of water, which forms an essential part of the crystal: \* this is termed the water of crystallization.

*Is this water simply interposed between the laminae of the salt, or combined with the salt?*

It is chemically combined with the salt.†

*What is meant by EFFLORESCENCE and DELIQUESCENCE, which are terms often made use of in speaking of salts?*

Some salts lose their water of crystallization by mere exposure to the air, in consequence of which they pass into the state of a dry powder, which change is called *efflorescence*. Other salts, on the contrary, not only retain this water very strongly, but even attract more on exposure to the atmosphere, and become a liquid, or *deliquesce*.‡

*We will now advert to the general characters of*

\* It is essential to the regularity of their form, as well as to their transparency and density, and cannot be expelled without reducing them to shapeless masses.

† The proportion of water of crystallization varies greatly in different salts, but is uniform in the same salt. In some instances it constitutes more than half the weight of the salt, as in the case of sulphate of soda, carbonate of soda, nitrate of ammonia, &c. while in others it is extremely small. On exposing a salt of the former kind to heat, it is dissolved, if soluble, in its own water of crystallization, undergoing what is called *watery fusion*.

‡ It is proper to remark here, that certain crystalline forms are peculiar to certain substances; in other words, every substance, in crystallizing, has a tendency to assume a particular geometric figure. Thus, common salt and fluor spar crystallize in cubes; Epsom salt, in four-sided prisms; alum, in octahedrons. The surfaces which limit the figure of crystals are called *planes* or *faces*, and are generally flat. Those who wish to study the science of *crystallography*, may have recourse with great advantage to a treatise thereon by Mr. H. J. Brooke.



*the salts, derived from their peculiar acids :\** what are the CHARACTERS OF THE SULPHATES?

They may always be detected by barytic water, or a solution of any salt containing that earth, for example, muriate of baryta. When a little of this water or salt is dropped into an aqueous solution of any sulphate, a white precipitate, the sulphate of baryta, invariably subsides, which is insoluble in all the acids and alkalis.† When heated to redness with charcoal, the sulphates are converted into *sulphurets*.‡

\* The principal salts are—

Sulphates.	Chlorates.	Chromates.
Muriates.	Phosphates.	Borates.
Nitrates.	Prussiates	Hydriodates.
Carbonates.	Arseniates.	Ferrocyanates.

In addition to these, there are many salts formed by the union of vegetable and animal acids, as the acetic, citric, tartaric acids, &c. with the salifiable bases. These vegetable and animal acids have not yet been described, but will be treated of under the chapters on *Vegetable and Animal Chemistry*, where these salts will be noticed. The principal salts of this description are—

Acetates.	Malates.	Gallates.
Tartrates.	Oxalates.	Succinates.
Citrates.	Benzoates.	

† This is a character by which the presence of sulphuric acid may always be recognized.

An insoluble sulphate, such as the sulphate of baryta or strontia, may be detected by mixing it, in fine powder, with three times its weight of carbonate of potassa or soda, and exposing the mixture in a platinum crucible for half an hour to a red heat. Double decomposition ensues; and on digesting the residue in water, filtering the solution, neutralizing the free alkali by pure muriatic, nitric, or acetic acid, and adding muriate of baryta, the insoluble sulphate of that base is precipitated.

‡ The *sulphites* are decomposed by sulphuric and muriatic acids, sulphurous acid gas escaping with effervescence, which gas may easily be recognized by its odour (p. 264). The nitric acid, by yielding oxygen, converts them into sulphates. When exposed to moist air, they also absorb oxygen, and pass into the state of sulphates. They possess a disagreeable taste and smell, analogous to that of burning sulphur.



*What are the general characters of the MURI-ATES?*

They are distinguished from other salts by being immediately decomposed by sulphuric acid, white acrid fumes of muriatic acid being evolved; and also by forming the white insoluble chloride of silver when mixed with nitrate of silver. When mixed with nitric acid, they exhale the odour of chlorine. They are soluble in water,\* and undergo no change when heated with combustibles.

*What are the distinguishing characters of the NITRATES?*

They deflagrate by heat,† as, for instance, when thrown on red-hot coals or charcoal; and when mixed with strong sulphuric acid they evolve white, dense fumes, having the odour of nitric acid gas.‡ They are all decomposed by heat, and yield at first oxygen gas: and when mixed with combustible matter, produce, at a red heat, inflammation and detonation.§

\* With the exception of muriate of ammonia, none of these salts can be said to exist in a dry state (page 454); by heat, the oxygen of the base and the hydrogen of the acid pass off, and true *metallic chlorides* remain.

† For example, nitre, which is a nitrate of potash, immediately deflagrates on being thrown into the fire.

‡ Nitric acid forms soluble salts with all alkaline bases, and therefore the acid of the nitrates cannot be precipitated by any re-agent.

Besides the distinguishing characters mentioned above, the nitrates have the power of dissolving gold leaf on the addition of muriatic acid. See page 178.

§ On this account the nitrates are much employed as oxidizing agents, and frequently act with greater efficacy even than nitro-muriatic acid. “Thus, metallic titanium, which resists the action of these acids, combines with oxygen when heated with nitre. The efficiency of this salt, which is the ni-



*How would you distinguish the salts called CARBONATES ?*

They are characterized by being decomposed, with effervescence, by nearly all the acids, even the acetic, when they evolve carbonic acid gas, which, passed into lime water by a tube, deprives it of its taste, and converts it into carbonate of lime or chalk, and pure water. All the carbonates, excepting those of potassa, soda, and lithia, may be deprived of their acid also by heat.\*

*What are the characters of the CHLORATES ? †*

They are decomposed by a red heat, with a disengagement of a great quantity of pure oxygen gas, (page 142,) nearly all of them being thereby converted into metallic chlorides. They detonate with combustible substances, as charcoal or sulphur, for instance, with much greater violence than the nitrates. They yield oxygen with so great facility, that an explosion is produced by slight causes, as by friction or percussion. Thus the mixture employed in the percussion locks for

trate usually employed for the purpose, depends not only on the affinity of the combustible for oxygen, but likewise on that of the oxidized body for potassa."—*Turner's Chem.* p. 572.

The process for oxidizing substances by means of nitre, is called deflagration, and is generally performed by mixing the inflammable body, with an equal weight of the nitrate, and projecting the mixture in small portions at a time into a red hot crucible.

\* Some of the species, as the carbonate of baryta and strontia, require an intense white heat for their decomposition; the others are decomposed either by a full red or dull red heat. Excepting the carbonate of potassa, soda, and ammonia, they are all sparingly soluble in water.

† In their properties they are analogous to the nitrates.



guns consists of sulphur and chlorate of potassa.\* By the action of strong sulphuric, nitric, or muriatic acid, the chlorates evolve yellow or green fumes, that is, either protoxide or deutoxide of chlorine, or chlorine itself.†

*How would you know the salts called PHOSPHATES? ‡*

They are precipitated by nitrate of barytes, which precipitate is resolvable in an excess of acid. They are soluble in nitric acid without effervescence, and are precipitated from that solution by lime water. Before the blow-pipe they are converted into a globule of glass, which in some cases is transparent, in others, opaque.§

*How do you distinguish the CHROMATES? ||*

These salts are mostly either of a yellow or red colour, the latter tint predominating whenever the acid is in excess. And on boiling a chromate in muriatic acid mixed with alcohol,

\* The mixture used for making the matches employed for procuring an instantaneous light, is composed of chlorate of potassa combined with a little sugar and colouring matter. With phosphorus the chlorate of potassa detonates most violently by percussion.

† All the chlorates are very soluble in water, excepting the proto-chlorate of mercury.

‡ The *phosphites* are of very little importance.

§ The neutral salts of phosphoric acid with fixed bases sustain a red heat without decomposition, but they are all fusible at a high temperature. The neutral phosphates, excepting those of potassa, soda, and ammonia, are of sparing solubility in water. Of all the phosphates, those of baryta, lime, and lead, are the most insoluble.

|| With regard to the arseniates, it may be observed, that most of them bear a red heat without decomposition; but they are all decomposed by being heated to redness along with charcoal, metallic arsenic being set at liberty. The soluble arseniates, when mixed with the nitrate of lead or silver, form insoluble arseniates, the former of which are white, and the latter a brick red colour.



the chromic acid is at first set free, and is then decomposed, a green muriate of the oxide of chromium being generated.

*In what way are the BORATES distinguished?*

If any borate is digested in a slight excess of strong sulphuric acid, evaporated to dryness, and the residue boiled in strong alcohol, a solution is formed, which has the property of burning with a green flame. This is the distinguishing mark of these salts.\*

*What is the distinguishing character of the FLUATES?*

They are known by dropping on them strong sulphuric acid, when a vapour (fluoric acid gas) exhales, which readily corrodes glass.

*We must now speak of the principal sulphates, muriates, &c. individually. Name THE PRINCIPAL SULPHATES.*

I have before remarked, that these are a class of salts of great value and importance. The chief are the *sulphates of potassa, soda, magnesia, iron, zinc, and copper*; and the *sulphates of baryta, strontia, lime, alumina, and potassa*.† The first six salts now named are valuable remedies in the hands of the

\* In regard to the *hydriodates*, chlorine, nitric acid, and concentrated sulphuric acid, instantly decompose them, and separate the iodine; but sulphurous and muriatic acids, and sulphuretted hydrogen, produce no change on them, at the usual temperature of the air. With solution of silver, the *hydriodates* give a white precipitate insoluble in ammonia; with the pernitrate of mercury, a greenish-yellow precipitate; and with corrosive sublimate, a precipitate of a fine orange-red, very soluble in an excess of hydriodate. They dissolve iodine, and acquire a deep reddish-brown colour.

† There are also *sulphates of lithia, ammonia, alumina, manganese, nickel, mercury, glucina, &c.* but all these are of very inferior importance.



skilful physician, and some of them are likewise useful in chemistry and the arts. Of the remaining five, none are employed in medicine, excepting the sulphate of alumina and potassa (alum,) but they are otherwise of great value.

*How is the SULPHATE OF POTASSA procured?*

It may be formed by saturating diluted potassa with sulphuric acid, and then evaporating the solution gently till crystals appear; but the usual and cheapest mode of procuring it is to ignite the bisulphate, left after the operation for preparing nitric acid.\*—See page 198.

*How is the SULPHATE OF SODA commonly prepared?*

\* There are two sulphates of potassa, the sulphate and bi or super-sulphate. As before remarked, the latter is called the acidulous sulphate. By ignition, the excess of sulphuric acid is driven off from the latter salt, leaving the former or neutral sulphate. The sulphate of potassa has had many names, having formerly been called *specificum purgans*, *arcantum duplicatum*, *panacea holsatica*, *sal de duobus*, &c. I have observed, at page 263, that it is of great service in medicine as a mild purgative. So great was its reputation in the 17th century, that the Duke of Holstein, about 1663, purchased the preparation of this salt for 500 dollars, as a remedy in fevers, stone, and scurvy. In the relief of these disorders it can act only as a gentle aperient or purgative, for it has no other medicinal operation; and if it is so effectual as our forefathers thought in such maladies, the circumstance may be brought forward as an additional corroboration of a fact I have long been endeavouring to impress upon the minds of my readers, namely, the paramount importance of the healthy actions of the alimentary canal to the well being of the whole frame.

This salt crystallizes in six-sided prisms, bounded by hexagonal pyramids. Its taste is bitter, acrid, and a little saline. It is soluble in 5 parts of boiling water, and 16 parts at 60°. The crystals contain no water of crystallization, and suffer no change by exposure to the air. In the fire it decrepitates, and is fusible by a strong heat. It is decomposable by charcoal at a high temperature. It is composed of 1 atom of acid = 40, and 1 of base = 48. Its atomic weight is therefore 88. The bisulphate of potassa contains 2 atoms of acid to 1 of base. It has a strong sour taste, and is much more soluble in water than the neutral sulphate.



From the residuum left after distilling muriatic acid. See page 177. It is likewise prepared in great quantities by the manufacturers of muriate of ammonia.\* It is found native in some countries, as Persia, Bohemia, and Switzerland, where it exists in large quantities under the surface of the earth.† It is an efflorescent salt, has a bitter saline taste, and is very soluble in water.‡

SULPHATE OF MAGNESIA is the well known EPSOM SALT:§ *How is it generally procured?*

This salt exists in considerable quantities in sea-water, and the uncrystallized residuum in the salt pans of the manufacturer, after all the common salt has crystallized, consists partly of sulphate of magnesia dissolved in water. The residuum is called *bittern*, from which the salt is extracted in great abundance. || Its taste is uni-

\* It crystallizes in hexagonal prisms bevelled at the extremities, sometimes grooved longitudinally, and of a very large size, when the quantity is great. When exposed to heat, it first undergoes the *watery fusion*, then its water evaporates, and it is reduced to a white powder; by urging the fire, it melts. It is composed of 1 atom of acid and 1 of base in its dry state, to which, when in crystals, 10 atoms of water are added.

† It is likewise found mixed with other substances in mineral springs, and sea-water; and sometimes effloresces on walls.

‡ It is soluble in 2.85 parts of cold water, and 0.8 at a boiling heat. When exposed to the air, it loses about 56 *per cent.* of its weight.

There is a *bisulphate of soda*, which, however, is of no importance.

§ The name of *Epsom salt* originated in its having formerly been procured from a mineral spring at Epsom in Surrey. Those waters contain it in considerable quantity (mixed with sulphate of soda), and were some years since in great repute for their efficacy in the cure of many diseases. That reputation has now passed away, having been transferred to the waters of Cheltenham and Leamington, which are undoubtedly of great medicinal efficacy, but assuredly not greater than the neglected water of Epsom.

|| For the purposes of commerce, it is often procured by the action of



versally known as cool and bitter. It is very soluble in water, requiring only an equal weight of cold water, and three-fourths of its weight of hot.\* It effloresces in dry air, though but slowly.†

*What are its USES?*

It is a very valuable purgative, and is employed for furnishing the carbonate of magnesia. Pure carbonate of magnesia can only be made by the decomposition of sulphate of magnesia.‡ These are its only uses.

*Sulphate of magnesia is frequently adulterated with sulphate of soda, the latter being a cheaper salt. How would you ascertain whether any sample of the former salt was so adulterated?*

The adulteration may be detected by the inferior weight of the precipitate, occasioned by adding carbonate of potassa: 100 parts of pure

dilute sulphuric acid on magnesian limestone, the native carbonate of lime and magnesia.

It has been found efflorescing on brick walls, both old and recently erected, and in small quantity in the ashes of coals.

\* When pure, it crystallizes in small quadrangular prisms, terminated by quadrangular pyramids or diëdral summits. Exposed to heat, it dissolves in its own water of crystallization, and dries, but is not decomposed, nor fused, but with extreme difficulty. According to Gay Lussac, the crystals are composed of 1 proportion of the dry sulphate and 7 proportions of water.

† If it attracts moisture from the air, (that is, if it *deliquesces*,) it contains muriate of magnesia or lime.

‡ For this purpose, it is usually decomposed by carbonate of potassa. Concentrated and hot solutions of carbonate of potassa and sulphate of magnesia are mixed altogether, when a double decomposition ensues, and carbonate of magnesia and sulphate of potassa are formed. The sulphate of potassa is removed by copious washing with water, and the carbonate of magnesia is then dried.



crystallized sulphate of magnesia furnish a precipitate of about 40 parts of dry carbonate.\*

*What is SULPHATE OF IRON called in commerce, and how is it procured?*

It is called GREEN VITRIOL or COPPERAS, and is generally formed by exposing native iron pyrites to air and moisture, when the sulphur and iron both absorb oxygen, and form sulphate of iron.†

*What are ITS PROPERTIES?*

It is in the form of beautiful green crystals, which are transparent and rhomboidal prisms. It has a strong styptic taste, reddens vegetable blues, and dissolves in two parts of cold and three-fourths of boiling water. It is insoluble in alcohol. Its specific gravity is 1.84. According to Dr. Thomson, it consists of 1 proportion of the dry salt and 7 proportions of water, but Mitscherlich says 6 proportions of water.‡

*What is the yellowish-red powdery incrustation which generally appears on the crystals of the sulphate of iron?*

\* There is an *ammoniaco-magnesian sulphate*, composed of sulphuric acid, magnesia, and ammonia, and also a *sulphate of magnesia and soda*, and a *sulphate of magnesia and potassa*. There is likewise a *sulphite of magnesia*.

† It is a *protosulphate* of iron, or a sulphate of the protoxide. There is a *persulphate* of iron. It is of no importance.

In this mode of preparing it, the solution always contains an excess of acid, and therefore it is necessary, in order to obtain the salt in crystals, to throw into it a quantity of old iron.

The protosulphate of iron we now advert to may be formed by the action of dilute sulphuric acid on metallic iron.

‡ According to Berzelius, its constituents are 28.9 acid, 28.3 protoxide, and 45 water.



It is the deutosulphate, which results from the protosulphate absorbing oxygen from the air.\*

*What is WHITE VITRIOL, and how is it prepared?*

It is a SULPHATE OF ZINC, and is usually prepared by roasting the native sulphuret of zinc.† Its crystals are four-sided flat prisms, terminated by quadrangular pyramids. The crystals dissolve in two parts and a half of cold water, and in very large quantity in boiling water. It has a strong styptic taste, and although a strictly neutral salt, like the sulphate of iron, it reddens vegetable blues. The crystals contain 7 atoms of water.

*And what is the salt commonly called BLUE VITRIOL, and how is it prepared?*

It is a SULPHATE OF COPPER, and is prepared by dissolving peroxide of copper in dilute sulphuric acid. It is a bisulphate. It consists of 1 atom of the peroxide of copper = 80, 2 atoms of sulphuric acid = 80, and 10 atoms of water = 90. Its atomic weight is therefore 250. Its specific gravity is 2.2. It forms regular crystals of a beautiful blue colour, reddens litmus paper, and

\* The sulphate of iron is employed in the preparation of sulphuric acid, and is used in medicine as a tonic.

† The sulphur attracts oxygen, and is converted into sulphuric acid; and the metal, being at the same time oxidated, combines with the acid. After some time, the sulphate is extracted by solution in water; and the solution being evaporated to dryness, the mass is run into moulds. Thus the white vitriol of the shops generally contains a small portion of iron, and sometimes of lead.

It is employed in medicine as an emetic, and sometimes as a tonic.



is soluble in four parts of cold water.\* It has a strong styptic metallic taste.

*What is the difference between VERDIGRIS and BLUE VITRIOL?*

They are both salts of copper, but the former is an acetate, while the latter, as I have just remarked, is a sulphate.†

*How is the SULPHATE OF BARYTA procured?*

It is found abundantly in a native state, forming what is commonly called *heavy spar*.‡ Its specific gravity is about 4.4. It bears an intense heat without undergoing any change, and is one of the most insoluble substances with which chemists are acquainted. Sulphuric acid, when concentrated and boiling, dissolves it sparingly, but it is precipitated by the addition of water. It appears to be constituted of 1 atom of baryta and 1 of sulphuric acid.§

\* The solution of sulphate of copper is decomposed by pure and carbonated alkalies; the former, however, redissolves the precipitate. Thus if we add pure ammonia to the solution, a precipitate occurs, but on a further addition of the alkali, it is redissolved, and a liquid of a beautiful bright blue colour results.

Sulphate of copper is decomposed by the alkalies and earths, the alkaline carbonates, borates, and phosphates, and by those metallic salts whose base forms with sulphuric acid a salt nearly insoluble, as the salts of lead.

† These salts of copper are poisonous in free doses. The best antidote is sugar.

‡ It may be artificially formed by dropping a solution of an alkaline sulphate into the solution of muriate or nitrate of barytes. It forms a white powder, which suffers no change by the action of the air, and is therefore sometimes used in water-colour painting.

According to Saussure, a heat equal to 35° Wedgwood is required to fuse it. When formed into a thin cake with flour and water, and heated to redness, it phosphoresces in the dark. This forms the *Bolognian phosphorus*, so called because it was first observed in a variety of heavy spar known by the name of Bologna stone.

§ *Sulphate of strontia* exists abundantly in different parts of the world,



SULPHATE OF LIME, *as before observed, is found native, in great abundance, under the names of GYPSUM, ALABASTER,\* &c. What are its PROPERTIES?*

It is insipid and free from smell, and is very sparingly soluble in water, requiring 500 times its weight of cold water, and 450 of hot water.† It is fusible by a moderate heat, and is decomposed by alkaline carbonates.‡ The anhydrous variety contains 1 atom of each ingredient; in its ordinary crystallized form, 2 atoms of water are added.

*What is ALUM?*

usually crystallized in rhomboidal prisms. It is the *celestine* of mineralogists. Its density is 3.858, and it is very sparingly soluble in boiling water.

\* All the varieties of *gypsum* are composed of this salt, united with water. The pure crystallized specimens of gypsum are sometimes called *selenite*; and the white compact variety is named *alabaster*. About 800 tons of alabaster are raised annually in Derbyshire, for the purpose of being wrought into columns, chimney pieces, and various ornaments.

When heated, it loses its water of crystallization, decrepitates, and falls into a soft white powder. This powder, when its water has been driven off by the application of a red heat, absorbs water very rapidly, and solidifies it; at the same time a slight increase of temperature takes place: so that if it be formed into a paste with water, it dries in a few minutes. In this state it is called *Plaster of Paris*, and is extensively employed for forming casts of anatomical and ornamental figures; as one of the bases of stucco; as a fine cement for making close and strong joints between stone, and joining rims or tops of metal to glass; for making moulds for the Staffordshire potteries; for cornices, mouldings, and other ornaments in building.

† From this it will be seen that it is much more soluble than the sulphates of baryta or strontia.

‡ In its decomposition by alkaline carbonates, a double exchange of principles ensues. Hence the milkiness which follows the addition of carbonate of potassa to many spring waters (from their containing sulphate of lime); the carbonate of lime, which is generated, being less soluble than the sulphate. This is also the reason why hard waters, which mostly contain sulphate of lime in solution, curdle soap, the alkali of which is detached by the sulphuric acid, and the oil is set at liberty.



It is a triple salt, the SULPHATE OF ALUMINA AND POTASSA.

*How is it made?*

It is usually prepared by roasting and lixiviating certain clays containing pyrites, sometimes called alum ores; to the leys, a certain quantity of potassa is added, and the triple salt is obtained by crystallization.\*

*What are its properties?*

It has a sweetish astringent taste, and a specific gravity of 1.71. It crystallizes in regular octahedrons, and dissolves in water, five parts of which, at 60°, take up one of the salt, but hot water dissolves about three-fourths of its weight. This solution reddens the blue colour of litmus. When heated, alum swells up, loses its regular form, and becomes a dry spongy mass, called burnt alum, *alumen ustum*.† Considerable difference of opinion exists regarding the composition of alum. Dr. Thomson states it to be—

\* Sulphuric acid and alumina will not crystallize, and are incapable of forming alum. The addition of potassa, or some other alkali, is necessary. In every case in which such additions are unnecessary, the earth from which the alum is obtained contains already a quantity of potassa.

† If the heat be considerable, it loses part of its acid; but Vauquelin says the whole of its acid cannot be thus expelled.

Alum is decomposed by charcoal, which combines with the oxygen of the sulphuric acid, and leaves the sulphur attached to the alumina. A combination of alumina, sulphur, and charcoal forms *Homborg's Pyrophorus*, which is a black, light powder, that instantly takes fire on being poured out of the bottle in which it is made. It also inflames suddenly in oxygen gas. It is prepared, by a particular process (see *Thomson's Chemistry*, vol. ii. p. 517), from equal parts of powdered alum and brown sugar.

All the varieties of alum are capable of combining with an additional dose of alumina, and forming perfectly neutral compounds.



1 atom of sulphate of potassa .....	=	88
3 atoms of sulphate of alumina ( $58 \times 3$ ) ..	=	174
25 atoms of water ( $9 \times 25$ ).....	=	225
		<hr/>
Atomic weight		487
		<hr/>

*What are the USES OF ALUM ?*

It is of extensive use in the arts, more especially in dyeing and calico printing, in which it is used as a *mordant*, to fix the dye-stuff, which it does in consequence of the attraction alumina has for colouring matter.\* It is sometimes employed in medicine as an astringent.†

\* In dyeing, a *mordant* is the substance combined with the vegetable or animal fibre, in order to fix the dye-stuff. It also usually modifies the colour. The art of dyeing is a chemical art, which consists in fixing permanently upon cloths of various kinds any colour which may be required, which object is usually accomplished by the intervention of a third substance, called the mordant. It is evident, that if the mordant be universally applied over the whole of a piece of goods, and this be afterwards immersed in the dye, it will receive a tinge over all its surface; but if it be applied only in parts, the dye will strike in those parts only. The former process constitutes the art of dyeing, properly so called; and the latter, the art of printing woollens, cottons, or linen, called calico printing. In the art of printing finer goods, the mordant is usually fixed with gum or starch, and applied by means of blocks or wooden engravings in relief, or from copper plates, and the colours are brought out by immersion in vessels filled with suitable compositions. Dyers call the latter fluid the bath. The art of printing affords many processes, in which the effect of mordants, both simple and compound, is exhibited.

The mordant employed for linens, intended to receive different shades of red, is prepared by dissolving in eight pounds of hot water, three pounds of alum and one pound of acetate of lead, to which two ounces of potassa, and afterwards two ounces of powdered chalk, are added.

A very common mordant for woollens is made by dissolving alum and tartar together; neither of which is decomposed, but may be recovered by crystallization upon evaporating the liquor.

† Alum is used in large quantities in many manufactories. When added to tallow it renders it harder. Printers' cushions, and the blocks used in the calico manufactory, are rubbed with burnt alum, to remove any greasiness, which might prevent the ink or colour from sticking. Wood sufficiently



*What are the PRINCIPAL MURIATES?*

The *muriate of potassa, soda, ammonia,\* lime, strontia, magnesia, baryta, and iron.*

*How is MURIATE OF LIME prepared?*

By neutralizing muriatic acid with pure marble (carbonate of lime). It is a very deliquescent salt even in a dry atmosphere, and is therefore very soluble in water. It crystallizes with difficulty in prisms, and is constituted of 1 atom of acid and 1 of base, with 7 atoms of water. It is the crystallized muriate of lime which produces so intense a degree of cold when mixed with snow.†

*In what way is MURIATE OF STRONTIA prepared?*

By dissolving the carbonate of strontia in dilute muriatic acid. It crystallizes in long slender hexagonal prisms, which are soluble in two parts of water at 69°, and to almost any amount in boiling water.‡ They dissolve in alcohol, and impart to it the property of burning with a blood-

soaked in a solution of alum does not easily take fire; and the same is true of paper impregnated with it, which is fitted to keep gunpowder, as it also excludes moisture. Paper impregnated with alum is useful in whitening silver, and silvering brass without heat. Alum mixed with milk helps the separation of its butter. If added in a very small quantity to turbid water, in a few minutes it renders it perfectly limpid, without any bad taste or quality; in which property it is superior to sulphuric acid. Crayons generally consist of the earth of alum, finely powdered, and tinged for the purpose.

\* The composition of *muriate of potassa* is described at p. 316; of *muriate of soda* at p. 461; and of *muriate of ammonia*, p. 209.

† See the chapter on *caloric*, and p. 335.

‡ They deliquesce in a moist atmosphere. The crystals consist of 1 atom of muriate of ammonia and 8 atoms of water.



red flame, which is one of the marks by which it is distinguished from muriate of baryta.\*

*How is MURIATE OF BARYTA best prepared?*

By dissolving the carbonate in dilute muriatic acid. When filtered and evaporated, the solution yields regular crystals of muriate of baryta, which have most commonly the shape of tables, bevelled at the edges, or of eight-sided pyramids, applied base to base. They dissolve in 5 parts of cold water, and in a still smaller quantity of boiling water. They contain 2 atoms of water.†

*What are the PRINCIPAL NITRATES?*

The *nitrate of potassa, ammonia, baryta, lead, mercury, and silver.*‡

*How is NITRATE OF POTASSA procured?*

This is the salt well known by the name of *nitre* or *salt-petre*. It is found in the East Indies,§

\* *Muriate of magnesia* is a deliquescent and very soluble salt, of an intensely bitter taste, and soluble in alcohol. It is contained abundantly in sea water, constituting above one-eighth of the solid ingredients of that water. It forms regular crystals, which consist of 1 atom of muriatic acid, 1 of magnesia, and 5 atoms of water.

† The crystals are not altered by exposure to the air. This salt is much used as a re-agent in chemistry. As a test of sulphuric acid it is of great use. Dr. Crawford recommended a solution of this salt as a remedy for scrophula and cancer, but it is not now considered worthy of any confidence.

‡ There are also *nitrates of soda, lime, strontia, magnesia, glucina, copper, &c.*

The *nitrate of soda* is analogous in its properties to nitrate of potassa. It was formerly called *cubic* or *quadrangular nitre*. It has been considered as useless; but Proust says, that 5 parts of it, with 1 of charcoal and 1 of sulphur, will burn three times as long as common powder, so as to form an economical composition for fire works.

*Nitrate of lime* is a very abundant natural production.

§ The greater part of the nitre used in Great Britain is brought from the East Indies. It may be made by saturating potassa, or its carbonate, with



in Spain, and elsewhere, in considerable quantities, generated spontaneously in the soil.\* In Germany and France it is artificially prepared in what are called *nitre beds*.†

*What are its properties?*

Its taste is saline and penetrating, accompanied with a sensation of coolness. It crystallizes in six-sided flattened prisms, with diëdral summits, and is dissolved in seven times its weight of

nitric acid, but it is purchased from the East India Merchants at a much less expence than could be incurred by its preparation in this way.

As it arrives from abroad it is a very impure salt, containing, besides other substances, a considerable proportion of common salt. In this state it is called rough nitre. For the purposes of chemistry and medicine, it requires to be purified by solution in water and re-crystallization; and it is then called refined or purified nitre.

\* Far the greater part of the nitrate of potassa made use of is produced by a combination of circumstances which tend to compose and condense nitric acid. This acid appears to be produced in all situations, where animal matters are completely decomposed with access of air, and of proper substances with which it can readily combine. Grounds frequently trodden by cattle, and impregnated with their excrements, or the walls of inhabited places, where putrid animal vapours abound, such as slaughter houses, drains, or the like, afford nitre by long exposure to the air.

† Artificial nitre beds are made by an attention to the circumstances in which this salt is produced by nature. The process consists in throwing animal substances, such as dung, or other excrements, with the remains of old mortar, or other loose calcareous earths, into ditches dug for that purpose, and covered with sheds, open at the sides, to keep off the rain. Occasional watering, and turning up from time to time, are necessary to accelerate the process, and to increase the surface to which the air may apply; but too much moisture is detrimental. After a succession of many months, nitre is formed in the mass, and may be extracted by lixiviation. If the beds contained much vegetable matter, a considerable portion of the nitric salt will be common salt-petre, but in other cases, the acid will for the most part be combined with calcareous earth, and the compound is made to yield nitre by mixture with subcarbonate of potassa. The nitrogen of the animal matters and the oxygen of the air appear in this process to combine and form nitric acid, which then unites to the potassa furnished by the decomposed vegetables, or with the calcareous matter present in the mixture.



water at  $60^{\circ}$ , and in its own weight of boiling water. It fuses at a moderate heat, and being cast into moulds forms what is called *sal prunelle*. At a red heat it is decomposed, and if it be distilled in an earthen retort, or in a gun-barrel, in consequence of the decomposition of its acid, a large quantity of oxygen gas will be evolved,\* and the pure alkali remains, which will corrode the earthen vessel in which it is heated. Its constituents are 1 atom of nitric acid = 54, and 1 of potassa = 48. Its atomic is therefore 102.†

*What are the USES OF NITRE?*

This substance is applied to various uses. It furnishes all the nitric acid used either by chemists or artists. It enters into the composition of fluxes,‡ and is indispensable in the assaying of various ores; it serves to promote the combustion of sulphur in the manufacture of its acid;§ it is used in the art of dyeing; it is added to common salt for preserving meat, to which it gives a red hue; and it is much employed in medicine, as a febrifuge and diuretic. It enters

\* One pound of nitre yields about 12.000 cubic inches of oxygen, of sufficient purity for common experiments, but not for purposes of accuracy.

† It is rapidly decomposed by charcoal at a high temperature, the products of which are nitrogen and carbonic acid gases, and a residuum of subcarbonate of potassa, which was formerly called *clyssus* of nitre.

So powerfully does this salt promote the combustion of inflammable substances, that 3 parts of it, 2 of subcarbonate of potassa, and 1 of sulphur, mixed together in a warm mortar, form the *fulminating powder*, a small quantity of which explodes with a loud noise, when laid on an iron (as the fire shovel) heated below redness.

Three parts of nitre, one of sulphur, and one of fine saw dust, well mixed, constitute what is called the *powder of fusion*.

‡ See page 408.

§ For the manufacture of sulphuric acid see page 257.



largely into the composition of *gunpowder*, forming about 75 parts in the 100 of that compound.\*

*What is the cause of the loud report attending the explosion of gunpowder?*

The sudden and forcible extrication and expansion of a large quantity of gaseous matter, acting on the surrounding air.†

*How is NITRATE OF BARYTA prepared?‡*

\* *Gunpowder* consists of a very intimate mixture of nitre, sulphur, and charcoal. The proportions vary, but the following table shows the quantities of the different materials in four sorts of powder:—

	Common Gunpowder.	Shooting Powder.	Shooting Powder.	Miners' Powder.
Nitre.....	75.0	78	76	65
Charcoal .....	12.5	12	15	15
Sulphur .....	12.5	10	9	20

Dr. Ure says the most effectual proportion of the materials is 75 parts of nitre, 16 of charcoal, and 9 of sulphur.

These ingredients are finely powdered, then *perfectly* mixed, moistened with water, and formed into a cake. This is afterwards broken up and forced through a sieve, by which it is granulated, and then it is dried. The best powder for fowling-pieces is put into a barrel which turns horizontally, in which there are a number of projecting pieces of wood, and in this it gets rounded and polished by attrition.

The violence of the explosion, or the strength of gunpowder, depends on the quantity of gaseous matter extricated, which is supplied by the action of the charcoal and sulphur on the nitre. The principal use of the sulphur is to make the whole mass inflame, and thus produce the greatest possible quantity of gaseous matter. The greater the quantity of nitre in proportion, the less the strength or quickness of the powder, but the greater the certainty that it will inflame. For this reason, the best shooting powder, which is required to explode rapidly, contains the most charcoal and nitre, while the miner's powder, which is used for blasting, the certainty of its operation being of more importance than its rapidity, has a greater quantity of nitre.

† Its *loudness* is closely connected with the combustion of the whole powder at the same instant. The gaseous results of the explosion of gunpowder are carbonic oxide, carbonic acid, nitrogen, and sulphurous acid; the solid matters which remain consist of subcarbonate, sulphate, and sulphuret of potassa.

‡ *Nitrate of ammonia*, sometimes called *nitrum flammans*, is described at page 210.



It may be prepared by dissolving either the artificial or native carbonate in nitric acid, diluted with eight or ten parts of water. On evaporation, it yields crystals, the primary form of which is a regular octahedron. They contain no water of crystallization.\* It consists of 1 atom of baryta = 78, and 1 of nitric acid = 54. It is sometimes used as a re-agent.

*How do you prepare NITRATE OF MERCURY?*

Nitric acid of specific gravity 1.42 dissolves mercury, both with and without the assistance of heat. At the common temperature, but little nitrous gas is evolved; and the acid becomes slowly saturated. The solution yields, by evaporation, large transparent crystals of *proto-nitrate of mercury*, consisting probably of 1 atom of acid, 1 of protoxide, and 2 of water. But if heat be used, and the acid be less diluted, a brisk effervescence arises, occasioned by the escape of nitrous gas, and a solution is obtained, in which the metal is more highly oxidated, constituting *per-nitrate of mercury*. It is composed of 1 equivalent of the peroxide and 1 of the acid.†

NITRATE OF SILVER forms the common LUNAR CAUSTIC ‡ of the surgeons: *How is it prepared, and what are its properties?*

\* It requires for solution 12 times its weight of water at 60°, and 3 or 4 parts of boiling water. It is insoluble in alcohol. It is not altered by exposure to the air.

† Nitrate of lead is formed by digesting litharge in dilute nitric acid.

‡ To form the *lapis infernalis* or *lunar caustic* used by surgeons, the nitrate of silver is liquefied by heat, and run into small cylindrical moulds. In its action as a caustic, the nitric acid appears to be the agent which destroys the animal texture, while the black stain is owing to the separation of the oxide of silver.



It is prepared by dissolving silver in dilute nitric acid, when an evolution of nitrous gas takes place, and a solution formed which yields transparent crystals of nitrate of silver. At the temperature of  $60^{\circ}$ , it dissolves in its own weight of water, and in four parts of alcohol. It is anhydrous, and consists of 1 atom of nitric acid = 54, and 1 of oxide of silver = 110. It deliquesces in the air; and when exposed to a strong light, it becomes brown, and the silver is partly reduced.\*

*What are ITS USES?*

It is used as a test of the presence of chlorine and muriatic acid; † and is of much use in medicine and surgery. ‡

*Name the most important CARBONATES.*

They are the *carbonates of potassa, soda, ammonia, lime, baryta, magnesia, and iron.* §

*There are two carbonates of potassa, the CARBONATE and BICARBONATE: How are they obtained? ||*

\* It is decomposed by all the alkalies and alkaline earths, and by the sulphuric, sulphurous, muriatic, phosphoric, and fluoric acids, and their salts. In its decomposition by muriatic acid, the hydrogen of the acid passes to the oxygen of the oxide, and the chlorine unites with the silver.

† It is a most delicate test of any muriatic salt.

‡ It certainly has sometimes great effect in allaying irritation in the stomach and bowels, and thus proves of service in many cases of indigestion, epilepsy, *angina pectoris*, &c.

§ The *carbonates* next in importance are those of *strontia, glucina, copper, lead, and mercury.*

|| The *carbonate* and *bi carbonate* of potassa were formerly called *sub-carbonate* and *carbonate*. The former are the proper names, as will be seen from considering their constituents.

*Carbonate of potassa* is composed of .. 1 atom of carbonic acid = 22

1 atom of potassa .... = 48

Atomic weight ..... 70



As before remarked, (p. 313,) the common *potash* or *pearl-ash* of the shops, obtained from the incineration of vegetables, is a *carbonate of potassa*, but as it is in that state very impure, it is, for chemical purposes, prepared from cream of tartar.\* On heating this salt to redness, the tartaric acid is decomposed, and a pure carbonate of potassa, mixed with charcoal, remains.† The *bicarbonate of potassa* is formed by passing a current of carbonic acid gas through a solution of the carbonate. By slow evaporation, the bicarbonate is deposited in regular crystals, which are prisms with eight sides, terminated by diëdral summits.

*What are the PROPERTIES of these two salts?*

The *carbonate of potassa* has a strong alkaline taste, is slightly caustic, turns vegetable blue colours green, and is very deliquescent on exposure to the air.‡ It dissolves readily in an equal weight of water at 60° F. but is insoluble in alcohol. It fuses at a red heat, but undergoes no other change. The *bicarbonate* differs from the carbonate in the greater mildness of its taste; §

<i>Bicarbonate of potassa</i> is composed of 2 atoms of carbonic acid	= 44
1 atom of potassa	..... = 48
To which add 1 atom of water	..... = 9
Atomic weight	..... 101

\* Hence it has been often called *salt of tartar*. By the above treatment, cream of tartar yields about one-third its weight of dry carbonate of potassa.

† The carbonate is then dissolved in water, and, after filtration, is evaporated to dryness in a capsule of platinum or silver.

‡ All the water thus absorbed is expelled again by a heat of 280° Fahr.

§ Though still alkaline, yet it may be applied to the tongue, or taken



in being unchanged by exposure to the air; in assuming the shape of regular crystals; and in requiring for its solution, four times its weight of water at 60° F. At a low red heat it is converted into the carbonate.\*

*How is the CARBONATE OF SODA obtained?*

By the incineration of *marine* plants, chiefly of the genus *salsola soda*, which afford, by lixiviation, the impure salt termed in commerce *Barilla*. This is imported from Spain and the Levant in hard porous masses, in which state it is contaminated by common salt, and other impurities.† It is called the *mineral alkali*. It is, however, found abundantly in nature, especially in Egypt, where it has been known from time immemorial by the name of *nitrum*, or *natron*.‡

into the stomach, without exciting any burning sensation, as is occasioned by the carbonate.

\* The question, *How is the quantity of pure carbonate of potassa contained in any given specimen of common American or Dantzick pearl-ash ascertained?* is a very interesting one to the merchant, and the point is most conveniently determined by a method proposed by Dr. Ure. He takes a tube divided into 100 parts, in which marks are placed, with the words carbonate of soda, carbonate of potassa, &c.; when any of the above substances are to be assayed, sulphuric acid of the specific gravity 1.146, is to be introduced up to the mark, and filled up to the hundredth part with water; this liquid is then to be dropped on a given weight of the sample, until its saturation is effected; when every measure of acid used will denote a grain of the alkali.

† It is cleared from these impurities by solution in a small portion of water, filtering the solution, and evaporating it at a low heat; the common salt may be skimmed off as its crystals form upon the surface. When required of great purity, it is best prepared either from pure acetate of soda, which is decomposed at a red heat, and converted into carbonate of soda and charcoal, the former of which is separable by water; and it may be obtained from the bicarbonate by calcination.

‡ The *bicarbonate of soda* is prepared in the same way as the bicarbonate of potassa, by saturating a solution of the carbonate with carbonic acid gas.



*How many carbonates of soda are there, and what are their properties?*

There are three, namely, the *carbonate*, *bicarbonate*, and *sesqui-carbonate of soda*.\* The carbonate of soda has strong alkaline properties. It crystallizes in octahedrons with a rhombic base, the acute angles of which are generally truncated. Its taste is urinous, and slightly acrid, but not caustic. It is soluble in less than its weight of boiling water, and twice its weight of cold. It is one of the most efflorescent salts known. When its crystals are heated they fuse, and are converted into a dry white powder from the loss of their water. Its specific gravity is 1.3591. The taste of the *bicarbonate* is much milder than that of the carbonate; it is soluble in nine or ten times its weight of cold water, and it affects the colour of vegetable blues in the same way as the carbonate.

\* The composition of these three salts may be represented at one view thus:—

<i>Carbonate of soda</i> consists of	....	1	atom	carbonic acid	=	22
		1	atom	soda	=	32
						54
				Atomic weight		54

<i>Sesqui-carbonate of soda</i> consists of	1½	atom	carbonic acid	=	33
	1	atom	soda	=	32
					65
			Atomic weight		65

<i>Bicarbonate of soda</i> consists of	....	2	atoms	carbonic acid	=	44
		1	atom	soda	=	32
						76
			Atomic weight			76

This table represents the composition of the anhydrous carbonates of soda, but in their ordinary state they contain water as follows:—

<i>Carbonate of soda</i> contains	.....	10	atoms of water	=	90
<i>Sesqui-carbonate of soda</i> contains	....	2	atoms of water	=	18
<i>Bicarbonate of soda</i> contains	.....	2	atoms of water	=	18



It is not crystallizable. The *sesqui-carbonate* of soda is a native production found near Fezzan, in Africa, and there called *trona*.

*How many CARBONATES OF AMMONIA are there, and how are they prepared?*

There are three carbonates of ammonia, the *carbonate*, *bicarbonate*, and *sesqui-carbonate*.\* The only method of procuring the first salt is by mixing dry carbonic acid over mercury, with twice its weight of ammoniacal gas. The bicarbonate was formed by Berthollet by impregnating a solution of the common carbonate with carbonic acid gas. The *sesqui-carbonate* is produced by exposing to heat, in a proper subliming apparatus, a mixture of 1 part muriate of ammonia and  $1\frac{1}{2}$  of dry chalk (carbonate of lime), by which a double decomposition is effected, the muriatic acid attaching itself to the lime, and the carbonic acid to the ammonia.

*What are the properties of these salts of ammonia?*

The *sesqui-carbonate of ammonia* is the only one

\* The composition of these salts are as follows :

*Carbonate of Ammonia* consists of .... carbonic acid .. 1 atom = 22  
ammonia ..... 1 atom = 17

Atomic weight .... 39

*Sesqui carbonate of Ammonia* consists of carbonic acid ..  $1\frac{1}{2}$  atom = 33  
ammonia ..... 1 atom = 17  
water ..... 1 atom = 9

Atomic weight .... 59

*Bicarbonate of Ammonia* consists of .... carbonic acid .. 2 atoms = 44  
ammonia ..... 1 atom = 17

Atomic weight .... 61



of these salts worthy of particular notice.\* It is the *subcarbonate of ammonia* of the shops, and forms the common smelling salts, and the carbonate of ammonia so often used in medicine as a stimulant.† When recently prepared, it has a crystalline appearance, and some transparency, and is hard and compact; its smell is pungent, and its taste sharp and penetrating. It affects vegetable colours like an uncombined alkali. It is soluble in about four times its weight of cold water, and in its own weight of hot water.‡

CARBONATE OF LIME is found in nature: In what state?

It is probably the most abundant native compound known, and is found in the different states of *chalk*, *limestone*, and *marble*.§ It is the basis also of calcareous spar and stalactites. In the animal kingdom, it forms the shells of innumerable animals, and enters likewise into the composition of bones. Carbonate of lime has scarcely

\* The carbonate of ammonia is a dry white volatile powder, of an ammoniacal odour, and alkaline reaction. The bicarbonate crystallizes in small six-sided prisms, has no smell, and but little taste.

† It was formerly prepared by the destructive distillation of stags horns, and other animal matters, which gave it the name of *salt of hartshorn*.

‡ When exposed to the atmosphere it loses weight very fast, ceases to be transparent, loses its odour and becomes brittle, and is ultimately converted into the *bicarbonate*. It therefore requires to be kept in closely stopped bottles.

§ All the varieties of marble and limestone consist essentially of carbonate of lime. The most celebrated statuary marble is that of Paros and of Mons Pentelicus, near Athens; of these, some of the finest specimens of ancient sculpture are composed. The marble of Carrara, or Luni, on the eastern coast of the Gulf of Genoa, is also much esteemed; it is milk-white, and less crystalline than the Parian. Many beautiful marbles for ornamental purposes are quarried in Derbyshire, and especially the black marble, called *Lucullite*. Westmoreland and Devonshire also afford beautiful varieties; and in Anglesea, a marble intermixed with green serpentine is found, little inferior in beauty to the *verd antique*.



any taste; is insoluble in pure water, but water saturated with carbonic acid takes up 1-1500th, though, as the acid flies off, this is precipitated. It suffers little or no alteration on exposure to the air. When heated strongly, it decrepitates, its water flies off, and lastly its acid. By this process it is burned into *quicklime*.\* It is composed of 1 atom of acid and 1 of base.†

*How is the CARBONATE OF MAGNESIA obtained?‡*

It is usually prepared by way of double decomposition, by dissolving two parts of sulphate of magnesia and one of carbonate of potassa, each in its own weight of boiling water, filtering them, and mixing them together hot—sulphate of potassa, and carbonate of magnesia will be formed; the former is separated by copious washing with water; and the carbonate of magnesia is then left to drain, and afterwards spread thin on paper, and carried to the drying stove. It is, as is well known, a white, insipid, and insoluble powder.§

\* In burning lime there are some particular precautions required for the different kinds of limestones. See Sir H. Davy's *Elem. of Agricult. Chem.*

† Carbonate of lime is decomposed by almost all acids.

‡ The *carbonate of baryta* is found native, particularly in the lead mines in the north of England. It was first found at Alston Moor, in Cumberland, in 1783, by Dr. Withering, and has hence received the name of *Witherite*. It may be prepared by exposing a solution of pure baryta to the atmosphere, when it will be covered with a pellicle of this salt by absorbing carbonic acid; or a solution of nitrate or muriate of baryta may be precipitated by a solution of either of the alkaline carbonates. The precipitate, being well washed, will be found to be very pure carbonate of baryta. It is very sparingly soluble in water, and is highly poisonous.

§ This is the common magnesia of the shops. On being exposed to a red heat, it loses its acid, and thus affords pure or *calcined* magnesia.

The *true* carbonate of magnesia consists of 1 atom of acid and 1 of base; and it is remarkable, that although it has never yet been formed artificially (what is prepared by the chemist always containing an excess of acid), yet it



*How is the CARBONATE OF IRON procured?*

It is an abundant natural production,\* but may be formed artificially by mixing carbonate of potassa with sulphate of iron. It is a proto-carbonate. Carbonic acid does not unite with the peroxide of iron.†

*We have spoken of the distinguishing characters of the chlorates. The only salt of this class worthy of particular notice here is the CHLORATE OF POTASSA. How is it prepared, and what are its properties?*

It may be formed by transmitting chlorine through a solution of caustic potassa.‡ In this process the water is decomposed; its oxygen unites with one portion of the chlorine, forming chloric acid, while its hydrogen unites with another portion, and produces muriatic acid, and hence chlorate and muriate of potassa are contemporaneously generated, and must be separated by crystallization.§ Some of its properties have already been described. It crystallizes in four and

exists as a natural product, in Moravia and the East Indies. At Madras there is an immense range of rocks formed of true carbonate of magnesia.

The properties of calcined magnesia have been described in the former chapter.

\* It exists in most of the chalybeate mineral springs.

† When the artificial salt is exposed to the atmosphere, it rapidly attracts oxygen and parts with carbonic acid; the oxide of iron passes from the state of protoxide to that of peroxide, and becomes red. The *subcarbonate of iron* of the pharmacopœia is a mixture of the carbonate and peroxide of iron.

‡ This may be done by means of Woulfe's apparatus.

§ This is easily accomplished, since the former salt will be the first to crystallize.

This salt may likewise be formed by the direct mixture of liquid chloric acid with solutions of potassa or carbonate of potassa. It was formerly called *oxymuriate of potassa*.



six-sided scales of a pearly lustre, is soluble in 16 parts of water at  $60^{\circ}$  F., and in  $2\frac{1}{2}$  boiling water; it is quite anhydrous; its specific gravity is 2. Its effects on inflammable bodies are very powerful, and give origin to some of the most striking experiments in chemistry.\* It consists of 1 proportion of acid and 1 of base; its equivalent is therefore  $(76 + 48) 124$ .

*What are the principal PHOSPHATES?*

The phosphates of *potassa*,† *soda*, *ammonia*, and *lime*. The phosphate of soda may be obtained by saturating with carbonate of soda the phosphoric acid obtained from bones (see p. 275), and evaporating the filtered liquor till a pellicle appears.‡ On cooling, crystals are formed, the primary form of which is an oblique rhombic prism. They are soluble in 4 parts of water at  $60^{\circ}$ , and in 2 parts at  $212^{\circ}$ . This salt generally contains an excess of base, and effloresces rapidly when exposed to the atmosphere. By a strong heat it loses 62 per cent. of water, and the residuum is fusible

\* Its effects on inflammables have been before adverted to. For the experiments above alluded to, see the Section on *Select Experiments* at the end of this volume.

† The *phosphate of potassa* does not possess any particular interest. It may be prepared in a manner similar to that described below for the preparation of phosphate of soda.

‡ It is also prepared by adding to the acidulous phosphate of lime as much carbonate of soda in solution as will fully saturate the acid. The carbonate of lime, which precipitates, being separated by filtration, the liquid is duly evaporated so as to crystallize the phosphate of soda. If there be not a slight excess of alkali, the crystals will not be large and regular.

The phosphate of soda is sometimes used in medicine as a purgative, and in chemistry as a re-agent. In assays with the blow pipe it is of great utility; and it has been used instead of borax for *soldering*.



into an opaque white glass or enamel. It consists of 1 equivalent of phosphoric acid, 1 of soda, and 12 of water.

*How is the PHOSPHATE OF AMMONIA prepared?*

By adding ammonia to concentrated phosphoric acid until a precipitate appears. On applying heat, the precipitate is dissolved; and on abandoning the solution to itself, the salt crystallizes, in prisms with four regular sides, terminating in pyramids, and sometimes in bundles of small needles. Its taste is cool, saline, pungent, and urinous. It is but little more soluble in hot water than in cold, which takes up a fourth of its weight. It is pretty abundant in human urine.\*

PHOSPHATE OF LIME is the principal ingredient in animal bones, but is it not found native?

Yes, forming a mineral called *apatite*. In its native state, it occurs both massive and crystallized. It consists, according to Klaproth's

\* It is an excellent flux both for assays and the blow pipe, and in the fabrication of coloured glass and artificial gems.

There is a triple salt, the *phosphate of ammonia and magnesia*, usually called *ammoniaco-magnesian phosphate*, which forms a distinct species of urinary *calculus*, or stone in the bladder. It has also been discovered in an intestinal calculus of a horse, by Fourcroy. It is easily procured by adding carbonate of ammonia, and afterwards phosphate of soda, to a solution of sulphate of magnesia, when the double phosphate subsides in the form of minute crystalline grains. It is insoluble in pure water, but is soluble in most acids.

When it occurs as a *calculus* in the bladder, it is white like chalk, is friable between the fingers, is often covered with dog-tooth crystals, and contains semi-crystalline layers. It is insoluble in alkalies, but soluble in nitric, muriatic, and acetic acids. This salt is almost always deposited on any extraneous body that may have got into the bladder.



analysis, of 53.75 lime + 46.25 phosphoric acid.\* It constitutes about 86 per cent. of animal bones.

*What are the most important FERROPRUSSIATES or FERROCYANATES?*

*The ferroprussiates of potassa and iron.*

*How is FERROPRUSSIATE OF POTASSA prepared, and what are its properties?*

It is manufactured on a large scale by igniting dried blood, or other animal matters, with potassa and iron, but it may be prepared extemporaneously by digesting pure *Prussian blue* in potassa until the alkali is neutralized, by which means the peroxide of iron, contained in the Prussian blue, is set free, and a yellow liquid is formed, which yields crystals of the ferroprussiate of potassa by evaporation.† It is a transparent salt, of a beautiful lemon or topaz-yellow colour, having a specific gravity of 1.830., and a saline, cooling taste. Water at 60° Fahr. dissolves nearly one-third of its weight, and boiling water almost its own weight. It is not altered by the air.‡ Its atomic constitution is uncertain.§

\* It occurs in primitive rocks; in the tin veins of the granite of St. Michael's Mount, Cornwall; near Chudleigh, in Devonshire; at Nantes in France; and with molybdena in granite, near Colbeck, Cumberland.

The mode of preparing it has been already described.

† The details may be found in *Dr. Ure's Dictionary*, p. 78.

‡ Exposed in a retort to a strong red-heat, it yields prussic acid, ammonia, carbonic acid, and a coaly residue consisting of charcoal, metallic iron, and potassa.

§ Berzelius, Phillips, and others, consider the following as the constituents of 1 atom of crystallized ferroprussiate of potassa:—



*What is the principal chemical use of this salt?*

As a test of the presence of iron, for which it is of great value. It is decomposed by almost all the salts of the permanent metals.\*

*What is the nature of that beautiful pigment called PRUSSIAN BLUE?†*

Cyanogen.....	78	or 3 equivalents.
Potassium .....	80	2 equivalents.
Iron .....	28	1 equivalent.
Hydrogen.....	3	3 equivalents.
Oxygen.....	24	3 equivalents.

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See page 251.

The *ferro-prussiates of ammonia, soda, lime, magnesia, baryta, and strontia*, may be obtained by boiling those alkalies and earths with Prussian blue.

\* The following table by M. Thenard, improved by Dr. Ure, presents a view of the colours of the metallic precipitates thus obtained.

<i>Solutions of</i>	<i>Give a</i>
Manganese,	White Precipitate.
Protoxide of Iron,	Copious White.
Deutoxide of Iron,	Copious clear Blue.
Tritoxide of Iron,	Copious dark Blue.
Tin,	White.
Zinc,	White.
Antimony,	White.
Uranium,	Blood-coloured.
Cerium,	White.
Cobalt.	Grass-green.
Titanium,	Green.
Bismuth,	White.
Protoxide of Copper,	White.
Deutoxide of Copper,	Crimson-brown.
Nickel,	Apple Green.
Lead,	White.
Deutoxide of Mercury,	White.
Silver,	White passing to blue in the air.
Palladium,	Olive.
Rhodium, Platinum, and Gold	None.

† So called because it was discovered by Diesbach, a colour-maker of Berlin, in 1710.



It is the ferroproussiate of the peroxide of iron.\* It is generally prepared in the following manner: equal parts of subcarbonate of potassa and various animal matters, such as hoofs and horns, dried blood, &c., are heated red-hot in large iron stills; the fused mass is then laded out into iron pans, where it concretes into solid blocks, called *metals* by the workmen; upon these when cold six or eight parts of water are poured. The solution is filtered, and mixed with a liquor containing two parts of alum and one of green vitriol (sulphate of iron). A precipitate falls, at first of a dingy green hue, but which, by copious washing with very dilute muriatic acid, acquires a fine blue tint.†

*The only salt among the CHROMATES worthy of notice here is the chromate of potassa:‡ How is it prepared?*

By igniting the ferruginous chrome ore, commonly called *chromate of iron*, with an equal weight of nitrate of potassa, when chromic acid is generated, and unites with the alkali of the nitre. By careful evaporation, it is obtained in crystals, the usual form of which is four-sided prisms terminated by diëdral summits. Their colour is

\* The ferrocyanate of the *protoxide* of iron is of a bluish white colour.

† In this process, the animal matter is decomposed, and furnishes the prussic acid, it being a new product arising from the reunion of some of its elements. Throughout the process the changes that take place are of a complicated nature.

The real nature of Prussian is not fully understood. A variety of opinions are entertained among chemists on this subject.

‡ It is from the chromate of potassa that all the compounds of chromium are directly or indirectly prepared.



bright yellow, and their taste cooling and disagreeable. It is soluble in twice its weight of water at 60° F., and to a much greater extent in boiling water.\*

*What is the principal salts of the class of BORATES?*

The only borate of importance is *borax*, which is a *bi-borate of soda*. This salt has been very long known, and is imported from India † in an impure state, under the name of *tincal*, which, when purified, is called borax. In its purified state it is white, transparent, and crystallizes in hexahedral prisms, which effloresce on exposure to the air, and dissolve in 20 parts of cold and 6 of boiling water. Its taste is styptic; it converts syrup of violets to a green; ‡ and when exposed to heat, it swells up, boils, loses its water of crystallization, and becomes converted into a porous, white, opaque mass, commonly called *calcined borax*. By a stronger heat it fuses, leaving a transparent substance, called *glass of borax*. Its atomic constitution appears to be 2 equivalents of boracic

\* There is a *bichromate of potash*, which is prepared by acidulating the neutral chromate with sulphuric acid, and allowing the solution to crystallize by spontaneous evaporation. The crystals have an exceedingly rich red colour, are anhydrous, and consist of 1 atom of the alkali, and 2 atoms of chromic acid. This salt is of great use in dyeing.

The salts called *arseniates* are so little worthy of notice that I shall pass them by in order to give more room for other and more important matter.

† It is found likewise in South America. It is said to be abundantly obtained at the mines of Requintipa, near Potosi, and in those in the neighbourhood of Escapa, where it is used by the natives in the fusion of copper ores.

‡ From this effect the alkali was formerly considered to predominate, and the salt used therefore to be called *sub-borate of soda*.



acid = 48, 1 equivalent of soda = 32, and 8 equivalents of water = 72, making together 152.\*

*Supposing borax was put into your hands, how would you know it with certainty to be that salt?*

It may be readily known by dissolving it in water, and dropping into it any strong acid, sulphuric acid for example, when boracic acid will fall down, insoluble, which is easily distinguished by the characters already described.

*Having described the general characteristics of the salts, derived from their acids, we ought now to speak of the characters as derived from their bases:† What are the general CHARACTERS OF THE AMMONIACAL SALTS?*

With very few exceptions, they are all soluble in water; when caustic potassa, or quicklime, is mixed with them, the peculiar smell of ammonia is exhaled; and they are all decomposed at a moderate red heat.‡

*How are the SALTS OF POTASSA distinguished FROM those of SODA?*

\* Borax is an excellent flux. It enters into the composition of reducing fluxes, and is of uncommon use in analysis by the blow-pipe. It may be applied with advantage in glass manufactories; for when the fusion turns out bad, a small quantity of borax re-establishes it. It is more particularly used in soldering; it aids the fusion of the solder, causes it to flow, and keeps the surface of the metals in a soft or clean state, which facilitates the operation. It has also been used in medicine, as an astringent, but is not worthy of confidence.

† In these descriptions I shall purposely avoid detail, and confine myself to a notice of the more striking distinctions between the different kinds of salts.

‡ If the acid be fixed, as the phosphoric, or boracic, the ammonia comes away pure.



All the salts of potassa afford a yellow or orange coloured precipitate with *muriate of platinum*, which does not affect salts of soda. And if tartaric acid, dissolved in water, be dropped into an aqueous solution of a salt of potassa, the liquid speedily deposits a white sediment, which has a sour taste, and proves to be cream of tartar.\*

*How do you distinguish the SALTS OF LIME?*

The salts of lime may be known by dropping on them oxalate of ammonia, which speedily throws down a dense white precipitate. Many of these salts are insoluble in water; such are decomposed by being boiled with carbonate of potassa, and afford a white powder, which is soluble with effervescence in nitric acid, and possesses all the characters of carbonate of lime.†

*What are the general characters of the SALTS OF BARYTA?*

They are almost all insoluble in water, and undecomposable by fire; if a little of a solution of sulphate of soda be let fall into them, a white powder immediately precipitates, which is insoluble in nitric acid; and most of them are poisonous.‡

\* If a solution of alumina be dropped into a salt of potassa, crystals of alum are very soon deposited, which does not take place when the alumina is added to salt of soda.

† The soluble salts of lime are not altered by the addition of pure ammonia, but they are decomposed by potassa and soda, which throw down a white precipitate of pure lime.

‡ The salts of baryta are in general more insoluble in water than those of lime.



*What are the characters of the SALTS OF MAGNESIA?*

They are generally soluble in water; they afford precipitates of magnesia, and of carbonate of magnesia, upon the addition of pure soda, and of carbonate of soda; and no precipitate appears when sulphate of soda is dropped into any of them.\*

*What are the distinguishing characters of SALTS OF IRON?*

They are, for the most part, soluble in water, and the solution is reddish-brown, or becomes so by exposure to air; they afford, with ferro-prussiate of potassa, a blue precipitate, or one which becomes so by exposure to air; and with hydrosulphuret of ammonia, a black precipitate. Infusion of gall-nuts produces a black or deep purple precipitate.

*How do you distinguish the SALTS OF ZINC?*

They all afford a white precipitate, with sulphuretted hydrogen.† They are soluble, colourless, and not precipitated by any metal, nor by infusion of galls.

*And how are the SALTS OF COPPER distinguished?*

They are nearly all soluble in water, and of a

\* The chief characters of the *salts of strontia* have been noticed at page 346.

*Salts of alumina* are soluble in water; and have a sweet and astringent taste, in which respect they resemble the salts of yttria and glucina, but the former differ from the latter, in not being precipitated by ferrocyanate of potassa, nor by tincture of galls.

† Ferro-prussiate and hydrosulphuret of potassa both occasion a white precipitate with salts of zinc.



blue or green colour. Ammonia, when added in excess to the solutions, produces a deep-blue colour. Hydrosulphuret of ammonia throws down a black precipitate, and when a clean plate of iron is plunged into a liquid salt of copper, the copper is precipitated in a metallic form.\*

*How are the SALTS OF LEAD characterized?*

By affording when heated with chromate of potassa, a peculiarly fine yellow, called *chrome yellow*.†

\* The salts of mercury have the following general characters:—a dull red heat volatilizes them; with ferro-prussiate of potassa they give a white precipitate; and with sulphuretted hydrogen, a black; gallic acid occasions an orange-yellow precipitate; a plate of copper introduced into a liquid mercurial salt, causes the precipitation of metallic mercury.

† This is the beautiful yellow with which coach pannels are now painted. It is of course a chromate of lead.

The soluble salts of lead have a sweetish austere taste, and are likewise characterized by the white precipitate produced by ferrocyanate of potassa; the brown, by hydro-sulphuret of ammonia; and the yellow, by hydriodate of potassa. The insoluble salts of lead are dissolved by soda and potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen. Heated by the blow-pipe upon charcoal, they afford a butter of lead.

With regard to the salts of silver, those which are soluble in water are characterized by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia; and by affording metallic silver, upon the introduction of a plate of copper. Those which are insoluble in water, are soluble in liquid ammonia, and when heated on charcoal, before the blow-pipe, afford a globule of silver.



## TABLE

*Exhibiting the Composition and Atomic Weight of the principal Salts, according to Dr. Thomson's views.*

## ACETATES.

	Atoms of acid.	Atoms of base.	Atoms of Water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Of alumina.....	1	1	1	9.625	77
ammonia .....	1	1	7	16.25	130
barytes .....	1	1	3	19.375	155
cadmium .....	1	1	2	16.5	132
copper .....	1	1	1	12.375	99
diacetate of copper ....	1	2	6	23	184
subsesquacetate .....	1	1½	3	17.125	137
trisacetate.....	1	3	2	23.5	188
iron .....	1	1	3	14.125	113
lead .....	1	1	3	23.625	159
diacetate of lead .....	1	2	10	45.5	364
trisacetate of lead ....	1	3	2	50.5	404
lime .....	1	1	6	16.5	132
magnesia .....	1	1	5	14.375	115
manganese .....	1	1	4	15.25	122
mercury .....	1	1	4	36.75	294
nickel .....	1	1	5	16.125	129
potash .....	1	1	2	14.5	116
binacetate of potash....	2	1	6	25.25	202
silver .....	1	1	0	21	168
soda .....	1	1	6	17	136
strontian .....	1	1	1	13.875	111
zinc .....	1	1	7	19.375	155

## ARSENIATES.

	Atoms of acid.	Atoms of base.	Atoms of Water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Arsenate of alumina .....	1	1	6	16.75	122
ammonia ....	1	1	0	9.875	79
Binarsenate of ammonia....	2	1	2	19.875	159
Arsenate of bismuth.....	1	1	2	20	160
cadmium ....	1	1	1	16.875	135
cobalt .....	1	1	4	16.5	132
Diprotarsenate of iron ....	1	2	3	20.125	161
Arsenate of lead .....	1	1	0	21.75	174
Subsesquarsenate of lead ..	1	1½	0	28.75	230
Arsenate of lime .....	1	1	0	11.25	90
magnesia ....	1	1	8	19.25	154
manganese ..	1	1	10	23.5	188
mercury ....	1	1	0	33.75	270
nickel .....	1	1	6	18.75	150
Binarsenate of nickel ....	2	1	10	31	248
potash ....	2	1	1	22.625	181
Arsenate of soda .....	1	1	8	20.75	166
Binarsenate of soda .....	2	1	5	25.125	201
Arsenate of strontian.....	1	1	8	23.25	186
zinc .....	1	1	8	22	176
Subsesquarsenate of silver	1	1½	0	29.875	237



## CARBONATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Carbonate of ammonia .....	1	1	0	3.875	31
Sesquicarbonate of do. ....	1½	1	1	7.375	59
Bicarbonate of do. ....	2	1	1	8.75	70
Carbonate of barytes .....	1	1	0	12.5	100
Triscarbonate of bismuth ..	1	3	2	35	280
Carbonate of cadmium .....	1	1	0	10.75	86
cobalt .....	1	1	1	8.125	65
Dicarbonate of copper .....	1	2	1	13.875	111
Ditto (anhydrous) ..	1	2	0	12.75	102
Carbonate of iron .....	1	1	0	7.25	58
lead .....	1	1	0	16.75	134
lime .....	1	1	0	6.25	50
magnesia ....	1	1	3	8.625	69
do. (anhydr.)	1	1	0	5.25	42
manganese ..	1	1	2	9.5	76
Sesquicarbonate of mercury	1½	1	0	30.125	241
Carbonate of nickel .....	2	1	3	10.375	83
potash .....	1	1	2	11	88
Sesquicarbonate of do. ....	1½	1	6	16.875	135
Bicarbonate of do. ....	2	1	1	12.625	101
Carbonate of silver .....	1	1	0	17.5	140
soda .....	1	1	10	18	144
Sesquicarbonate of do. ....	1½	1	2	10.375	83
Bicarbonate of do. ....	2	1	1	10.625	85
Carbonate of strontian ....	1	1	0	9.25	74
uranium .....	1	1	1	31.875	255
yttria .....	1	1	1	9.125	73
zinc .....	1	1	1	9.125	73
do. (anhydr) ..	1	1	0	8	64

## CHLORIDES.

	Atoms of chlorine.	Atoms of base.	Atomic weight of chloride.	
			Oxygen = 1	Hydrog. = 1
Protochloride of antimony	1	1	10	80
Dichloride of do. ....	1	2	15.5	124
Chloride of barium .....	1	1	13.25	106
bismuth .....	1	1	13.5	108
cadmium .....	1	1	11.5	92
cerium .....	1	1	10.75	86
chromium ....	1	1	8	64
cobalt .....	1	1	7.75	62
copper .....	1	1	8.5	68
Dichloride of do. ....	1	2	12.5	100
Chloride of glucinum .....	1	1	6.75	54
gold .....	1	1	29.5	236
Bichloride of do. ....	2	1	34	272
Chloride of iron .....	1	1	8	64



## CHLORIDES CONTINUED.

	Atoms of chlorine.	Atoms of base.	Atomic weight of chloride.	
			Oxygen = 1	Hydrog. = 1
Sesquichloride of iron .....	1½	1	10·25	82
Chloride of lead .....	1	1	17·5	140
lime .....	1	1	7	56
lithium .....	1	1	5·75	46
magnesium .....	1	1	6	48
manganese .....	1	1	8	64
Protochloride of mercury .....	1	1	29·5	236
Bichloride of do. ....	2	1	34	272
Chloride of nickel .....	1	1	7·25	58
palladium .....	1	1	11·5	92
platinum .....	1	1	16·5	132
Bichloride of do. ....	2	1	21	168
Chloride of potassium .....	1	1	9·5	76
rhodium .....	1	1	10	80
silver .....	1	1	18·25	146
sodium .....	1	1	7·5	60
strontium .....	1	1	10	80
tin .....	1	1	11·75	94
Bichloride of do. ....	2	1	16·25	130
Chloride of uranium .....	1	1	30·5	244
yttrium .....	1	1	8·75	70
zinc .....	1	1	8·75	70
zirconium .....	1	1	9·5	76

## TARTRATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Tartrate of alumina .....	1	1	1	11·625	93
ammonia .....	1	1	0	10·375	83
barytes .....	1	1	0	18	144
bismuth .....	1	1	5	23·875	191
cadmium .....	1	1	2	18·5	148
cobalt .....	1	1	2	14·75	116
copper .....	1	1	3	16·625	133
iron .....	1	1	2	15	120
lead .....	1	1	0	22·25	178
lime .....	1	1	4	16·25	130
magnesia .....	1	1	2	13	104
Bitartrate of do. ....	2	1	1	20·125	161
Tartrate of manganese .....	1	1	2	15	120
mercury .....	1	1	0	34·25	284
nickel .....	1	1	0	12·5	100
potash .....	1	1	2	16·5	132
Bitartrate of do. ....	2	1	2	24·75	198
Tartrate of silver .....	1	1	0	23	184
soda .....	1	1	2	14·5	116
strontian .....	1	1	3	18·125	145
zinc .....	1	1	0	13·5	108



## MURIATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Muriate of alumina.....	1	1	3	10.25	82
ammonia .....	1	1	0	6.75	54
barytes .....	1	1	1	15.5	124
bismuth .....	1	1	x		
cadmium .....	1	1	1	13.75	110
cerium .....	1	1	x		
chromium.....	1	1	9	19.25	154
cobalt .....	1	1	4	13.375	107
copper .....	1	1	2	11.875	95
glucina .....	1	1	x		
iron .....	1	1	3	12.5	100
lime .....	1	1	6	14.875	119
lithia.....	1	1	x		
magnesia .....	1	1	5	12.75	102
manganese ....	1	1	4	13.625	109
nickel .....	1	1	5	14.5	116
strontian .....	1	1	8	20.125	161
Bimuriate of tin....	2	1	3	21.875	213
Muriate of zinc .....	1	1	0	9.875	79
zirconia.....	1	1	5	16.25	130

## NITRATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salts.	
				Oxyg. = 1	Hydrog. = 1
Dinitrate of alumina .....	1	2	10	22.5	180
Trisnitrate of ditto .....	1	3	6	20.25	162
Nitrate of ammonia .....	1	1	1	10	80
barytes .....	1	1	0	16.5	132
bismuth .....	1	1	3	20.125	161
Dinitrate of bismuth .....	1	2	2	29	232
Nitrate of cadmium .....	1	1	4	19.25	154
cobalt.....	1	1	6	17.75	142
copper .....	1	1	7	19.625	157
iron .....	1	1	7	19.125	153
Persesquinitrate of iron....	1½	1	8	24.125	193
lead ....	1	1	0	20.75	166
lime ....	1	1	6	17	136
magnesia..	1	1	6	16	128
manganese	1	1	7	19.125	153
mercury ..	1	1	2	35	280
Pernitrate of mercury.....	1	1	0	33.75	270
Nitrate of nickel .....	1	1	5	16.625	133
potash .....	1	1	0	12.75	102
silver .....	1	1	0	21.5	172
soda .....	1	1	0	10.75	86
strontian .....	½	1	4	17.75	142
do. (anhydrous)	1	1	0	13.25	106
Sesquinitrate of uranium ..	1½	1	17	57.25	458
Nitrate of zinc .....	1	1	6	18.75	140



## OXALATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Oxalate of alumina .....	1	1	3	10.125	81
ammonia .....	1	1	2	8.875	71
Binoxalate of do. ....	2	1	8	20.125	161
Oxalate of barytes .....	1	1	3	17.625	141
Binoxalate of do. ....	2	1	3	22.125	177
Oxalate of bismuth .....	1	1	0	14.5	116
cadmium .....	1	1	3	15.875	127
cobalt .....	1	1	2	11	88
copper .....	1	1	1	10.625	85
iron .....	1	1	2	11.25	90
lead .....	1	1	0	18.5	148
lime .....	1	1	2	10.25	82
magnesia .....	1	1	2	9.25	74
Binoxalate of do. ....	2	1	7	19.375	155
Oxalate of manganese ....	1	1	3	12.375	99
mercury .....	1	1	1	31.625	253
nickel .....	1	1	4	13.25	106
potash .....	1	1	1	11.625	93
Binoxalate of do. ....	2	1	2	17.25	138
Quadroxalate of do. ....	4	1	7	31.875	255
Oxalate of silver .....	1	1	0	19.25	154
soda .....	1	1	0	6.5	68
Binoxalate of do. ....	2	1	3	16.375	131
Oxalate of strontian .....	1	1	2	13.25	106
Binoxalate of do. ....	2	1	0	15.5	124
Teroxalate of uranium ....	3	1	0	11.5	332
Oxalate of zinc .....	1	1	2	12	96

## PHOSPHATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Phosphate of alumina ....	1	1	3	9.125	73
ammonia ....	1	1	2	7.875	63
Biphosphate of ditto .....	2	1	0	9.125	73
Phosphate of barytes .....	1	1	0	13.25	106
bismuth ....	1	1	3	16.875	135
cadmium ....	1	1	1	12.625	101
cobalt .....	1	1	2	10	80
copper .....	1	1	1	9.625	77
Ditto anhydrous .....	1	1	0	8.5	68
Phosphate of iron .....	1	1	3	11.375	91
Pertrisphosphate of iron ..	1	3	3	21.875	175
Phosphate of lead .....	1	1	0	17.5	140
Diphosphate of ditto .....	1	2	0	31.5	252
Phosphate of lime .....	1	1	0	7	56
Apatite .....	1	1½	0	8.75	70
Phosphate of magnesia ....	1	1	7	13.875	111
mercury ....	1	1	0	29.5	236
nickel .....	1	1	3	11.125	89
potash .....	1	1	1	10.625	85
soda .....	1	1	12	21	168
Biphosphate of ditto .....	2	1	3½	14.9375	119.5
Phosphate of strontian ....	1	1	1	11.125	89
Biphosphate of ditto .....	2	1	2	15.75	146
Phosphate of zinc .....	1	1	2	11	88



## SULPHATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Sulphate of alumina .....	1	1	7	15.125	121
Bisulphate of do. ....	1	2	x		
Trisulphate of do. ....	1	3	9	21.875	215
Sulphate of ammonia .....	1	1	1	8.25	66
barytes .....	1	1	0	14.75	118
bismuth .....	1	1	0	15	120
cadmium .....	1	1	4	17.5	140
Ditto, in crust .....	1	1	2	15.25	122
Sulphate of cerium .....	1	1	3	15.625	125
cobalt .....	1	1	7	17.125	137
Bisulphate of do. ....	2	1	3	17.625	141
Sulphate of copper .....	1	1	5	15.625	125
Bisulphate of glucina ....	2	1	5	18.875	151
Sulphate of iron .....	1	1	7	17.375	139
Persesquisulphate of iron..	1½	1	x		
Sulphate of lead .....	1	1	0	19	152
lime .....	1	1	2	10.75	86
Ditto, anhydros. ....	1	1	0	8.5	68
Sulphate of lithia .....	1	1	1	8.375	67
magnesia ....	1	1	7	15.375	123
manganese ....	1	1	5	15.125	121
mercury .....	1	1	2	33.25	266
Persulphate of do. ....	1	1	0	32	256
Sulphate of nickel .....	1	1	7	17.125	137
platinum .....	1	1	0	19	152
potash .....	1	1	0	11	88
Bisulphate of do. ....	2	1	2	18.25	146
Sulphate of silver .....	1	1	0	19.75	158
soda .....	1	1	10	20.25	162
strontian .....	1	1	0	11.5	92
Sesquisulphate of uranium..	1.5	1	4	40	320
Sulphate of yttria .....	1	1	x		
zinc .....	1	1	7	18.125	145

## CHROMATES.

	Atoms of acid.	Atoms of base.	Atoms of water.	Atomic weight of salt.	
				Oxyg. = 1	Hydrog. = 1
Chromate of ammonia ....	1	1	0	8.625	69
Bichromate of do. ....	2	1	2	17.375	139
Chromate of barytes .....	1	1	0	16.25	130
Chromate of bismuth .....	1	1	2	18.75	150
cadmium .....	1	1	5	20.125	161
chromium ....	1	1	0	11	88
cobalt .....	1	1	2	13	104
copper .....	1	1	2	13.75	110
lead .....	1	1	0	20.5	164
lime .....	1	1	0	10	80
magnesia ....	1	1	2	11.25	90
mercury .....	1	1	0	32.5	260
nickel .....	1	1	4	15.25	122
potash .....	1	1	0	12.5	100
Bichromate of do. ....	2	1	0	19	152
Chromate of silver .....	1	1	0	21.25	170
soda .....	1	1	12	24	192
strontian ....	1	1	0	13	104
zinc .....	1	1	0	11.75	94



## OXIDES.

	Atoms of oxygen.	Atoms of base.	Atomic weight of oxides.	
			Oxygen = 1	Hydrogen = 1
Oxide of aluminum .....	1	1	2.25	18
Antimony, protoxide.....	1	1	6.5	52
deutoxide .....	1.5	1	7	56
peroxide .....	2	1	7.5	60
Barium, protoxide.....	1	1	9.75	78
peroxide .....	2	1	10.75	86
Bismuth, oxide .....	1	1	10	80
Cadmium, do.....	1	1	8	64
Calcium, do.....	1	1	3.5	28
Cerium, protoxide.....	1	1	7.25	58
peroxide .....	1.5	1	7.75	62
Chromium, protoxide ....	1	1	4.5	36
deutoxide .....	2	1	5.5	44
acid.....	3	1	6.5	52
Cobalt, protoxide .....	1	1	4.25	54
peroxide .....	1.5	1	4.75	38
Copper, suboxide.....	1	2	9	72
oxide .....	1	1	5	40
Glucinum, oxide .....	1	1	3.25	26
Gold, protoxide.....	1	1	26	208
tritoxide .....	3	1	28	224
Iron, protoxide.....	1	1	4.5	36
peroxide .....	1.5	1	5	40
Lead, protoxide.....	1	1	14	112
deutoxide.....	1.5	1	14.5	116
peroxide .....	2	1	15	120
Lithium, oxide .....	1	1	2.25	18
Magnesium, oxide.....	1	1	2.5	20
Manganese, suboxide ....	1	2	8	64
oxide .....	1	1	4.5	36
deutoxide .....	1.5	1	5	40
tritoxide.....	2	1	5.5	44
Manganeseous acid ?.....	3?	1	6.5	52
Manganesic acid .....	4	1	7.5	60
Mercury, protoxide .....	1	1	26	208
peroxide.....	2	1	27	216
Nickel, protoxide .....	1	1	4.25	34
peroxide .....	1.5	1	4.75	38
Palladium, oxide .....	1	1	8	64
Platinum, protoxide .....	1	1	13	104
peroxide .....	2	1	14	112
Potassium, protoxide ....	1	1	6	48
peroxide.....	3	1	8	64
Rhodium, protoxide .....	1	1	6.5	52
peroxide .....	2	1	7.5	60
Silver, oxide.....	1	1	14.75	118
Sodium, oxide .....	1	1	4	32
peroxide .....	1.5	1	4.5	36
Strontium, oxide .....	1	1	6.5	52
Tin, protoxide .....	1	1	8.25	66
peroxide .....	2	1	9.25	74
Uranium, protoxide .....	1	1	27	216
peroxide .....	2	1	28	224
Yttrium, oxide .....	1	1	5.25	42
Zinc, oxide.....	1	1	5.25	42
Zirconium, oxide .....	1	1	6	48



## CHAPTER XII.

### OF VEGETABLE CHEMISTRY.

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*In speaking of the chemical constitution of vegetable substances, we must first advert to the ultimate elements or principles of which they are composed, and then of their proximate or immediate principles. What is meant by the ULTIMATE ELEMENTS of vegetable bodies?*

Their elementary composition, that is, the common elements of matter of which they are constituted. Thus the ultimate elements of vegetables are but few in number, and consist of *oxygen, hydrogen, and carbon*.\* Therefore, notwithstanding the great diversity witnessed in the form and structure of vegetables, they may all (with very few exceptions) be ultimately resolved into these elements.

\* Nitrogen is also a constituent or elementary principle of some vegetables, but for the most part in very small quantity.

*Animal* substances, as will be noticed in the next chapter, also generally contain oxygen, hydrogen, carbon, and nitrogen, but with a much greater proportion of the latter principle, the preponderance of which, indeed, forms one of their most distinctive characters. It is true, that both in animals and vegetables, potassa, soda, phosphorus, lime, magnesia, &c. either pure, or more commonly in combination with some of the acids, may sometimes be found, but they occur in very small quantities, and ought not to be considered *essential* ingredients in vegetables. Thus, to use the words of Mr. Children, "With four elements has a bountiful Omnipotence composed the beautiful volume of the living world."



*And what is to be understood by the PROXIMATE PRINCIPLES of vegetables?*

They are those compounds which exist ready formed in the organized body, and are separable from it, without further decomposition, by simple processes of art. They are, in fact, products of vegetation.\* Thus sugar, starch, and wax, are proximate principles.

*Are the proximate like the elementary principles, few in number?*

No, they are numerous, consisting of above forty different substances. The chief proximate principles of vegetables are,

- |                        |                          |
|------------------------|--------------------------|
| 1. Sugar.              | 10. Camphor.             |
| 2. Gum.                | 11. Resins.              |
| 3. Starch, or Farina.  | 12. Gum Resins.          |
| 4. Gluten.             | 13. Bitter Principle.    |
| 5. Gelatine, or Jelly. | 14. Lignin, or Wood.     |
| 6. Tannin.             | 15. Balsams.             |
| 7. Fixed Oils.         | 16. Vegetable Acids.     |
| 8. Volatile Oils.      | 17. Vegetable Alkalies.† |
| 9. Wax.                |                          |

*From what plant is the sugar we commonly use obtained?*

It is prepared by a certain process‡ from the

\* It has been correctly remarked, that in these organized substances, the chemist discovers principles of a more compounded nature than any which can be obtained from the mineral kingdom. These do not previously exist in the earth, and must therefore be the result of vegetable life.

† Beside these, there are *sarcocol*, *asparagin*, *ulmin*, *inulin*, *indigo*, *albumen*, *fibrin*, *extractive matter*, *colouring matter*, *birdlime*, *guaiacum*, *caoutchouc*, and *cotton*, which are all vegetable proximate principles, although very inferior in importance to those enumerated above.

‡ A full account of this process, as employed in the West Indies, may be read in *Mr. Edwards's History of the West Indies*. The essential part of it is as follows: The juice, extracted by passing the cane between iron



sugar cane (*Arundo Saccharifera*), which contains it in greater quantity than any other plant. It may, however, be extracted from a great variety of plants, and from ripe fruits.\*

*What are the PROPERTIES OF SUGAR?*

It is white, and when crystallized somewhat transparent; its specific gravity is about 1.5; when pure, it undergoes no change by exposure to the air;† it is soluble in an equal weight of cold water, and almost to an unlimited extent in hot water; boiling alcohol dissolves about one-

roller, after being brought to a boiling heat, is mixed with slaked lime, with the view of neutralizing any acid present, and also to facilitate the separation of extractive and other vegetable matters; after which the clear fluid is drawn off into evaporating basins, and evaporated as quickly as possible, the scum being removed as it rises to the surface, and the boiling continued, till it becomes of such consistence that it will crystallize on cooling. It is then poured into wooden troughs, where it deposits small crystals, surrounded by a brownish fluid. The crystalline mass thus obtained is put into hogsheads, in the bottom of which there are a number of small holes, and placed over a large cistern, which is to collect the *molasses* or *treacle* that drops through; after it has dropped for two or three weeks, it is nearly dry, in which state it is imported into this country, under the name of *muscovado*, or *raw sugar*. When brought to Europe, it is freed from its impurities by the process of refining, and is then called *loaf* or *refined sugar*.

\* It is afforded in considerable quantity by the maple tree, and by beet root, skirret, parsnips, and dried grapes. In Canada, and the United States, sugar is largely extracted from the maple, which does not appear to be in any respect inferior to that of the West Indies. From calculations grounded on facts, it is ascertained, that America is now capable of producing a surplus of one-eighth more than its own consumption; that is, on the whole, about 135,000,000 pounds; which, in the country, may be valued at 15 pounds weight for one dollar. In Germany and France, the beet has lately been much cultivated, for the purpose of extracting sugar from its root. Lampadius obtained from 110lb of the roots 4lb of well-grained white powder sugar; and the residuum afforded 7 pints of a spirit resembling rum. Achard says, that about a ton of roots produced him 100lb. of raw sugar, which gave 56lb. of refined sugar, and 35lb. of treacle.

† The deliquescent property of raw sugar depends on impurities.



fourth of its weight. Alkalies unite with sugar, and destroy its taste. Strong sulphuric and muriatic acids decompose sugar, charcoal is deposited, and much of the sugar destroyed. Nitric acid converts it into oxalic acid, and chlorine into malic acid. The sulphurets, hydrosulphurets, and phosphorets, convert it into a substance not unlike gum. It has the property of rendering oils miscible with water. It decomposes several of the metallic salts, when boiled with their solutions.\*

*May not RAGS BE CONVERTED INTO SUGAR?*

Yes. It is a remarkable fact that a pound of rags may be converted into more than a pound of

\* Sugar has been often analysed, but its constituents have not been exactly determined. According to Dr. Prout, it is composed, as near as may be, of 5 atoms of each of its constituents, viz. carbon, oxygen, and hydrogen. The following are the results of the analysis of three distinguished chemists.

	<i>G. Lussac and</i>		
	<i>Thenard.</i>	<i>Berzelius.</i>	<i>Prout.</i>
Oxygen.....	50.63	49.856	53.35
Carbon.....	42.47	43.265	39.99
Hydrogen.....	6.90	6.879	6.66
	<hr/>	<hr/>	<hr/>
	100.000	100.000	100.000

The *uses* of sugar are well known. In its domestic use, there can be no doubt that it is a wholesome, as well as a very nutritious substance, when taken moderately.

*Molasses, honey, and manna*, are different varieties of sugar. *Molasses*, or treacle, appears to possess an unusual quantity of extractive matter. All *honeys* contain two species of sugar; one similar to sugar of grapes, the other like the uncrystallizable sugar of the cane, that is, molasses. These combined, and mingled in different proportions with an odorant matter, constitute the honey of good quality. Those of inferior quality contain besides a certain quantity of wax and acid. *Manna* is the produce of several vegetables, and especially of certain species of ash. Some think the sweetness of manna is not owing to sugar, but to a distinct principle called *mannite*, which is mixed with a peculiar vegetable extractive matter.



sugar, merely by the action of sulphuric acid. When shreds of linen are triturated in a glass mortar, with sulphuric acid, they yield a gummy matter on evaporation, and if this matter be boiled for some time with dilute sulphuric acid, we obtain a crystallizable sugar.\*

*From what plant is GUM obtained?*

It exists very abundantly in the vegetable kingdom. It is found in all young plants, in greater or less quantity; and is often so plentiful as to be discharged by spontaneous exudation. It abounds also in their seeds, roots, stalks, and leaves. The purest variety is the *gum arabic*, which flows naturally from the *acacia* tree in Egypt, Arabia, and elsewhere.

*What are the properties of Gum?†*

It is an inodorous, glutinous, and nearly taste-

\* This is not an extraction of sugar from rags, but a *real conversion* of one substance into the other. Nitric acid has a similar power in converting linen rags into sugar. Even wood, for instance, well dried elm dust, may be converted into sugar by sulphuric acid. In the same manner, silk is convertible into gum, and glue into sugar. In M. Braconnot's experiments, twelve grammes of glue, reduced to powder, were digested with a double weight of concentrated sulphuric acid without artificial heat. In twenty hours the liquid was not more coloured than if mere water had been employed. A decilitre of water was then added, and the whole was boiled for five hours, with a renewal of water, from time to time, as it wasted. It was next diluted, saturated with chalk, filtered, and evaporated to a syrupy consistence, and left in repose for a month. In this period a number of granular crystals had separated, which adhered pretty strongly to the bottom of the vessel, and had a very decided saccharine taste. This sugar crystallizes much more easily than cane sugar. Its taste is nearly as saccharine as grape sugar; its solubility in water scarcely exceeds that of sugar of milk. See M. Braconnot's Experiments detailed in *Ann. de Chimie*, tom. xii. and *Tilloch's Magaz.* vol. lv. and lvi.

† There is a considerable variety in the chemical properties of different gums. I therefore take above gum arabic as an example.



less substance, which undergoes no change on exposure to the air, but is readily soluble in water, forming with it a thick viscid solution, called *mucilage*.\* It is insoluble in alcohol and ether, the former of which precipitates† it from water, in opaque white flakes. It is soluble in pure alkalies, and in lime water, from which it is precipitated unchanged by acids. The dilute acids dissolve gum, and the concentrated acids decompose it. Strong sulphuric acid, for instance, converts it into water, acetic acid, and charcoal. Nitric acid dissolves it with a disengagement of nitrous gas; and the solution, in cooling, deposits a peculiar acid, called *saccholactic* or *mucic* acid, which forms a good character of gum.‡ Some malic acid is also formed; and by continuing the heat, the gum is changed into *oxalic* acid, amounting in weight to nearly one-half of that of the gum employed.§ Gum is precipitated

\* Mucilage may be kept a long time without undergoing any change; but it finally becomes sour, and exhales an odour of acetic acid.

† This precipitation is owing to the strong attraction existing between the water and alcohol. This action of alcohol on gum affords an easy mode of detecting its existence in vegetables; we have only to boil gently the matter to be examined with water; the gum will be thus dissolved, and if much of that principle be present, the solution will be glutinous. It may be allowed to remain till the impurities have subsided, then be evaporated to the consistence of thin syrup; when the addition of 3 parts of alcohol will separate the whole of the gum in flakes.

‡ That is, the production of *mucic* acid by the action of nitric acid appears to be the characteristic property of mucilage.

§ Chlorine, transmitted through a solution of gum, changes it into *citric acid*.

The atomic constitution of gum has not been accurately determined. The following are the results of the analyses of three different chemists :



from its solution in water by several metallic salts.\*

*What is the BEST TEST OF GUM?*

Sub-acetate of lead, which precipitates it from its solution in water, in a thick curdy form.

*In what vegetables is STARCH found?†*

It may be obtained from the flour of most varieties of grain, and from tuberosc roots, as the potatoe, &c. It is extracted by a very simple process. The grain, in the state of fine powder, or the root well rasped, is to be washed with a quantity of *cold* water, which becomes turbid, and, if the starch is white, milky. The starch, however, is not dissolved, but merely suspended mechanically, and after separating the fibrous and grosser parts by a sieve, it subsides to the bottom of the vessel. The liquid is then to be

	<i>Gay Lussac.</i>	<i>Berzelius.</i>	<i>Thomson.</i>
Carbon .....	42.23	41.906	40.
Oxygen .....	50.84	51.306	53.34
Hydrogen .....	6.93	6.788	6.66
	<hr/>	<hr/>	<hr/>
	100.	100.	100.

\* When gum is submitted to destructive distillation, an acid substance passes over, which was formerly considered as a distinct body under the name of *pyro-mucous* acid: but it is now ascertained to be no other than acetic acid, holding in solution a portion of essential oil and some ammonia.

Gum is nutritious, and it is said that the conductors of the caravans which cross the great Deserts of Arabia often subsist for a long time almost on it alone. But it is chiefly used for suspending substances in water; hence its use in dyeing, and in ink-making. For the same reason, it is employed in medicine, with the view of keeping oily or resinous matter in suspension in water.

† *Starch* has also the names of *Farina* or *Fecula*. It exists abundantly in the vegetable kingdom, chiefly in the white and brittle parts of vegetables, and particularly in the grains and roots noticed above.



decanted, and the fecula washed by repeated affusions of cold water. It may afterwards be dried by a gentle heat.\*

*What are the* PROPERTIES OF STARCH *or* FECULA?

It is a white, insipid, combustible substance, insoluble in cold water, but forming a jelly with boiling water.† The solution of starch in a large quantity of water is precipitated by sub-acetate of lead, but not by any other metallic salt. Starch is insoluble also in alcohol and ether, but is readily dissolved by pure liquid alkalies. This alkaline compound is soluble in alcohol; it is decomposed by acids, and the starch is recovered. By a high temperature, or by roasting, starch undergoes a very important change. At first it becomes yellow, then reddish-brown; it after-

\* In preparing starch in the large way, the grain is steeped in water, until it becomes soft; it is then put into coarse linen bags, which are pressed in vats of water; a milky juice exudes, and the starch falls to the bottom of the vessel. The vats are then allowed to remain undisturbed for some time, by which the supernatant liquid undergoes a slight fermentation and becomes sour; this is an essential part of the process, since the acid thus formed dissolves some of the impurities in the deposited starch. The sediment is then collected, washed, and dried in a moderate heat, during which it splits into the columnar masses of a small size, which we meet with in commerce, and which are generally tinged slightly blue, by a preparation of cobalt.

A very pure starch may be obtained by a similar process from the potatoe. It appears that starch constitutes from 83 to 85 per cent. of rice. Useful information respecting the quantity of starch in different varieties of the potatoe, may be found in a paper by Mr. Skrimshire, in the 21st vol. of *Nicholson's Journal*. The proportion of starch in sound and unsound grain, and the causes of unsoundness in corn and flour, have been ably investigated by Mr. E. Davy, and his opinions are published in the 49th vol. of the *Philosop. Magaz.*

† It should be observed, that it is not soluble in hot water unless the heat be above 160°.



wards swells, and exhales a penetrating smell. If the process be stopped, a substance is the result, which is known in commerce by the name of *British gum*.\*

*What is the best test of starch?*

Iodine. This principle forms a blue compound with starch, whether in a solid state or when dissolved in cold water.

*May not starch be converted into sugar?*

Yes. It is convertible into sugar by digesting it in dilute sulphuric acid, a process which was first discovered by M. Kirchoff, of St. Petersburg. According to the analysis of Gay Lussac and Thenard, starch is composed, in 100 parts, of carbon 43.55, oxygen 49.68, and hydrogen 6.77, which are generally considered to be very nearly the exact proportions of the elements existing in starch, and which being so very analogous to those of sugar, accounts for the conversion of the former into the latter. All that is necessary in order to insure this conversion is to augment the proportion of oxygen and diminish that of carbon. See page 502.†

\* In this state, it is no longer sensible to the action of *iodine*, and possesses many of the habitudes of gum, although it gives only oxalic acid, without a trace of mucic acid, when treated with nitric acid.

*British gum* is used by calico printers. Potatoe starch answers best for making this gum.

The mucilage formed by dissolving starch in boiling water, may be dried, and will then be semi-transparent, and much resembling gum, all the products of which it affords. When dissolved, it is much more easily digested and nutritious than before it has undergone this operation.

† One part of sulphuric acid converts 100 parts of starch into 110 of sugar; and it is singular that scarcely any of the acid is lost. The sulphuric acid here destroys part of the carbon of the starch, and thus brings up the



*But is there not a very important process, adopted on an extensive scale in this country, which is founded on this property of the CONVERSION OF STARCH INTO SUGAR?*

Yes. That process is **MALTING**. Malt is grain which has become sweet, from the conversion of its starch into sugar, by an incipient growth, or germination, artificially induced.\*

*Are there not several substances in common use as articles of diet, which consist chiefly or wholly of starch or fecula? †*

You refer to **ARROW-ROOT**, **SAGO**, and **TAPIOCA**. *Indian arrow-root* is prepared from the root of the

carbon and oxygen to the relative proportions in which they are found in sugar.

\* The constituents of barley, the grain from which malt is most commonly prepared, are *resin*, *gum*, *sugar*, *gluten*, *starch*, and a peculiar principle, (nearly resembling saw-dust in its external character,) called *hordein*. It appears that the formation of malt from barley consists in the increase of gum, sugar, and starch, and the diminution of gluten and hordein, as is shown by the following table of the constituents of malted and unmalted barley, as ascertained by analysis.

	<i>In 100 parts of barley.</i>	<i>In 100 parts of malt.</i>
Resin .....	1	1
Gum .....	4	15
Sugar.....	5	15
Gluten .....	3	1
Starch .....	32	56
Hordein.....	55	12

† It probably cannot be said with certainty to what the superiority of *Indian arrow-root* is owing, but I believe the fact is undoubted. A great deal of the arrow-root sold in England is extracted from potatoes, and although it is often very good, yet this starch differs perceptibly from that of wheat, and still more so from that of the *maranta arundinacea*. It is more friable than that of wheat; is composed of ovöid grains about twice the size of the other; it requires a lower temperature to reduce it into a jelly with water; it is soluble in more dilute alkaline leys, and is less readily decomposed by spontaneous fermentation.



*Maranta Arundinacea*, (a plant cultivated in the West Indies,) and is nearly pure starch. *Sago* and *tapioca* both exist in the plants from which they are extracted in the form of starch; but the heat employed in their preparation seems to change their nature a little.\*

*It is universally known that wheat flour is of all kinds of flour the best adapted for making good bread: Why is this?*

Because it contains more of a peculiar principle than any other kind of flour, which principle is absolutely necessary to the perfect formation or *rising* of the *dough*. This principle is called GLUTEN.†

*What are the properties of gluten?*

Its colour is grey, and its structure fibrous, accompanied with a slight degree of viscosity and elasticity. It is almost without taste, is very

\* The observations of M. Caventon on the varieties and properties of starch, in the *Ann. de Chim. et de Phys.* tom. xxxi. contain much useful information.

† Gluten may be obtained from wheat flour, by a simple process. The flour is first to be formed, by the gradual addition of a small quantity of water, into a soft and ductile paste. This is to be washed by a very slender stream of water, and, at the same time, to be constantly worked between the fingers. The water carries off the starch, and for some time is rendered milky. When it passes off transparent, the washing may be discontinued; and the pure gluten remains in the hands.

Gluten exists in most kinds of grain, and in other vegetable substances, but the very small quantity of it found in barley, rye, oats, &c. is the cause of its being impossible to make good *light* bread from the flour of those kinds of grain. From the experiments of Sir H. Davy, it appears that good wheat flour contains from 19 to 24 per cent. of gluten, and that a larger proportion of gluten is found in North American wheat, and in the wheat of warm climates, than in that of this country. It is in consequence of its abounding in this principle, that the wheat of the South of Europe is peculiarly fitted for making macaroni and other glutinous preparations.



slightly soluble in cold water, and insoluble in alcohol and ether. It is precipitated from its solution in water, by acetate and subacetate of lead, by muriate of tin, and by several other re-agents. When kept moist, it ferments and undergoes a species of putrefaction, exhaling a very offensive odour; at the same time a species of acid is developed.\* All acids dissolve gluten, and alkalies precipitate it, but considerably changed, and deprived of its elasticity. It undergoes a similar change when dissolved in pure alkalies, and precipitated by acids. When suddenly heated it shrinks, then melts, blackens, and burns like a piece of horn.†

*What constitutes the principle of ASTRINGENCY in vegetables? ‡*

TANNIN.§ It was formerly confounded with the gallic acid, but Seguin ascertained it to be a

\* This acid is perceivable by its smell, and considerably retards the putrefaction of the gluten. In this circumstance, chiefly, it differs from animal gluten or fibrin.

† M. Taddei, an Italian chemist, has lately ascertained that the gluten of wheat may be decomposed into two principles, which he has distinguished by the names *gliadine* (from γλία, gluten,) and *zimome* (from ζυμεν, ferment). The mode of separating these principles is described in *Ann of Philos.* vol. xv.

‡ VEGETABLE JELLY has not been noticed. It is obtained from the recently expressed juice of various acid fruits, by gentle evaporation. It is a tremulous soft coagulum, almost colourless after it has been well washed, and of an agreeable subacid taste. In cold water it is scarcely soluble, but in hot water it is abundantly dissolved; and when the solution cools, it again assumes a gelatinous form. By long boiling, however, it loses this property of coagulating.

§ Being the principle of astringency, it is of course found in all vegetables which are remarkable for their rough and astringent taste. It exists largely in *gall-nuts*; in the bark of most trees; in the leaves of the tea plant, sumach, and whortleberry. Sir H. Davy says, that the purest form of tannin is that derived from bruised grape seeds. In barks, the layers next



distinct principle, and gave it the name of tannin, from its great use in the tanning of leather, which it effects by its characteristic property, that of forming with the gelatine, or jelly, of animal matter, (of the hide, for instance,) a tough insoluble matter.\*

*What are the other properties of tannin? †*

In its dry state, it forms a brown friable mass, which is soluble both in hot and cold water, affording a deep brown solution, of a sharp bitter taste; although it is insoluble in pure alcohol,

to the wood contain the largest proportion; the middle and coloured part the next; and in this it is accompanied with more extract. The epidermis (or skin) affords very little. It is frequently associated with gallic acid, as, for example, in gall-nuts, most kinds of bark, and in tea; but in kino, catechu, and Peruvian bark, no gallic acid is present. Extract of rhatany consists of tan in a purer form than is contained in catechu.

\* In this country, the preference is universally given to oak bark, on account of its cheapness, for the purpose of tanning, but the Leicester willow contains as much tan, or more. A great deal of leather lately brought into the market, has been quickly made, and a short time since I inquired of a tanner, whether leather made quickly was as good as that prepared by the old slow process. He answered, he thought one was as good as the other, and that the only objection to the quick process was its greater cost, from their being obliged to use a very strong solution of tan, from which they could not extract all its virtue in the time allotted, and therefore incurred an augmented expense. By this answer, the tanner showed how little he knew respecting the principles of his own art, for certainly the operation is most perfect when performed slowly, because if too rapidly effected, the outer surface of the skin is soon covered with a coat of leather, which defends the interior from a thorough change.

† Tannin may be obtained by digesting bruised gall-nuts, grape seeds, oak bark, or catechu, in a small quantity of cold water. The solution, when evaporated, affords a substance of a brownish-yellow colour, extremely astringent, and soluble both in water and in alcohol, but not in ether. This is *tannin* in a very impure state. A process for procuring pure tan has not yet been discovered.

There is a substance called *artificial tannin*, which was discovered by Mr. Hatchett about 20 years ago, and is made by digesting charcoal in dilute nitric acid,



the presence of a very small proportion of water enables this liquid to act as a solvent. From its aqueous solution, it is precipitated by almost all the acids, with which it forms insoluble compounds. The alkaline bases have a similar effect. It is precipitated, for example, by the carbonates of potassa and ammonia, by the alkaline earths, by alumina, and many of the oxides of the common metals. But its most characteristic property, next to that of forming an insoluble compound with animal jelly, as above mentioned, is its forming with the peroxide of iron, a black coloured compound.\*

*There are two kinds of oils obtained from vegetables, namely, FIXED and VOLATILE OILS: What are the principal differences between them?*

The *fixed oils*† are obtained by expression,

\* This black precipitate, together with the gallate of iron, constitutes the basis of writing ink and the black dyes. Common ink for writing is made by adding an infusion or decoction of gall-nuts to sulphate of iron, dissolved in water. A very fine black precipitate is thrown down, the speedy subsidence of which is prevented by the addition of a proper quantity of gum-arabic.

The following is a valuable recipe for making good ink. Take 8 ounces of Aleppo galls (in coarse powder); 4 ounces of logwood (in thin chips); 4 ounces of sulphate of iron; 3 ounces of gum-arabic (in powder); 1 ounce of sulphate of copper, and 1 ounce of sugar-candy. Boil the galls and logwood together in 12 pounds of water for one hour, or till half the liquid has evaporated. Strain the decoction through a hair sieve or linen cloth, and then add the other ingredients. Stir the mixture till the whole is dissolved, more especially the gum; after which, leave it to subside for 24 hours. Then decant the ink, and preserve it in bottles of glass or stoneware, well corked.

† *Fixed oils* are generally obtained, by pressure, from certain vegetable seeds, as the almond, linseed, &c. They are liquid, and almost tasteless, and differ from each other greatly in specific gravity, which, however, is always below that of water. They do not boil under 600° Fahr., but are extremely combustible. In burning, they afford only carbonic acid and



either in cold or with heat ; they do not rise in distillation at the temperature of boiling water—thence called fixed oils ; they form soaps by combination with alkalies ; they give a permanent greasy stain to paper ; and they are all, excepting castor oil, sparingly soluble in alcohol. The *volatile*, or *essential oils*, on the contrary, are obtained by distillation ; they rise in distillation at the boiling point with water, or under  $320^{\circ}$  by themselves. They do not unite with alkalies, and therefore will not form soaps ; they leave a stain when dropped on paper, but it is speedily removed by holding it before the fire ; and they are all very soluble in alcohol, which compounds are termed *essences*.\*

*What is the chemical nature of soap ?*

Until lately no clear ideas were entertained respecting the chemical nature and constitution of soaps, but a French chemist, M. Chevreul, has thrown great light on this subject. He has found that fixed oils and fats are not pure proximate principles, but really consist of two substances,

water. They are divided into *drying* and *fat* oils ; the former become dry on exposure to air, the latter rancid. Linseed oil, for example, is a drying oil ; olive oil, a fat oil.

*Volatile oils* have commonly a fragrant and penetrating smell, and an acrid but not disagreeable taste. Nitric acid, when poured upon these oils, inflames them. By long exposure to air they are thickened, a change which depends on the absorption of oxygen. When digested with sulphur, they unite with it, and form a series of compounds, which were formerly distinguished by the term of *balsams of sulphur*. They dissolve phosphorus at a digesting heat.

\* Essential oils when pure exhibit no milkiness, when dropped into water ; if they have been mixed with any alcohol (no uncommon practice), an immediate milkiness is thus produced.



one of which is a solid, and the other a liquid. The former he has called *stearine*, the latter *elaine*. When fixed oil or fat is treated with a hot ley of potassa or soda, the constituents react on one another, so as to generate the solid pearly matter *margaric acid*, the fluid matter *oleic acid*, both of which enter into a species of saline combination with the alkali; while the third matter that is produced, the *sweet principle*, remains free. We must therefore regard our common soap as a mixture of an alkaline margarate and oleate, in proportions determined by the relative proportions of the two acids producible from the peculiar species of fat employed.\*

*Is not CAMPHOR a species of essential oil?*

It appears to be an essential oil, combined with some acid. It exists ready formed in the *laurus camphora* of Japan, and is obtained from it by sublimation. Its specific gravity is 0.988. It melts at 288°, and boils at 400° Fahr. It is inso-

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

The following are the products gained by Gay Lussac in the analysis of olive oil, and by Dr. Ure from spermaceti oil, and oil of turpentine.

	<i>Olive Oil.</i>	<i>Spermaceti Oil.</i>	<i>Oil of Turpentine.</i>
Carbon.....	77.213	78.91	82.51
Hydrogen....	13.360	10.97	9.62
Oxygen ....	9.427	10.12	7.87
	<hr/> 100.000	<hr/> 100.00	<hr/> 100.00



luble in water;\* but is dissolved freely by alcohol, and is thrown down by the addition of water. It is likewise soluble in the fixed and volatile oils, and in strong acetic acid.†

*What is the difference between WAX‡ and RESINS?*

Wax is tenacious, and insoluble in nitric acid. Resins are brittle rather than tenacious, and nitric acid converts them into artificial tannin. Wax is less soluble in alcohol than resins. With the heat of boiling water no principle is distilled from it; whereas with that heat, some essential oil, or at least a spirituous rector, is obtained from every resin.

*What is the real NATURE OF RESINS?*

\* When triturated with hot water, especially if a little sugar be added, it communicates its flavour to that fluid.

† Sulphuric acid decomposes camphor. Oil of turpentine, by the action of muriatic acid, is converted into a substance very much resembling camphor, both in its sensible and chemical properties.

‡ Wax forms the varnish, which is conspicuous on the upper surface of the leaves of many trees and plants. The bloom of fruit is also said to be real wax. It exists likewise in the fecula of some vegetables, particularly in that of the small house-leek. Wax is, however, both a vegetable and an animal product, for bees afford it when fed on nothing but sugar, which proves that it is not derived simply from the dust of the stamina of plants, as was formerly supposed, but is truly an animal production.

Wax is deprived of its natural disagreeable yellow colour, and perfectly whitened, by exposure to the united action of air, light, and water. It is employed for many purposes, more especially as a better material than any other for candles. Its composition is stated to be—

	<i>By Gay Lussac.</i>	<i>By Ure.</i>
Carbon .....	81.784	80.69
Hydrogen .....	12.672	11.37
Oxygen .....	5.544	7.94
	<hr/> 100.000	<hr/> 100.00



They are with much reason considered to be nothing else but volatile oils, rendered concrete by their combination with oxygen.\*

*What constitutes the difference between RESINS and GUM-RESINS?*

Gum-resins† form milky solutions with water; resins do not. The former are odoriferous, the latter have little or no smell.‡

*What is CAOUTCHOUC, commonly called Indian rubber?*

It is the juice of certain trees growing in South America. It is a very elastic substance, insoluble in water and alcohol, but soluble in ether, volatile

\* Resins are the inspissated juices of certain plants. They are solid inflammable substances, soluble in alcohol, and in oil, but not at all in water; and usually afford much soot by combustion. Some resins are very pure, and perfectly soluble in alcohol, such are the balsam of Mecca and of Capivi, turpentine, tacamahaca, and elemi; others are less pure, and contain a small portion of extract, which renders them not totally soluble in alcohol, such are mastic, sandarach, guaiacum, labdanum, and dragon's blood. The following are the results of the analysis of resin by the chemists named.—

	<i>Thenard.</i>	<i>Ure.</i>	<i>Thomson.</i>
Carbon.....	75.944	75.	63.15
Oxygen .....	13.337	12.5	25.26
Hydrogen .....	10.719	12.5	11.59

† *Gum-resins*, along with resin, have an admixture of extractive matter. The principal gum-resins are assafetida, aloes, gamboge, myrrh, and gum-ammoniac. These are substances of great use in medicine.

*Resins* are the bases of varnishes, and are likewise used in surgery, to form, with wax and oil, ointments and plasters. Sealing-wax is composed of lac, Venice turpentine, and common resin. The composition is coloured black by means of lamp-black, or red by cinnabar or red lead. Guaiacum differs from other resins in giving oxalic acid by the action of nitric acid, and very little tannin.

‡ *Balsams* are merely liquid resins, combined with a proportion of benzoic acid. They are insoluble in water, but dissolve readily in alcohol and ether. The principal are *balsam of Peru*, and *tolu*, *storax*, and *benzoin*. They are frequently used in medicine.



oils, and petroleum. The ether, however, requires to be washed with water repeatedly, before it will completely dissolve it. Cajeput oil is one of its most active solvents. Caoutchouc is remarkable for being perhaps the only vegetable substance that does not contain oxygen. Its atomic constituents have not been accurately determined, but they appear to be very nearly 3 proportions of carbon and 2 of hydrogen.\*

COLOURING MATTER, *although usually arranged among the proximate principles of vegetables, rarely or never occurs in an insulated state, being always attached to some other immediate principle, such as extractive matter, gum, farina, or resin: What are the chief colouring matters used?*

Indigo, cochineal, archil, Brazil wood, madder, and logwood; quercitron bark, turmeric, and saffron.†

\* The general uses of *Indian rubber* or *elastic gum*, are well known. A solution of it in 5 times its weight of oil of turpentine, and this solution dissolved in 8 times its weight of drying linseed oil by boiling, is said to form the varnish of air-balloons.

Mr. James Syme of Edinburgh, has discovered that the purified naphtha from coal-tar dissolves it readily, and as this solvent is cheap, and the properties of the caoutchouc are unaltered by the process, the solution may be conveniently employed for forming elastic tubes, or other apparatus of a similar kind. It is used by Mr. Mackintosh of Glasgow, for covering cloth with a thin stratum of caoutchouc, so as to render it impermeable to moisture.

† Indigo is one of the most important of colouring substances, on account of its richness and durability. It is the chief substance employed for giving the blue dye, and is obtained from a plant, the *indigofera*, cultivated in the East and West Indies, and in America. It is a soft friable substance, destitute of taste and smell, of a deep blue colour, and insoluble in water and alcohol. Its only proper solvent is strong sulphuric acid. When thus dissolved, it is sometimes applied directly, in a diluted state, to various fabrics, and dyes what is called a *Saxon blue*.



*What is meant by the BITTER PRINCIPLE of vegetables?*

The supposed peculiar principle which gives the bitter taste to certain vegetables. I say the supposed principle, because it is now very much doubted whether it be in any case an independent principle, while it is certain that in many instances it is not so. For example, the bitterness of *nux vomica* is ascertained to be owing to the vegetable alkali *strychnia*; that of opium, to *morphia*; and that of Peruvian bark, to *cinchonia* and *quina*.

*What are we to understand by the term EXTRACTIVE MATTER?*

A distinct product of vegetation. At least, it was till lately considered as a distinct or proximate principle of vegetables, but now chemists are much disposed to doubt its identity. It appears to be a mixture of proximate principles.\*

*What is LIGNIN?*

It is the WOODY FIBRE of vegetable substances, constituting their fibrous structure. It is of

Cochineal, archil or litmus, Brazil wood, madder, and logwood, are *red* dyes. Quercitron bark, turmeric, and saffron, are *yellow* dyes. The *black* dye consists essentially of a compound of the oxide of iron with gallic acid and tannin. From the addition of logwood and acetate of copper, the black receives a shade of blue. The most valuable information respecting *dyeing* will be found in *Berthollet's Treatise on the Art of Dyeing*, *Bancroft on Permanent Colours*, a paper by Mr. Henry, in vol. iii. of *Manchester Memoirs*, and a Memoir of Thenard in vol. lxxiv of *Ann. de Chimie*.

\* It is said to have a bitter taste, and a deep brown colour, to be brittle, with a shining fracture when it is dried; to yield on distillation an acid and ammoniacal liquor; to be soluble in water and alcohol; to combine with the greater part of metallic oxides; and lastly, to combine with oxygen and become insoluble in water.



course the most abundant principle in plants, and the different kinds of *wood* contain about 96 per cent. of it; of which carbon constitutes about 50 per cent., oxygen 43 per cent., and the rest is hydrogen.\*

*There is a peculiar acid called PYROLIGNEOUS ACID, which is now in very extensive use. Is it not obtained from lignin?*

Yes. The woody fibre, by being heated in close vessels, yields a large quantity of pyroligneous acid, which is an impure acetic acid.† The charcoal which remains in the retort is greatly superior to that procured by the ordinary process.‡

*What are INULIN, NICOTIN, and EMETIN? §*

They are new substances that have been disco-

\* It is perfectly destitute of taste, smell, and colour; in specific gravity, is generally inferior to water; is insoluble in water, alcohol and dilute acids. According to M. Braconnot, by digestion in a concentrated solution of pure potassa, it is converted into a substance similar to ulmin. By strong sulphuric acid it is converted into a matter resembling gum; and in boiling the liquid for some time, the mucilage disappears, and a saccharine principle like the sugar of grapes is generated. By digestion in nitric acid, lignin is converted into the oxalic, malic, and acetic acids.

† When this acid is purified, it is employed in the preservation of animal food, and indeed for all the purposes to which the best vinegar is applied.

‡ Hence distillation in iron cylinders has been, for some time past, practised as the best method of obtaining charcoal for the manufacture of gunpowder.

§ In addition to the above, we should notice the peculiar principles *asparagin*, obtained from the juice of asparagus; *ulmin*, from a species of elm; *fungin*, from the fleshy part of mushrooms; *pollenin*, from the pollen of tulips; *lupulin*, from the hop; *sarcocoll*, from the *pænea sarcocolla*; *cathartine*, from the leaves of senna, and in which the purgative property of that plant resides; and *colocyntine* from colocynth. These all appear to be distinct products of vegetation, but do not require particular notice.



vered in particular vegetables, and are considered peculiar proximate principles. *Inulin* is found in the roots of elecampane; *nicotin* is one of the active principles of tobacco; and *emetin* is the peculiar matter in the root of ipecacuanha, in which the emetic virtue of the root exclusively resides.

*What are the principal VEGETABLE ACIDS?*

They are,

- |                   |                    |
|-------------------|--------------------|
| 1. Acetic Acid.   | 5. Malic Acid.     |
| 2. Citric Acid.   | 6. Benzoic Acid.   |
| 3. Tartaric Acid. | 7. Gallic Acid.    |
| 4. Oxalic Acid.   | 8. Succinic Acid.* |

*How is ACETIC ACID obtained?†*

It is commonly prepared in this country by fermentation from an infusion of malt, and in France from weak wines.‡ It may likewise be made from

\* Besides the above vegetable acids, there are the *camphoric* acid, obtained by digesting camphor in nitric acid; *mucic*, or *saccholactic*, which is procured from the sugar of milk, &c.; *moroxylic*, existing in the bark of the white mulberry; *boletic*, found in the *boletus pseudo-igniarius*; *prussic*, already described; *mellitic*, found in the rare substance called *honey-stone*; *suberic*, obtained by the action of nitric acid on cork; *meconic*, which is united with morphia, in opium, and a few others, which we shall not particularly notice here.

† Acetic acid is the same acid which, in a very dilute and somewhat impure state, is called vinegar. It is found, mostly combined with potassa, in the juices of a great many plants. Sweat, urine, and even fresh milk contain it. Almost all dry vegetable substances, and some animal, subjected in close vessels to a red heat, yield it copiously. It is the result likewise of a spontaneous fermentation, to which liquid vegetable, and animal matters are liable.

The terms *actous* and *acetic* were used to denote what were supposed to be two distinct acids, common vinegar purified by distillation being termed the *actous*, and the highly concentrated acid, formerly called *radical vinegar*, being denominated *acetic*. It is now known that these are the same acids, and differ only in point of strength.

‡ The following is the plan of making vinegar at present practised in Paris. The wine destined for vinegar is mixed in a large tun with a quan-



sugar by fermentation, and, as we have above remarked, is sometimes extracted from wood. In obtaining it from malt or sugar, those substances are first made to undergo the vinous fermentation, when the liquor is exposed in casks partly filled, and open to the atmosphere, at a temperature between  $75^{\circ}$  and  $90^{\circ}$  of Fahr. The liquor soon becomes warm; a number of ropy filaments appear; and after several weeks, it will be found to have acquired an acid taste and smell. Little or no gas is evolved; but, on the contrary, an absorption of oxygen takes place.\*

*Acetic acid thus prepared contains many impurities, from which it is purified by distillation. For chemical purposes, this acid is prepared in a manner different from either of the preceding. What is it?*

tity of wine lees, and the whole being transferred into cloth-sacks, placed within a large iron-bound vat, the liquid matter is extruded through the sacks by superincumbent pressure. What passes through is put into large casks, set upright, having a small aperture in their top. In these it is exposed to the heat of the sun in summer, or to that of a stove in winter. Fermentation supervenes in a few days. If the heat should then rise too high, it is lowered by cool air, and the addition of fresh wine. In the skilful regulation of the fermentative temperature consists the art of making good wine vinegar. In summer, the process is generally completed in a fortnight; in winter, double the time is requisite. The vinegar is then run off into barrels, which contain several chips of birch-wood. In about a fortnight it is found to be clarified, and is then fit for the market. It must be kept in close casks.

\* There is an essential difference, therefore, between the circumstances attending the vinous and acetous fermentations. The latter requires the access of air as an indispensable condition; whereas the vinous fermentation may be performed in close vessels, or at least in vessels which only allow egress to the elastic fluids that are produced. It must not, however, be supposed that the vinous fermentation is required as a previous step to acetification; for many liquids containing sugar, mucilage, or starch, become sour at once, without undergoing the former change.



It is by decomposing the acetates, acetate of potassa, for example, by strong sulphuric acid.\*

*What are the PROPERTIES OF STRONG ACETIC ACID?*

The concentrated acid has an extremely pungent but agreeable smell, and is so corrosive as to blister the skin; when gently heated in a silver spoon it is volatilized, and its vapour may be inflamed. It has a specific gravity of 1.063. In its most concentrated form it crystallizes when exposed to a low temperature, retaining its solidity until the thermometer rises to 50° Fahr.† It dissolves resins, gum-resins, camphor, and essential oils.

*Acetic acid unites with the different bases, forming a class of salts called ACETATES: What are the principal Acetates?*

They are the *acetates of potassa, ammonia, lead, copper, and zinc.*‡ The *acetate of potassa* is usually prepared by saturating acetic acid with the car-

\* The processes are described in *Henry's Chem.* vol. ii, p. 368, or in *Ure's Dictionary*, p. 10.

† It is the only vegetable acid, except the *prussic*, that rises in distillation in combination with water. There is some doubt respecting the atomic constituents of this acid. It is generally considered to be composed of 4 atoms of carbon = 24, 3 of oxygen = 24, and 2 of hydrogen = 2, making together 50; but Dr. Ure thinks its atomic weight is 56. Dr. Prout regards it as 51, namely, 4 proportions of carbon, 3 of oxygen, and 3 of hydrogen.

Acetic acid and common vinegar are sometimes fraudulently mixed with sulphuric acid to give them strength. This adulteration may be detected by muriate of baryta, which will immediately throw down a white precipitate, the insoluble sulphate of baryta.

‡ The ACETATES are distinguished by their great solubility in water; and by the pungent smell of vinegar, which they exhale on dropping on them sulphuric acid.



bonate of potassa. It usually occurs in the shops in a foliated form, is colourless, and nearly inodorous; its taste is pungent and saline; it is very deliquescent; extremely soluble in water, and soluble in twice its weight of boiling alcohol. Its atomic weight is 98. The *acetate of ammonia* is made by neutralizing the common carbonate of ammonia with acetic acid. It crystallizes with difficulty, and is much used in medicine, in saline draughts, under the name of *spirit of Mindererus*.

*How many ACETATES OF LEAD are there?*

Two; the *acetate* and *subacetate*.\* The *acetate of lead* is formed by dissolving the carbonate of lead in acetic acid, and then crystallizing the solution. It is usually crystallized in needles, which have a silky appearance. Their taste is sweet and astringent. They are soluble in  $3\frac{1}{2}$  times their weight of cold water, and in somewhat less of boiling water. It was formerly called *superacetate* of lead, but it is a neutral salt, and consists of 1 atom of acid = 50, 1 of lead = 112, and 3 atoms of water = 27, making together 189.†

\* *Acetate* of lead is sometimes called *sugar of lead*, and *salt* or *extract of saturn*. Goulard's *extract of lead* is the *subacetate*.

The *white lead*, or *ceruse*, used by painters, is made by dissolving lead in vinegar.

† Acescent wine is sometimes sweetened with sugar of lead. This deleterious adulteration may be detected by sulphuretted hydrogen water, which will throw down the lead in the state of a dark brown sulphuret. Subcarbonate of ammonia also is a very delicate test, and will precipitate the lead in the state of a white carbonate; which, on being washed and digested with sulphuretted hydrogen water, will instantly become black.



*How is the SUBACETATE OF LEAD prepared?*

By boiling litharge in vinegar; or by boiling one part of the preceding acetate with two parts of litharge, deprived of carbonic acid by heat, with 25 parts of water. It crystallizes in plates, and is less sweet and soluble than the acetate. It appears to consist of 1 atom of acid and 3 atoms of oxide of lead.

*What is the best ANTIDOTE to POISONOUS doses of ACETATE OF LEAD?*

SUGAR, or EPSOM SALT. One of these should be given directly in water, and will be found an effectual antidote, if administered in time.\*

*What is VERDIGRIS?*

An impure *Acetate of copper*. The verdigris of commerce is prepared by a long continued exposure of copper to the fumes of vinegar.†

*How is CITRIC ACID procured?‡*

By adding powdered chalk to lemon-juice, as long as any effervescence ensues; an insoluble citrate of lime falls down, which, after being well washed with water, is to be decomposed by

For further information on this subject, see my *Modern Domestic Medicine*, art. Poisons.

The acetate of lead is used in medicine, being of remarkable service in checking hæmorrhages, and other inordinate discharges. The subacetate, when diluted with water, forms the well-known lotion, *Goulard-water*.

\* Sugar is likewise the best antidote to *Verdigris*.

† There appear to be three distinct acetates of copper, viz. the *subacetate*, consisting of 1 acid and 2 peroxide of copper; the *acetate* of 1 acid and 1 peroxide; and the *binacetate* of 2 acid and 1 peroxide.

‡ Citric acid exists in the expressed juice of the lime and lemon, along with a quantity of extractive matter and mucilage, and with variable proportions of malic and sometimes of acetic acid.



dilute sulphuric acid.\* The sulphuric acid combines with the lime, forming a sulphate of lime, which is removed by a filter, while the disengaged citric acid remains dissolved in the fluid. The fluid is then evaporated to the consistence of a thin syrup, which yields the pure citric acid in little needle-like crystals. To get them quite pure, they are repeatedly dissolved in water, and re-crystallized.†

*What are the properties of Citric Acid?*

The crystals are colourless and large, and very soluble in water. They absorb moisture from damp air, but when kept dry may be preserved a long time without change. Their taste is extremely sour, but when diluted very agreeable. According to Berzelius, they contain 79 per cent. of real acid; the rest is water.‡

*In what way is TARTARIC ACID § prepared?*

It is generally obtained from *cream of tartar*, the supertartrate or bitartrate of potassa, by the

\* The sulphuric acid must be equal to the weight of the chalk employed, and previously diluted with 10 parts of water.

† This process was originally described by Scheele, and has not since been improved.

‡ The atomic constitution of this acid is undetermined. Dr. Thomson and Berzelius regard it as consisting of 4 proportions of carbon, 4 of oxygen, and 2 of hydrogen.

Citric acid combines with the various bases forming *citrates*, but their salts are of little importance.

§ Casks in which certain wines are kept become incrustated with a hard substance, tinged with the colouring matter of the wine, and is called *argal* or *tartar*. This, when purified by solution and crystallization, constitutes *cream of tartar*, and was long considered to be a product of fermentation. Boerhaave, Newman, and others, however, showed that it existed ready formed in the juice of the grape. It has likewise been found in other fruits, particularly before they are completely ripe.



following process:—Let 100 parts of finely powdered cream of tartar be intimately mixed with about 30 parts of pulverized chalk, and the mixture be thrown, by spoonfuls, into 8 or 10 times its weight of boiling water. On each addition, a brisk effervescence ensues, owing to the escape of carbonic acid, and a quantity of insoluble tartrate of lime will be formed, which is to be allowed to subside, and washed with abundance of cold water. It is then diffused through a sufficient quantity of water, to which is added concentrated sulphuric acid, equal in weight to the chalk employed, which uniting with the lime forms a sulphate of lime, and the tartaric acid is set free. The sulphate of lime is separated by the filter, and the tartaric acid obtained by evaporation and crystallization as above directed for the citric acid.

*What are the properties of this acid?*

It is met with in the shops usually in the form of a white powder, which is very acid to the taste, but agreeable. It forms with alkalies neutral salts called *tartrates*. The crystals require for solution 5 parts of water at 60°, but are much more soluble in boiling water. They are decomposed by the sulphuric and nitric acids, and if the latter be concentrated, the tartaric will be converted into oxalic acid.\*

\* The atomic weight of *anhydrous* tartaric acid is 66. The crystals contain 1 atom of water = 9, which makes their equivalent 75.

Tartaric acid is distinguished from other acids by forming a white precipitate, the bitartrate of potassa (*cream of tartar*), when mixed with any salt of potassa.



*What are the principal TARTRATES?\**

They are the *tartrate of potassa*, or *soluble tartar*, the *bitartrate of potassa*, or *cream of tartar*, and the *tartrate of antimony and potassa*, or *tartar emetic*.† The last of these salts is the most important. It is prepared by boiling together cream of tartar and glass of antimony, in fine powder. Tartar emetic is colourless, and in transparent tetrahedrons or octahedrons. It reddens litmus, and its taste is nauseous and caustic. Boiling water dissolves half its weight, and cold water a fifteenth part. Sulphuric, nitric, and muriatic acids, when poured into a solution of this salt, precipitate its cream of tartar; and soda, potassa, ammonia, and their carbonates, throw down its oxide of antimony. The precipitate produced by the alkaline hydrosulphurets is wholly formed of kermes; while that caused by sulphuretted hydrogen contains both kermes and cream of tartar. Decoctions or infusions of Peruvian bark, rhubarb, and catechu, decompose it.‡

\* The TARTRATES are characterized by being converted into *carbonates* at a red heat; and by those with earthy bases being scarcely soluble in water, while the alkaline tartrates are soluble. The latter, when combined with an excess of acid, become much less so.

† There is also the *tartrate of potassa and soda*, or *Rochelle salt*, which is the *soda tartarizata* of the Pharmacopœia; and the *tartrates of soda, iron, &c.*

It is evident from this enumeration, that the tartaric acid has a remarkable tendency to form double salts, one of which is of great importance, namely, the *tartrate of antimony and potassa*, or *tartar emetic* of the shops.

‡ When tartar emetic is exposed to a red heat, it first blackens, like all organic compounds, and afterwards leaves a residuum of metallic antimony



*What is OXALIC ACID?*

It is a peculiar vegetable acid, which exists, in union with potassa, in the common wood sorrel; and which may be procured artificially from a variety of vegetable substances, by treating them with nitric acid. It is thus procured from sugar,\* gum, honey, the acids of cherries, currants, citrons, raspberries, &c. and even from silk, hair, tendons, and wool.†

*How is this conversion of different substances into oxalic acid explained?*

and subcarbonate of potassa. From this phenomenon, and the deep brownish red precipitate, by hydrosulphurets, this antimonial combination may readily be recognized. The precipitate may further be dried on a filter, and ignited with black flux, when a globule of metallic antimony will be obtained. Infusion of galls is an active precipitant of tartar emetic.

Dr. Thomson states the composition of this salt to be

2 atoms of tartaric acid .....	= 132
3 atoms of protoxide of antimony .....	= 156
1 atom of potassa .....	= 48
2 atoms of water.....	= 19

Atomic weight ..... 355

Mr. Phillips says there are 3 atoms of water. Tartar emetic is of remarkable use in medicine, more particularly as an alterative in diseases of the skin, and in disorders of the important organs of digestion. It is sometimes of uncommon utility in inflammatory diseases. In all cutaneous complaints, its effects are rendered both more certain and decisive by combining it with calomel, &c.

\* Oxalic acid may be obtained from sugar in the following way:—To 6 ounces of nitric acid in a stoppered retort, add, by degrees, one ounce of lump sugar, coarsely powdered. A gentle heat may be applied during the solution, and nitrous gas will be evolved in abundance. When the whole of the sugar is dissolved, distil off a part of the acid, till what remains in the retort has a syrupy consistence, and this will form regular crystals, amounting to 58 parts from 100 of sugar. These crystals must be dissolved in water, re-crystallized, and dried on blotting paper.

† M. Berthollet observes, that the quantity of oxalic acid obtained by treating wool with nitric acid was very considerable, being above half the weight of the wool employed.



On the fact, that oxalic acid contains more oxygen than any other principle, whether animal or vegetable. It is consequently the highest term of vegetable acidification. It cannot receive more oxygen without being decomposed, neither can it be made to return to a state of lower acidification.

*What are the PROPERTIES OF OXALIC ACID ?*

It has a strong acid taste, and acts powerfully on vegetable colours.\* It dissolves in twice its weight of water at 60°, and in an equal weight of boiling water; it is also soluble in boiling alcohol. It is decomposed by a red heat; at first swelling, and abandoning a large quantity of water; after the operation, nothing remains but charcoal. It is a virulent poison.† It is considered to be composed of 2 atoms of carbon = 12, and 3 of oxygen = 24; its atomic weight is therefore 36. Oxalic acid has a greater affinity

\* One grain, even when dissolved in 3600 grains of water, reddens the colour of litmus paper. The crystals of oxalic acid effloresce in the air, and become covered with a white powder. They have the figure of a four-sided prism, whose sides are alternately larger, terminated by diëdral summits. They contain half their weight of water of crystallization, 28 per cent. of which only can be expelled by heat, without decomposing the acid itself.

From its composition, as above stated, it is evident that it contains no hydrogen, in which circumstance it differs from all other vegetable acids.

† It has unhappily often been taken by mistake for Epsom salt, to which it bears a resemblance. It may readily be distinguished from this salt by its sour taste; or by putting a little of the suspected substance in a teaspoonful of water, when, if it be oxalic acid, it will immediately effervesce with a little scraped chalk or common whiting, which Epsom salt will not do.

The best *antidotes* of this poisonous acid are chalk and magnesia given in water.



for lime than for any other of the bases.\* With the bases it unites and forms a class of salts called *Oxalates*.†

*How is BENZOIC ACID obtained?*

The best method is by sublimation. A thin stratum of powdered benzöin is spread over the bottom of a glazed earthen pot, to which a tall conical paper covering is fitted; gentle heat is then to be applied to the bottom of the pot, which fuses the benzöin, and fills the apartment with a fragrant smell, arising from a portion of essential oil and acid of benzöin, which are dissipated into the air; at the same time the acid itself rises very suddenly in the paper head, which may be occasionally inspected at the top. This acid sublimate is condensed in the form of long needles, or straight filaments of a white colour, crossing each other in all directions.‡

*What are its properties?*

\* The *oxalate of lime* is a white powder, and remarkable for its extreme insolubility in pure water. On this account a soluble oxalate is an exceedingly delicate test for lime. The oxalate of lime is the basis of what is called the *mulberry calculus*.

† The chief of these salts are the *oxalates of potassa, soda, lime, magnesia, and ammonia*. The oxalate of potassa exists in two states, that of a neutral, and that of an acidulous salt. The latter is usually obtained from the juice of the leaves of the *oxalis acetocella*, wood sorrel, or *rumex acetosa*, or common sorrel. It is sold in the shops under the name of *essential salt of lemons*, and is much used in taking out ink spots from linen. With water and sugar it forms a pleasant cooling beverage, well adapted as a drink in summer. It is a *binoxalate* of potassa, consisting of 2 atoms of acid to 1 atom of base.

‡ Benzoic acid is found in *storax, balsams of Peru and Tolu, varilla, and cinnamon*, as well as in gum benzöin. It has also been found in the urine of man and herbivorous quadrupeds.



It has a peculiar and not disagreeable odour, and it reddens the colour of litmus, although to the taste it has no acidity. Its crystals are soft and ductile, and cannot be reduced to powder. It is volatilized, in white fumes, by a moderate heat. It is soluble in alcohol, and requires for its solution in boiling water 24 times its weight. It consists of carbon, oxygen, and hydrogen, but the proportions have not been satisfactorily determined. It unites with alkaline and earthy bases, forming salts, called *benzoates*, none of which are worthy of particular notice.\*

*From what vegetable substance is GALLIC ACID obtained in the greatest quantity?*

It is found in different vegetables possessing astringent properties, but most abundantly in the excrescences termed gall-nuts, whence it derives its name. It may be procured by macerating the galls in water, filtering, and suffering the liquor to stand exposed to the air. It will grow mouldy, be covered with a thick glutinous pellicle, abundance of glutinous flocks will fall down, and, in the course of two or three months, the sides of the vessel will appear covered with small yellowish crystals, abundance of which will like-

\* The *malic acid* does not possess any properties of great interest. It was first obtained from apples, whence its name; but it exists in the juice of various fruits mixed with the citric acid, and occasionally with other acids. It may be obtained most conveniently, and in greatest purity, from the berries of the mountain ash, called *Sorbus*, or *Pyrus Aucuparia*. It is a liquid acid, and incapable of crystallization. With the bases it forms salts, called *malates*.



wise be found on the under surface of the supernatant pellicle.\*

*What are the PROPERTIES OF GALLIC ACID ?*

It has an acido-astringent taste; is soluble in 24 parts of cold, and 3 of boiling water, and in an equal weight of hot alcohol. When placed on a red-hot iron, it burns with flame, and emits an aromatic smell. It effervesces with alkaline, but not with earthy carbonates. By nitric acid it is converted into oxalic.† It precipitates most metals from their solutions,‡—gold, silver, and copper, of a brown colour; lead, white; mercury, orange; bismuth, yellow; and iron, deep black. Of these compounds the *tanno-gallate of iron* is the most important, as forming the basis of writing ink; and as indicating by its formation the pre-

\* These crystals may be purified by solution in alcohol, and evaporation to dryness.

In the experiments of Sir H. Davy, 400 grains of a saturated infusion of galls yielded, by evaporation, 53 of solid matter, composed of nine-tenths tannin, and one-tenth gallic acid.

Another and more summary method of obtaining gallic acid is by removing the tannin from the infusion of gall-nuts, by muriate of tin. For this purpose the muriate must be added, until no more precipitate falls down; the excess of oxide, remaining in the solution, may then be precipitated by sulphuretted hydrogen gas, and the liquor will yield crystals of gallic acid by evaporation. According to Haussman about 3 drachms of gallic acid may be thus obtained from an ounce of galls.

† It unites with alkaline solutions without producing any deposit; but from watery solutions of lime, baryta, and strontia, it occasions a bluish precipitate. Of the combination of earths with acids, it decomposes those only with base of glucina, yttria, and zirconia, a property distinguishing those earths from all others.

‡ Its great affinity for metallic oxides is its most distinguishing characteristic. When combined with tannin, it will take them from powerful acids. The more readily the metallic oxides part with their oxygen, the more they are alterable by the gallic acid.



sence either of iron or gallic acid, according as one or the other of these bodies is applied.\* Its atomic weight is probably 63.† The salts of gallic acid, called *gallates*, do not deserve particular notice.

*Describe the mode of procuring SUCCINIC ACID, and its properties?*

It has been usually obtained by distilling amber in a retort with a regulated temperature, when the crystallized acid sublimes into the upper part of the vessel.‡ When purified, this acid may be

\* In order, however, to produce this characteristic compound, the iron must exist in the state of *per-oxide*, for the *prot-oxide* does not form a black compound with these substances. Iron filings indeed will dissolve in an infusion of galls with an extrication of hydrogen gas; but the compound is not black till after exposure to air, which oxidizes the iron still farther. Upon the same principle the colour of ink is destroyed by metallic iron, or by a stream of sulphuretted hydrogen. In both these cases the oxide of iron undergoes a partial decomposition. We are thus also enabled to explain why ink, at first pale, becomes black by exposure to air. As the *tanno-gallate* is decomposed by alkalies, the colour of writing ink is discharged by the action of these bodies, the characters becoming brown, and an oxide of iron alone remaining on the paper; but the fresh application of an infusion of galls will take up this oxide, and the characters be again rendered legible. In this manner a spot of ink on linen is immediately decomposed on the contact of soap, and the oxide of iron being precipitated constitutes an *iron mould*, for the removal of which citric or oxalic acid is usually recommended; but after it has remained long on the cloth, the iron acquires a degree of oxidation which renders it insoluble in the acid; when it may be washed with a solution of sulphuret of potassa, or be wetted with some recent ink, by which the oxide will be sufficiently deoxidized to render it soluble.

† Its atomic constitution has not been accurately determined, but it appears to be as follows:—

Carbon .....	6 atoms .....	36 .....	57.14
Oxygen .....	3 atoms .....	24 .....	38.10
Hydrogen .....	3 atoms .....	3 .....	4.76
		<hr/>	<hr/>
		63	100.

‡ M. Julin, of Abo, states, that by mixing with coarsely powdered amber  $\frac{1}{12}$ th part of sulphuric acid, diluted with an equal weight of water, the



obtained by evaporation, in white transparent prismatic crystals. Their taste is sour, they red- den powerfully tincture of turnsole, and are so- luble in both water and alcohol. Heat melts and partially decomposes it. Its atomic weight is considered to be 50. With the bases it forms salts called *succinates*.\*

*We shall now pass on to the notice of the VEGETA- BLE ALKALIES, a class of bodies of recent discovery:† What are their general properties?*

They have in common with the alkalies which have been long known, the power of combining with acids, and forming salts;‡ in a pure state they are very sparingly soluble in water, and have for the most part a very bitter taste; they are inodorous, and are not altered by air, or light, but are decomposed, both when separate and in combination, at low degrees of heat;§ they are

succinic acid will be produced in about twice the quantity got in the old way.

\* The succinates have not been accurately examined. The succinate of ammonia is useful in analysis to separate oxide of iron from manganese.

† The class of vegetable alkalies was originally discovered by Sertuerner, a German apothecary, in 1803, and they have since been ably investigated by M. Robiquet, M. Lassaigne, MM. Pelletier and Caventou, and others.

‡ Their affinities for acids are much weaker than those of the more important alkalies already noticed in the tenth chapter.

They are all crystallizable, with the exception of the *nitrate of cinchonia* and the salts of *veratria*.

§ Ammonia is always a product of their destructive distillation; a sufficient proof of their containing nitrogen. The following is a tabular view of the relations of carbon and nitrogen in the vegetable alkalies.

	Carbonic Acid.	Nitrogen.
Quina, .....	100 .....	5.1
Cinchonia .....	100 .....	5.0
Strychnia, .....	100 .....	4.9



nearly all soluble in alcohol, and many of them in ether; they never exist in an insulated state in the plants which contain them, being apparently always combined with an acid, with which they form a salt more or less soluble in water. They all appear to contain nitrogen, in addition to carbon, hydrogen, and oxygen.

*Enumerate the principal vegetable alkalies?*

They are, *morphia*, which is obtained from opium; *quina* and *cinchonia*, procured from Peruvian bark; *emetia*, from ipecacuanha; *strychnia*, from *nux vomica*; *atropia*, from belladonna; *hyoscyama*, from henbane; *veratria*, from hellebore and meadow-saffron, and *picrotoxia*, from *cocculus indicus*.

*As all these vegetable alkalies agree in their leading chemical properties, the principle on which chemists proceed in extracting them from the vegetables containing them, is the same: What is it?*

It has been just remarked, that they exist in union with an acid in the plants which contain them, and the principle referred to is that of separating the vegetable alkali from its acid by the addition of a more powerful alkali, or earth, as ammonia or magnesia, when the vegetable alkali

	Carbonic Acid.	Nitrogen.
Narcotine, .....	100 .....	4.5
Brucia, .....	110 .....	5.0
Morphia, .....	100 .....	3.2
Veratria, .....	100 .....	3.2
Emetia, .....	100 .....	3.1
Cafeine, .....	100 .....	20.0

Cafeine is the alkaline principle of coffee, and on looking over this table we are struck with the large proportion of nitrogen it appears to contain.



falls down insoluble, and may be collected on a filter.\*

*What are the PROPERTIES OF MORPHIA?*

Morphia is the narcotic principle of opium, and when pure, is quite white, has a pearly lustre, is without smell, and has an intensely bitter taste. It is insoluble in cold, and only slightly soluble in hot water, but is very soluble in heated alcohol and ether.† It forms neutral salts with acids, and decomposes the compounds of acids with metallic oxides. It fuses at a moderate heat, and then resembles melted sulphur. On cooling, it again crystallizes. It burns readily. By nitric acid it is turned red. It acts with great energy on the animal system in the

\* The following process of M. Robiquet for extracting morphia is considered the best. A concentrated infusion of opium is prepared by macerating 300 parts of the pure drug in 100 parts of common soft water for five days; to this solution when filtered, 15 parts of the best calcined magnesia (*carbonate* of magnesia must be carefully avoided) are to be added; then boil the mixture for ten minutes, and separate the greyish and abundant deposit by a filter, washing it with cold water till the water passes off clear. After this, wash it with hot and weak alcohol, which takes up a small quantity of morphia and much colouring matter. Then wash it with a little cold and concentrated alcohol, and afterwards boil it with a large quantity of the same fluid, which, at that temperature, dissolves morphia. This liquid being filtered while hot, on cooling it deposits the morphia in crystals, and very little coloured. The solution in alcohol, and crystallization, being repeated two or three times, colourless morphia is obtained.

The theory of this process is as follows:—Opium contains a meconiate of morphia. The magnesia combines with the meconic acid, and the morphia is separated.

The average produce of morphia, from a pound of good Turkey opium, may perhaps be estimated at about 500 grains, or  $\frac{1}{14}$ th of its weight.

† The watery and alcoholic solutions of morphia affect test papers like an alkali.



smallest doses, and in large doses is a violent poison.\*

*From what kinds of bark are QUINA and CINCHONIA obtained, and what are their properties?*

*Quina* is obtained from the *yellow* bark, and *cinchonia* from the *pale* bark.† The former is ob-

\* *Morphia*, when properly administered, is of great value in medicine. It appears to produce the soothing effects of opium, without occasioning the feverish excitement and head-ache which so frequently accompany the employment of that drug. The best mode of exhibiting it is in the form of acetate of morphia, which is supposed to be the basis of Mr. Battley's *sedative solution of opium*. The *black drop* is likewise chiefly an acetate of morphia.

I ought to observe here, that the chief principles found in opium are morphia, meconic acid, narcotine, resin, gum, extractive matter, and a small quantity of caoutchouc. Morphia we have just described. *Meconic acid*, with which morphia is combined in opium, may be obtained from the magnesian residuum described above, by a process I need not describe here. It possesses the usual properties of acids, and is characterized by producing a red colour when added to a solution of a salt of the peroxide of iron. When taken into the stomach, it does not produce any sensible effect.

*Narcotine* is not a vegetable alkali, but a peculiar principle in which the stimulating properties of opium are supposed to reside. It was formerly called the *salt of Derosne*, and was long supposed to be the meconate of morphia. Its crystals have a pearly lustre, are inodorous and insipid. They are insoluble in water, and very slightly soluble in alcohol, but are soluble in fixed oil, and in acids. They have no action on vegetable colours.

† Both *quina* and *cinchonia* were discovered by the French chemists, MM. Pelletier and Caventou, but Dr. Gomez, of Lisbon, first recognized the existence of cinchonia, though he did not ascertain its alkaline nature. Many processes have been given for the separation of cinchonia. The following method is recommended by Mr. Brande, *Manual of Pharmacy*, p. 61. A pound of *pale* bark, bruised, is to be boiled in about a gallon of water, to which three drachms of sulphuric acid have been previously added. A similar decoction is to be repeated with about half the quantity of liquid, and so on till all the soluble matter is extracted. The decoctions are then to be mixed together and strained, and powdered slaked lime to be added, in proportion somewhat greater than is required to saturate the acid. From the precipitate, which is a mixture of cinchonia and sulphate of lime, repeated boilings for some minutes with alcohol, decanting the fluid while hot, separate the cinchonia, which may be obtained by distilling off the alcohol at a very gentle heat. *Quina* may be extracted from *yellow* bark by a similar process. For further information respecting the most eligible



tained in a white porous mass, incapable of crystallization. It has a very bitter taste, and is insoluble in water, but very soluble in alcohol and ether. It unites with the acids, forming crystallizable salts. Its febrifuge and tonic virtues are more powerful than those of cinchonia. Cinchonia is white, translucent, and crystalline, insoluble in cold water, sparingly soluble in boiling water and ether,\* but very soluble in hot alcohol. Its taste is bitter, but much less so than that of quina. It restores the colour of litmus which has been reddened by an acid, unites with all the acids, and gives rise to a class of salts.

*What is QUININE, the medicine which is now in so great repute as a tonic?*

It is a *sulphate of quina*, that is, quina united with sulphuric acid. It forms crystals which are remarkable for their satin-like and pearly lustre. It is soluble in water, and is considered the most powerful preparation of bark. When good, eight grains are considered equivalent to an ounce of bark.† It consists of 90 quina + 10 acid.

processes for separating these alkalies, see *Ann. de Chim. et de Phys.* tom. xv. p. 289, and tom. xvii. p. 273; and *Journal of Science*, vol. xvi. p. 282.

Both the above alkalies exist in bark in combination with a peculiar acid, called *kinic acid*. They are found in the *red bark*, as well as in the *yellow* and *pale barks*.

Quina is sometimes called *quinia*, or *quinina*.

The atomic constitution of these alkalies, as well as of morphia, &c. have not been satisfactorily determined.

\* Since quina is very soluble in ether, and cinchonia is not, this liquid may be employed to separate the two alkalies.

† *Sulphate of quina*, or *quinine*, is often much adulterated. It dissolves readily in strong alcohol, by the aid of heat, a character which may be had recourse to as a useful test of its purity.



STRYCHNIA is the poisonous principle both of nuxvomica and of the deadly Upas tree of Java: What are its properties?\*

Its crystals form four-sided prisms, terminated by four-sided low pyramids. It is almost insoluble in cold water, and very sparingly soluble in boiling water; it is white, without smell, but so intensely bitter to the taste, that water which contains only the 600.000th part of a grain in solution has a sensible bitterness when tasted. It is not changed by exposure to the air, and is neither volatile nor fusible. It is very soluble in hot alcohol, but insoluble in ether. It has a distinct alkaline re-action, and neutralizes acids, forming salts. It is a most deadly poison, and its operation is very generally accompanied with symptoms of locked jaw, and other tetanic affections.†

What are the PROPERTIES OF VERATRIA, the active medicinal principle of white hellebore and meadow saffron?

Veratria is white, pulverulent, destitute of smell, and without bitterness, but when inhaled into the nostrils, even in the minutest quantity, it produces violent and dangerous sneezing, and its

\* It was discovered by Pelletier and Caventou in 1818. It is found also in St. Ignatius's bean. For the processes by which it may be separated, see *Ann. de Chim. et de Phys.* tom. x. and xxvi; *Journal of Science*, vol. xv. p. 170; and *Journal de Pharmacie* for Oct. 1825.

† One eighth of a grain, blown into the throat of a rabbit, brought on a locked-jaw in two minutes, and in five minutes proved fatal. According to the analysis of Pelletier and Dumas, its constituents are, carbon 78.22, nitrogen 8.92, hydrogen 6.54, oxygen 6.38.



taste is eminently acrid. It is very sparingly soluble in cold water, but somewhat more so in boiling water. It is extremely soluble in alcohol, and less so in ether. It has an alkaline reaction, and neutralizes acids.\*

\* It is a weaker base than morphia, quina, or strychnia. It fuses at 122° Fahr., and has then the appearance of melted wax; in cooling, it becomes semi-transparent, and amber-coloured. It exists in the plants mentioned in union with an excess of gallic acid, and was discovered by Pelletier and Caventou in 1819.

*Emetia*, the active principle of ipecacuanha, forms transparent brownish-red scales; it has no smell, but a bitter acrid taste; at a heat somewhat above that of boiling water, it is resolved into carbonic acid, oil, and vinegar, but affords no ammonia, which proves that nitrogen does not enter into its composition. It is uncrystallizable; is soluble both in water and alcohol, but not in ether; and is precipitated by protonitrate of mercury and corrosive sublimate, but not by tartar emetic. It acts like an alkali on vegetable colours. Half a grain of it acts as a powerful emetic, followed by sleep; six grains vomit violently, and produce stupor and death. For an improved process for extracting this principle, see *Ann. de Chim. et de Phys.* tom. 24.

*Atropia* is obtained from the *atropa belladonna*, or deadly nightshade. Its external appearance varies considerably, according to the mode of its preparation, being either granular, or flaky, or gelatinous, like precipitated alumina. When quite pure, it is white and tasteless. It is not soluble in cold water, and sparingly so in hot water. Cold alcohol has not much effect upon it, but boiling alcohol dissolves it readily, but deposits the greater part of it on cooling. Ether and oil of turpentine, even when boiling, have little effect upon it. It forms salts with acids, the greater number of which are readily soluble in water. MM. Brandes first extracted the *atropia* from belladonna, and also the *hyocyama*, from henbane.

*Picrotoxia* is the bitter poisonous principle of the *cocculus indicus*, and has hitherto been ranked among the vegetable alkalies, but its claim to the title of an alkali has been lately called in question by M. Casaseca, who remarks that it has no alkaline reaction, and does not neutralize acidity. It does, however, combine with acids, and with the acetic and nitric acids forms crystallizable compounds. It is asserted also, that the menispermic acid, supposed by M. Boullay to be mixed in the *cocculus indicus* with picrotoxia, is merely a mixture of sulphuric and malic acids.

There are many other other vegetable alkalies, beside those above described. Indeed, the active principle of most, if not all plants, which are either poisonous or exert any very energetic action on the human system, appears to reside in an alkali. We have, therefore, *delphia*, the active principle found in stavesacre, *solania*, that found in woody nightshade, &c.



*There is a class of substances called BITUMENS, which we have not yet referred to: What are they?*

They are inflammable substances, burning with flame in the open air, which, although extracted from the earth,\* are generally considered to have been formed originally by the decomposition of vegetables.

*Enumerate the native bituminous substances?*

They are *Naphtha, Petroleum, Mineral Tar, Mineral Pitch, Asphaltum, Jet, Pit-coal, Bituminous Wood, Turf, and Peat.*†

\* From being obtained from the earth, they have often been classed among mineral substances, but, in chemical properties, they are more closely allied to the products of the vegetable kingdom.

† Some authors add *amber* and the *honey-stone* to the number of bituminous bodies. *Amber* is no doubt of vegetable origin. It is a hard, brittle, tasteless substance, sometimes perfectly transparent, but mostly semi-transparent or opaque, and of a glossy surface. It is found of all colours, but chiefly yellow or orange. Its specific gravity is from 1.065 to 1.100; its fracture is even, smooth, and glossy; it is capable of a fine polish, and becomes electric by friction. It is insoluble in water and alcohol, but is soluble in sulphuric acid, which then acquires a reddish-purple colour. Water precipitates it from its solution in this acid. By distillation, it affords a small quantity of water, with a little acetic acid, an oil, and a peculiar acid called *succinic acid*, or the acid of amber. Amber is met with plentifully in regular mines in some parts of Prussia. Detached pieces are also found occasionally on the sea-coast in various countries. In the Royal Cabinet at Berlin there is a mass of 18lbs. weight, supposed to be the largest ever found.

*Mellite, or Mellilite, or Honey-stone*, is a very rare production, of the colour of honey. It has been found, accompanying brown coal, chiefly, if not solely, at Artern in Thuringia. Its specific gravity is 1.56. It is consumed when ignited in the open air, but without flame or smoke. By being treated first with boiling water and then with alcohol, with trituration and subsequent evaporation, it yields crystals of a peculiar acid, called *mellitic acid*. This acid has a sweetish-sour taste, with some bitterness. It is decomposed by nitric acid, without the production of any oxalic acid. Dropped into the watery solutions of lime, baryta, or strontia, it gives a precipitate, which is soluble in muriatic acid. It neutralizes potassa, soda, and ammonia, and affords with them crystallizable salts.



*We have already often spoken of NAPHTHA: How is it obtained, and what are its properties?*

It is a fine, white, thin, fragrant, colourless oil, which issues out of white, yellow, or black clays, in Persia or Media, and is also found on the surface of the water of certain springs in Italy, and on the shores of the Caspian Sea. It is very volatile, highly inflammable, and burns with a penetrating smell and much smoke. It is remarkable for containing no oxygen in its composition,\* and for being the lightest of all dense fluids, its specific gravity being .708.

*What are the CHARACTERS OF PETROLEUM?*

It is a yellow, reddish, brown, greenish, or blackish oil, found dropping from rocks, or issuing from the earth, in the Duchy of Modena, and in various other parts of Europe, and in Asia. It is considerably thicker than naphtha, and has a specific gravity of .878.†

*What are the Characters of ASPHALTUM?*

Asphaltum is a solid bitumen, which is found in considerable abundance, especially in the island of Trinidad, on the shores of the Dead Sea, and in Albania, where it is met with in vast strata. It is brownish-black, brittle, shining,

\* As we have already remarked, this circumstance renders it of great use in preserving the new metals discovered by Sir H. Davy, (see page 312). When recently distilled, these metals have no action upon it; but in naphtha that has been exposed to the air, they soon oxidate, and alkali is formed, which unites with the naphtha into a kind of brown soap.

† Naphtha may be obtained from petroleum, by distilling it at a low degree of heat. Petroleum is highly inflammable. It has the property of combining with fat and essential oils, with resins, camphor, and sulphur, and, when rectified, it dissolves caoutchouc.



and does not stain the fingers. It is extremely inflammable, burns with a yellow flame, and has a specific gravity varying from 1.07 to 1.65. It is insoluble in water, alcohol, acids, and alkalis; but dissolves in oils, ether, and especially in naphtha.\*

*What is the chemical nature of the COAL we usually burn?*

It is a compound of charcoal and bitumen; or it may be stated to consist of the ordinary elements of vegetable substances, carbon, hydrogen, and oxygen, united with a proportion of nitrogen.† Coal is commonly divided into three varieties, namely, brown, black, and glance

\* Naphtha is its proper solvent, of which it requires five times its weight. The solution is of a deep black colour, and forms an excellent varnish.

The asphaltum found in Albania is supposed to have constituted the chief ingredient of the *Greek fire*. The Egyptians appear to have employed this bitumen in embalming, and to have called it *mumia mineralis*. It was used instead of mortar in building the walls of Babylon.

*Maltha*, or *sea-wax*, sometimes called *mineral pitch*, is a solid; *mineral tar* is a viscid fluid. They both resemble petroleum in their characters. The substance called *mineral tallow* is of the same kind.

*Elastic Bitumen*, or *mineral caoutchouc*, is a singular and rare substance, hitherto found only in Derbyshire. It is soft and elastic, not unlike *common caoutchouc*. It is inflammable, and burns with much smoke. It resists the action of almost all solvents.

*Retinasphaltum* is another rare production, found only accompanying *bovey coal*, in Devonshire. It has a pale brown ochre yellow colour, is very brittle, and breaks with a vitreous fracture. Its specific gravity is 1.135. It melts on the application of heat, and burns with a bright flame.

*Peat*, or *turf*, consists chiefly of the fibres of several mosses, with occasionally branches, and even trunks, of various trees. It is extremely inflammable in the open air; and, when distilled in close vessels, yields products similar to those of coal. The gas, however, which is evolved, approaches more in its characters to carbonic oxide than to carburetted hydrogen.

† The following is the result of Kirwan's analysis of different kinds of coal, in respect to the relative proportions of charcoal and bitumen,



coal.\* Black coal is that which is commonly applied to the purposes of fuel. The principal varieties of black coal are *caking coal*, *flint coal*, *cherry coal*, and *cannel coal*.†

In 100 parts of	Charcoal.	Bitumen.	Earth.	Spec. Gravity.
Cannel Coal ..	75.2 .....	21.7 .....	3.1 .....	1.232
Slate Coal ....	47.6 .....	32.5 .....	19.9 .....	1.426
Whitehaven ..	57.0 .....	41.3 .....	1.7 .....	1.257
Wigan .....	61.7 .....	36.7 .....	1.6 .....	1.268
Swansey .....	73.5 .....	23.1 .....	3.4 .....	1.357
Leitrim .....	71.4 .....	23.4 .....	5.2 .....	1.351
Newcastle ....	58. ....	40. ....	2. ....	1.271

\* *Brown coal* is an imperfect coal. It is not perfectly bitumenized, and exhibits remains of the vegetables, from whose decay it has originated. It is brown, opaque, somewhat flexible and elastic, and nearly light enough to float on water. *Glance coal* consists almost entirely of charcoal and a little earthy matter; it containing either no bitumen at all, or only a very small proportion. It is less common than the black coal, and is usually called *stone coal*. It is remarkable for its metallic lustre, and for the slowness with which it consumes. It is found in considerable quantity in Kilkenny.

† *Black Coal* is a compound of bitumen and charcoal, and according to the proportion of these two ingredients, its properties vary considerably. The best kinds melt on the application of a moderate heat, and burn almost entirely away, with a clear bright flame. The Newcastle coal is *caking coal*, and is so called because its fragments melt at a certain temperature, and unite into one mass. *Splint coal* is a hard coal, which breaks with a splintery appearance. It is the sort best adapted for making coke, and extracting iron from its ores. *Cherry coal* abounds in the neighbourhood of Glasgow, and in Staffordshire. It breaks very readily, burns with a clear yellow flame, and is consumed much faster than either of the preceding species. The best quality of *cannel coal* is found at Wigan, in Lancashire. It is eminently combustible, and emits a vivid light. It does not at all soil the fingers, and is easily turned by the lathe, so that it is sometimes made into snuff-boxes, and various other useful articles.

*Naphthaline* is a species of naphtha, found during the rectification of the petroleum of the coal gas works, incrusting the pipes. It is a greyish-white substance, insoluble in water, but very soluble in ether, and moderately so in alcohol and oils. Its sp. gravity is 1.048. According to Dr. Ure's analysis it is a solid bicarburet of hydrogen, consisting of 2 atoms of carbon and 1 of hydrogen.



*We must now advert to the spontaneous decomposition of vegetable substances: What is meant by the term FERMENTATION?*

It is intended to signify the spontaneous changes which aqueous combinations of vegetable or animal matter undergo, when exposed to the ordinary temperature of the atmosphere.\* A somewhat elevated temperature, such as 80° or 100° Fahr., is very favourable to the process of fermentation.

*How many kinds of fermentation are there?*

Three; namely, the ACETOUS, VINOUS, and PUTREFACTIVE.† The product of the first is acetic acid, or vinegar;‡ that of the second a beer, or wine. The result of putrefaction is the entire decomposition of the substance exposed to that process.§

\* It is a striking distinction between the substances belonging to the animal and vegetable kingdom, and minerals, that the former are subject to perpetual alteration, while the latter, if left to themselves, remain almost unchanged, or change so slowly that the alteration is scarcely perceptible to our senses. Vegetables and animals, while living, grow and decay; and when dead, unless under very peculiar circumstances, invariably undergo spontaneous decomposition. Chemical researches have demonstrated, that during the life time of plants, the substances of which they are composed are continually changing their nature. Mucilage in the young plant becomes starch in an old one, and the acid of the green fruit, as the season advances, is gradually converted into sugar. The constituent parts, then, of plants are gradually entering into new combinations, and forming new compounds; and this takes place after the plant has been removed from the earth and the fruit gathered from the tree.

† Some authors divide the *genus* of fermentation differently, but the above appears to me the best. It includes all the distinct and unequivocal varieties of fermentation.

‡ The *acetous* fermentation, and its product, vinegar, has been already described.

§ The spontaneous decomposition of animal or vegetable matters, when attended with a fetid smell, is, as is well known, called *putrefaction*. An



*What conditions are necessary to the establishment of the VINOUS FERMENTATION?*

The presence of water, sugar, yeast, or some ferment,\* and a certain temperature. All those

exposure to air, moisture, and a certain temperature, is necessary to the process taking place readily and perfectly. The contact of air is not absolutely necessary, but exposure to the open air greatly expedites the process. Water is the grand resolvent of organic matter, and a certain degree of moisture is therefore essential. Consequently, the abstraction of moisture by drying, or its fixation by cold, will counteract the process of putrefaction. The temperature most favourable to putrefaction is between 60° and 100° Fahr. A strong heat is unfavourable by expelling moisture; and a cold of 32°, (the freezing point of water,) arrests its progress entirely.

The fetid odour present arises from the emission of certain offensive gasses, which differ in their nature according to that of the putrefying substance. Under ordinary circumstances, subcarburetted hydrogen gas is most abundantly given out in the putrefaction of vegetables; in that of animal matter, ammonia is usually formed in considerable quantity, and some vegetable substances, as gluten and cruciform plants, emit ammonia. Carbonic acid gas is also frequently present, and in the putrefaction of animal substances, phosphuretted and sulphuretted hydrogen gases. But there is likewise a solid substance of a dark pulverulent nature, originating from the decay of leaves and other parts of plants, which forms vegetable mould. This consists of charcoal combined with a little oxygen and hydrogen, and, when mixed with a proper quantity of earth, constitutes the soil necessary to the growth of plants.

Sir H. Davy has correctly remarked, that the pernicious effluvia disengaged in putrefaction, point out the necessity of burying putrefying substances in the soil, where they are fitted to become the food of vegetables. The fermentation and putrefaction of organized substances in the open air are noxious processes; beneath the surface of the ground, they are salutary operations. In this case the food of plants is prepared where it can be used; and that which would offend the senses and injure the health if exposed, is converted by gradual processes into forms of beauty and of usefulness; the fetid gas is rendered a constituent of the aroma of the flower, and what might be poison, becomes nourishment to man and animals.

\* *Yeast* is the scum and sediment collected from liquids in which fermentation is going on, and is supposed to act in promoting that process in other liquids, by inducing the operation of affinities different from those by which the ingredients are held together. The principle essential to fermentation, and of which yeast contains a considerable proportion, appears to be *gluten*. This substance can be extracted from *must*, and exists ready formed in the grape, which renders the juice of that fruit capable of perfect vinous fermentation without the addition of yeast. *Wort*, on the contrary, will not



nutritive vegetable and animal matters which contain sugar ready formed, are susceptible of the vinous fermentation,\* but of all such substances the juice of the grapes of France† afford the best wine. The expressed juice of the grape is called *must*, and contains all the ingredients essential to the most perfect vinous fermentation. In the making of wine, the *must*, contained in vats, is placed in a temperature of about 70° F., when its principles immediately begin to act upon one another, the liquor becomes turbid, an intestine motion is evident in it, its temperature increases, a scum collects on the surface, and carbonic acid gas is disengaged. In a few days, its activity gradually decreases, the scum and impurities subside to the bottom; and the liquor clears, having lost its saccharine taste, and become *wine*.‡

ferment without the addition of yeast, probably because it contains too little gluten. If the gluten is separated from yeast, it loses the property of exciting fermentation.

Exposure to air favours vinous fermentation, but is not absolutely necessary, for if by any means the gaseous fluid which is generated is allowed to escape, it goes on, though not so speedily. On the other hand, free admission of air, though it expedites the process, weakens the product, by carrying a great deal of it off by evaporation.

\* Thus wine may be made of all the juices of plants, the sap of trees, the infusions and decoctions of farinaceous vegetables, and the milk of animals, as well as of the juice of the grape and other ripe succulent fruits.

† Or of other countries that are nearly in the same latitude, or of the same temperature.

‡ The changes that take place during the vinous fermentation are involved in some obscurity. The principal results of the process are undoubtedly alcohol and carbonic acid, and Lavoisier, on comparing the composition of sugar with that of alcohol, was led to the conclusion, that, during the vinous fermentation, part of the carbon, by uniting with the



*How are ARDENT SPIRITS, that is, Brandy, &c. obtained?*

By the distillation of fermented liquors; and these spirits receive various names according to the nature of the fermented liquor employed. Thus *Brandy*\* is procured by the distillation of wine; *Rum*, by the distillation of the fermented juice of the sugar cane; *Whisky*† and *Gin*, from

oxygen of the sugar, passes to the state of carbonic acid, and that the remaining carbon, with the hydrogen of the sugar, compose alcohol.

In the production of *malt liquor*, (which may correctly be called the wine of grain,) from the fermentation of *sweet* barley, the changes that take place are no doubt mainly the same as those which occasion the fermentation of the juice of the grape.

\* The greatest quantities of *brandy* are made in Languedoc, where this manufacture first commenced. It is obtained by distillation in the usual method by a still, which contains five or six quintals of wine, and has a capital, or head, and worm tube applied. Its peculiar flavour seems to depend in some measure on the wood of the cask in which it is kept. It is said that a little nitrous ether, added to malt spirit, imparts to it the flavour of French brandy.

† The process of malting developes the saccharine principle of grain, and it would therefore appear to render it fitter for the purpose of distilling *whisky*, &c.; but the common practice is to use about six parts of raw grain with one of malt. For this, two reasons may be assigned: by using raw grain the expense of malting is saved, as well as the duty on malt; and the process of malting requires some nicety of attention, since, if it be carried too far, part of the saccharine matter is lost, and if it be stopped too soon, this matter will not be wholly developed. Besides, if the malt be dried too quickly, or by an unequal heat, the spirit it yields will be less in quantity, and more unpleasant in flavour. Another object of economical consideration is, what grain will afford the most spirit in proportion to its price, as well as the best in quality. Barley appears to produce less spirit than wheat; and if three parts of raw wheat be mixed with one of malted barley, the produce is said to be particularly fine. This is the practice of the distillers in Holland for producing a spirit of the finest quality; but in England they are expressly prohibited from using more than one part of wheat to two of other grain. Rye, however, affords still more spirit than wheat. The distillers in Scotland use one part of malted with from four to nine parts of unmalted grain. This mixture yields an equal quantity of spirit, and at a much cheaper rate than when the former proportions are taken.



the fermented infusion of malt or grain. From whatever substances these intoxicating liquors are obtained, they consist almost entirely of three ingredients, namely, water, pure spirit, or *alcohol*, and a peculiar oil, to which each spirit owes its flavour and colour.

*And in what way is ALCOHOL, or SPIRIT, OF WINE procured?\**

From the re-distillation of ardent spirits. Spirit of wine, or *rectified spirits*, (as it is sometimes called,) as commonly sold, is not pure, or as strong as possible, since it contains a considerable portion of water. It is freed from this

The finest *gin* is said to be made in Holland, from a spirit drawn from wheat mixed with a third or fourth part of malted barley, and twice rectified over juniper berries; but in general rye meal is used instead of wheat. They pay so much regard to the water employed, that many send vessels to fetch it on purpose from the Meuse; but all use the softest and clearest water they can get. In England, it is the common practice to add oil of turpentine, in the proportion of two ounces to ten gallons of raw spirit, with three handfuls of bay salt, and drawn off till the *feints* begin to rise.

\* Alcohol, the intoxicating ingredient of all fermented liquors, exists ready formed in wine, and in the fermented liquor (called the wash) of malt or other grain, combined with other substances; and the art of distillation consists in separating the alcohol from the other substances in the cheapest and best manner. It is an established fact, that alcohol boils at a temperature at least forty degrees below the boiling point of water, and consequently it is volatilized much sooner than any of the other ingredients, except, perhaps, the peculiar volatile oils with which it is combined, and to which the different spirits owe their flavours. The object is, to apply this degree of heat, and no more, to the mixture containing the alcohol, so that it may be separated, and nothing carried over with it. In general, however, this principle has not been strictly attended to, and a far greater degree of heat has been applied than is necessary to vaporize the alcohol. Thus, according to the mode of distillation at present in use in England, the process has to be repeated. What is first obtained is termed *low wines*, which, on being again distilled, yield raw spirit, and this gives, by a third distillation, the rectified spirit, or *spirit of wine* of the shops.



water by mixing it with hot and dry subcarbonate of potash, which absorbs the water, sinks to the bottom, and leaves the *pure* alcohol floating above.\*

*What are the PROPERTIES OF ALCOHOL?*†

It is a limpid, colourless liquid, of an agreeable smell, and a strong flavour. Its specific gravity varies with its purity, but it is always lighter than water. When of the specific gravity of .820, it boils at 176° Fahr., or in vacuo at 56°; at the specific gravity of .800 its boiling point is 173.5.‡ Alcohol is extremely volatile, and produces considerable cold by its evaporation;§ it is

\* The proportions are about two parts of alkali to one of spirit of wine. M. Lowitz, of St. Petersburg, first discovered the means of obtaining alcohol in a state of absolute purity. The strongest spirit that has hitherto been procured is of specific gravity 0.796, at the temperature of 60° Fahr. and is called *pure*, or *absolute alcohol*, as no method known can deprive it of any more water. The alcohol of the London Pharmacopœia is of specific gravity .815, and is supposed to contain 7 per cent. of water; *rectified spirits*, specific gravity 835°, 15 per cent.; and *proof spirit*, 56 per cent.

† The atomic constitution of alcohol is generally considered to be as follows:

Carbon	.....	2 atoms	=	12	.....	52.17
Oxygen	.....	1 atom	=	8	.....	34.79
Hydrogen	....	3 atoms	=	3	.....	13.04
						<hr/>
Its atomic weight ..						23 ..... 100.

‡ If water be added, its boiling point is raised.

§ The degree of cold produced by its evaporation is proportional to the strength of the spirit employed, the stronger the spirit the greater being the cold produced. When a thermometer, after being immersed in spirit of wine, is suspended in the air, the quicksilver sinks two or three degrees. By repeated dippings and exposures, and by blowing upon the bulb with a pair of bellows, Dr. Cullen caused the thermometer to sink from 44° to below the freezing point.

Alcohol has never yet been congealed by any known method of producing artificial cold. Mr. Walker, of Oxford, found that it continued fluid at -91° Fah. Even when diluted with an equal weight of water, it requires a cold of 6° below zero to congeal it.



highly inflammable;\* is remarkably expansible by heat; unites chemically with water in every proportion;† and is a very powerful solvent of many substances.‡

\* It burns away with a blue flame, without leaving any residuum. The light emitted by its combustion is feeble, but considerable heat is evolved.

† The union of alcohol and water is accompanied by an evolution of heat. Equal measures of alcohol and water, each at  $50^{\circ}$  Fahr., give by sudden admixture an elevation of nearly  $20^{\circ}$  of temperature; and equal measures of proof spirit and water occasion an increase of  $9\frac{1}{2}^{\circ}$ . The bulk of the resulting liquid is also less than that of the two before admixture.

The circumstance of alcohol combining in all proportions with water is its most remarkable characteristic property, and is possessed by no other combustible substance, except the acetic spirit obtained by distilling the dry acetates.

‡ Alcohol dissolves soaps with great facility, and it dissolves also vegetable extract, sugar, oxalic, camphoric, tartaric, gallic, and benzoic acids, volatile oils, resins, and balsams. Fixed oils are sparingly soluble in it, except castor oil, which it dissolves abundantly. It combines likewise with sulphur, phosphorus, and the pure alkalies; but not with their carbonates, nor, when pure, with any of the earths. Of the class of salts, it dissolves many copiously, some sparingly, and others not at all. All deliquescent salts are soluble; the sulphates are insoluble.

When alcohol, containing certain saline substances in solution, is set on fire, its flame is often tinged of different colours, according to the substance in solution; thus, nitrate of strontian tinges it purple; boracic acid and salts of copper, green; muriate of lime, red; and nitre and corrosive sublimate, a yellow colour.



The following Table drawn up by Lowitz, with an additional column by Dr. Thomson, shows the Specific Gravity of different Mixtures of pure Alcohol of a specific gravity .791, and Distilled Water, at the temperature of 60° and 68° of Fahrenheit.

100 parts by weight.		Sp. Gravity.		100 parts by weight.		Sp. Gravity.		100 parts by weight.		Sp. Gravity.	
Alco.	Wat.	at 68°	at 60°	Alco.	Wat.	at 68°	at 60°	Alco.	Wat.	at 68°	at 60°
100	—	791	796	66	34	877	880	32	68	952	955
99	1	794	798	65	35	880	883	31	69	954	957
98	2	797	801	64	36	882	886	30	70	956	958
97	3	800	804	63	37	885	889	29	71	957	960
96	4	803	807	62	38	887	891	28	72	959	962
95	5	805	809	61	39	889	893	27	73	961	963
94	6	808	812	60	40	892	896	26	74	963	965
93	7	811	*815	59	41	894	898	25	75	965	967
92	8	813	817	58	42	896	900	24	76	966	968
91	9	816	820	57	43	899	903	23	77	968	970
90	10	818	822	56	44	901	904	22	78	970	972
89	11	821	825	55	45	903	906	21	79	971	973
88	12	823	827	54	46	905	908	20	80	973	974
87	13	826	830	53	47	907	910	19	81	974	975
86	14	828	832	52	48	909	912	18	82	976	
85	15	831	†835	51	49	912	915	17	83	977	
84	16	834	838	50	50	914	917	16	84	978	
83	17	836	840	49	51	917	920	15	85	980	
82	18	839	843	48	52	919	922	14	86	981	
81	19	842	846	47	53	921	924	13	87	983	
80	20	844	848	46	54	923	926	12	88	985	
79	21	847	851	45	55	925	928	11	89	986	
78	22	849	853	44	56	927	†930	10	90	987	
77	23	851	855	43	57	930	933	9	91	988	
76	24	853	857	42	58	932	§935	8	92	989	
75	25	856	860	41	59	934	937	7	93	991	
74	26	859	863	40	60	936	939	6	94	992	
73	27	861	865	39	61	938	941	5	95	994	
72	28	863	867	38	62	940	943	4	96	995	
71	29	866	870	37	63	942	945	3	97	997	
70	30	868	871	36	64	944	947	2	98	998	
69	31	870	874	35	65	946	949	1	99	999	
68	32	872	875	34	66	948	951	—	100	1000	
67	33	875	879	33	67	950	953				

\* Alcohol of the Lond. and the Dub. Pharm.

† Ditto, (Edin.) rectified spirit, (Lond.) ‡ Proof spirit, (Lond. Dub.)

§ Proof spirit, (Edin.)



TABLE, extracted from the Tables of M. Gilpin, showing the Real Specific Gravity of different mixtures of Spirit and Water at every 5° of temperature from 50° to 70°.\* The standard spirit employed was of the specific gravity 0.825; or contained 89 pure alcohol, and 11 water in 100 parts.

Proportions by weight of		REAL SPECIFIC GRAVITY.				
Spirit.	Water.	at 50°.	at 55°.	at 60°.	at 65°.	at 70°.
100	—	.82977	.82736	.82500	.82262	.82023
100	5	.84076	.83834	†.83599	.83362	.83124
100	10	.85042	.84802	.84568	.84334	.84092
100	15	.85902	.85664	.85430	.85193	.84951
100	20	.86676	.86441	.86208	.85975	.85736
100	25	.87384	.87150	.86918	.86680	.86415
100	30	.88030	.87796	.87569	.87337	.87105
100	35	.88626	.88393	.88169	.87938	.87705
100	40	.89174	.88945	.88720	.88490	.88254
100	45	.89684	.89458	.89232	.89006	.88773
100	50	.90160	.89933	.89707	.89479	.89252
100	55	.90596	.90367	.90144	.89920	.89695
100	60	.90997	.90768	.90549	.90328	.90104
100	65	.91370	.91144	.90927	.90707	.90484
100	70	.91723	.91502	.91227	.91066	.90847
100	75	.92051	.91837	.91622	.91400	.91181
100	80	.92358	.92145	.91933	.91715	.91493
100	85	.92647	.92436	.92215	.92010	.91793
100	90	.92919	.92707	.92499	.92283	.92069
100	95	.93177	.92960	.92758	.92546	.92333
100	100	.93419	.93208	‡.93002	.92794	.92580
100	95	.93658	.93462	.93247	.93040	.92828
100	90	.93897	.93696	§.93493	.93285	.93076
100	85	.94149	.93948	.93749	.93546	.93337
100	80	.94414	.94213	.94018	.93822	.93616
100	75	.94683	.94486	.94296	.94099	.93898
100	70	.94958	.94767	.94579	.94388	.94193
100	65	.95243	.95087	.94876	.94689	.94500
100	60	.95534	.95467	.95181	.95000	.94813
100	55	.95831	.95662	.95493	.95318	.95139
100	50	.96126	.95966	.95804	.95635	.95469
100	45	.96420	.96262	.96122	.95902	.95802
100	40	.96708	.96595	.96437	.96288	.96143
100	35	.96995	.96277	.96752	.96620	.96484
100	30	.97284	.97181	.97074	.96959	.96836
100	25	.97589	.97800	.97410	.97309	.97203
100	20	.97920	.97887	.97771	.97688	.97996
100	15	.98293	.98289	.98176	.98106	.98028
100	10	.98745	.98702	.98654	.98594	.98527
100	5	.99316	.99284	.99244	.99194	.99134

\* Phil. Trans. for 1704, p. 320—370. † Alcohol, (Edin.) rectified spirit, (Lond.) ‡ Proof spirit, (Lond. Dub.) § Proof spirit, (Edin.)



*What is ETHER?*

It is a light, volatile, and very inflammable fluid, produced by the mutual action between alcohol and acids. Thus, when a mixture of strong sulphuric acid and alcohol is distilled it produces *sulphuric ether*, which is the ether in common use; the distillation of a mixture of nitric acid and alcohol produces *nitric ether*.\*

*What are the PROPERTIES OF SULPHURIC ETHER?†*

It is an extremely light,‡ volatile, and inflammable fluid, possessing a grateful odour, and a pungent taste. It does not, like alcohol, combine in any considerable proportion with water.

\* Nitric ether is the *sweet spirit of nitre* of the shops.

From the mutual action between muriatic, chloric, hydriodic acids, &c. and alcohol, there are obtained *muriatic, chloric, hydriodic ethers*, &c.

† That is, of the ether in common use. Sulphuric ether is prepared in the following manner. Let a quantity of alcohol be introduced into a glass retort, and then an equal weight of sulphuric acid be gradually added in divided portions, taking care to agitate the mixture after each addition, and to allow a sufficient interval, to prevent its exceeding the temperature of  $120^{\circ}$ . The retort is then to be cautiously placed in a sand-bath, previously heated to  $200^{\circ}$ , so that the liquor may boil as quickly as possible, and the ether may pass over into a tubulated receiver, to which another receiver is adapted and kept cool by ice or water. As soon as the materials begin to boil, ether is produced, and passes over into the receiver. The ebullition is to be continued, till white vapours appear in the retort, or a smell of sulphurous acid is perceived, when the receiver is to be removed. Care should be taken to avoid breathing the penetrating fumes of this acid.

‡ Its specific gravity varies; for the purpose of medicine, it should never exceed .750, in which state it contains nearly 25 per cent. of alcohol. It may be procured of specific gravity .700, or according to Lowitz of .632.

Ten parts of water combine with one of ether. The circumstance of its not combining with water in any considerable proportion, directs us to an easy mode of purifying it from alcohol; for by repeated agitation with water it is deprived of most of the spirit which it may contain, and is brought to a high degree of purity.



At  $46^{\circ}$  below zero of Fahr. it becomes solid. It dissolves essential oils, resins, and camphor, very plentifully. It boils in the atmosphere at  $90^{\circ}$  or  $98^{\circ}$  Fahr., and in *vacuo* at  $-20^{\circ}$ .\*

\* Its evaporation produces extreme cold. It is still more inflammable than alcohol, and burns with a more luminous flame, which is of a deep blue. By pouring a little ether on a piece of white sugar, and throwing it into a glass of warm water, the vapour is instantly given off, and may be kindled.

Ether has been analyzed by several chemists; they differ in regard to its atomic constitution, but the following view is generally considered most correct.

Carbon .....	4 atoms	=	24	.....	64.86
Oxygen .....	1 atom	=	8	.....	21.62
Hydrogen ....	5 atoms	=	5	.....	13.52
			<hr/>	<hr/>	
			37	100.	

If we suppose that 1 atom of oxygen and 1 of hydrogen are combined to form water, then there remain 4 atoms of hydrogen and 4 of carbon, which are the constituents of olefiant gas (p. 238). Contrasting, then, the composition of alcohol and that of ether, it will be easy to perceive what takes place when the former is converted into the latter.

<i>Alcohol consists of</i>	<i>Ether consists of</i>
Olefiant gas ——— 4 atoms.	Olefiant gas ..... 4 atoms.
Aqueous vapour .... 2 ditto.	Aqueous vapour .... 1 atom.

To change alcohol into ether, all that is necessary is to take away one atom of aqueous vapour; and in this removal of one half the water, which forms an element of alcohol, it seems to be universally agreed that etherification consists, even among those who differ as to the precise number of atoms constituting those fluids.



## CHAPTER XIII.

## OF ANIMAL CHEMISTRY.

*What are the ULTIMATE ELEMENTS of animal substances?*

The elements of animal matter are the same as those of vegetables, namely, *oxygen*, *hydrogen*, and *carbon*, with the addition of a considerable proportion of *nitrogen*. The presence of the latter principle gives them some of their most important qualities. Hence it is, that instead of passing through the vinous or acetous fermentation, they are peculiarly prone at once to undergo putrefaction, and that, during this process, they yield among other products, both ammonia and nitrogen gas.\*

*Are the PROXIMATE PRINCIPLES of animal substances so numerous as those of vegetables?*

No. These principles are here not numerous.

\* It should be observed, that animal substances being the results of still more delicate processes, and of a more refined organization, than vegetables, the balance of affinities, by which they exist, is disturbed by slighter causes.

Beside oxygen, hydrogen, carbon, and nitrogen, some animal compounds contain phosphorus, sulphur, iron, and saline matters in small quantity. From their containing phosphorus and sulphur, the process of animal putrefaction is frequently attended with the disengagement of sulphuretted and phosphuretted hydrogen gases, to which the very offensive odour usually accompanying this process is chiefly owing.



The following list comprehends nearly the whole of what are well characterized.\*

- |                       |                         |
|-----------------------|-------------------------|
| 1. Gelatine or Jelly. | 5. Urea.                |
| 2. Albumen.           | 6. Sugar.               |
| 3. Mucus.             | 7. Animal Oils or Fats. |
| 4. Fibrin.            | 8. Animal Acids.        |

*Animal GELATINE or JELLY† is an abundant ingredient, both of the fluids of the body and of the hard and solid parts: What are its properties?*

It is a hard brittle substance, inodorous, insipid, soluble in water, capable of assuming a well-known elastic or tremulous consistence, by cooling, when the water is not too abundant,‡ and liquefiable again by increasing its temperature.§ It is insoluble in alcohol, but readily dissolves in most of the diluted acids. It is dissolved by alkaline solutions.|| It is precipitated

\* The above are properly called the proximate principles of animal compounds, but we shall have to describe other and more complex products of animal organization, such are the *blood, gastric juice, bile, chyle, urine, urinary calculi, bones, muscles, tendons, nails, &c.* all of which will be noticed after the above proximate principles.

† *Glue*, which is the common gelatine of commerce, is a thickened jelly made from the parings of hides and other offals, by boiling them in water, straining through a wicker basket, suffering the impurities to subside, and then boiling it a second time. The articles should first be digested in lime water, to cleanse them from grease and dirt; then steeped in water, stirring them well from time to time; and lastly, laid in a heap, to have the water pressed out, before they are put into the boiler.

Shreds or parings of vellum, parchment, or white leather, make a clear and almost colourless glue.

‡ Its tendency to form a jelly is such, that one part of gelatine, dissolved in 100 parts of water, becomes solid in cooling.

§ This property of its liquefying again by heat distinguishes it from albumen, which thus becomes consistent.

|| The compound formed by its solution in liquid alkalies has none of the properties of soap, and is not decomposed by acids; which distinguishes it from other animal principles.



in an insoluble form by tannin; and, as we before remarked, this action of tannin or gelatine is the foundation of the art of tanning leather. *Isinglass* is the purest variety of gelatine.\*

*The white of eggs consists of ALBUMEN, in a state of tolerable purity, and from its examination we are enabled to ascertain the properties of this principle: What are they?†*

Albumen is a thick glairy fluid, insipid, inodorous, and easily miscible with cold water. Its chief characteristic is its coagulability by the action of heat.‡ At 160° Fahr. it coagulates into

\* *Isinglass* is made from certain fish found in the Danube and the rivers of Muscovy. It is prepared chiefly from the sounds of fish of the genus *acipenser*. Mr. Jackson remarks, that the lakes of America abound with fish from which the very finest sort of isinglass may be obtained. Boiled in milk it forms a mild nutritious jelly, which, when flavoured by the art of the cook, is the blanc-mange of our tables. A solution of isinglass in water, with a very small proportion of some balsam, spread on black silk, is the court-plaster of the shops.

According to the Analysis of MM. Gay Lussac and Thenard, 100 parts of gelatine consist of carbon 47.881, hydrogen 7.914, oxygen 27.207, and nitrogen 16.998; but these results require confirmation.

† Albumen is an abundant constituent principle of the animal solids and liquids. It is found in considerable quantity in the serum of blood, the vitreous and crystalline humours of the eye, the fluid of dropsy, and other secretions. It appears to be the chief basis of several of the solids, namely, of the cellular membrane, the skin, glands, and vessels.

‡ The causes of the coagulation of albumen is not certainly known. Fourcroy and several other chemists have ascribed it to its oxygenation. Dr. Thomson refers the solubility of albumen to the presence of free soda, and its coagulation to the removal of the alkali. Dr. Ure thinks cohesive attraction is the real cause of the phenomenon, which is the opinion I am disposed to adopt. He says, (*Dict. of Chemistry*, p. 116,) "In proportion as the temperature rises, the particles of water and albumen recede from each other, their affinity diminishes, and then the albumen precipitates."

Water which contains only  $\frac{1}{1000}$ th of its weight of albumen is rendered opaque by boiling. This property of coagulability makes it of great use in



a solid mass. It is coagulated also by alcohol and the stronger acids, and by several of the metallic salts, particularly by corrosive sublimate, ferrocyanate of potassa, and nitro-muriate of tin.\*

*There is some doubt whether MUCUS be in reality a distinct or primary animal fluid, but we shall now consider it as such:† What are its characters?*

clarifying liquids, for when dissolved in them, as it coagulates it involves all the impurities not actually dissolved, and carries them with it to the surface.

\* Corrosive sublimate has no effect on gelatine or mucus, but is a delicate test of the presence of albumen. A drop of a saturated solution of corrosive sublimate let fall into water containing  $\frac{1}{2000}$ th of its weight of albumen, occasions a milkiness and curdy precipitate. Ferrocyanate of potassa is likewise an extremely delicate test of the presence of albumen, and may be used to discover it in fluids to which other tests are inapplicable. To enable it, however, to produce a precipitate, a very slight excess of acetic acid should be previously added to the liquid suspected to contain albumen, or to the test.

Galvanism may be applied to the detection of very minute quantities of albumen, which are not rendered sensible by any other test. Mr. Brande first observed this phenomenon, and he produced a rapid coagulation, at the negative galvanic pole, in several animal fluids, in which albumen had not been supposed to exist. It has been ascertained also by Sir E. Home (*Philos. Trans. for 1809*.) that albumen is coagulated by galvanic arrangements of too low a power to affect even the most delicate electrometer; and hence he has proposed albuminous fluids as tests of the presence of small quantities of electricity. M. Lassaigne, on the contrary, asserts, (*Annal de Chim. et de Phys. tom. xx. p. 97.*) that pure albumen is not congluable by galvanism, and that the effect, when it does take place, is owing to the decomposition of saline matter, the elements of which react upon the albumen.

According to the analyses of Gay Lussac and Thenard, and Dr. Prout, the constituents of albumen are in 100 parts,—

<i>Gay Lussac.</i>			<i>Dr. Prout.</i>		
Carbon,	52.883 or 17 atoms	.....	50.	or 15 atoms.	
Hydrogen,	7.540 13 atoms	.....	7.78	14 atoms.	
Oxygen,	23.872 6 atoms	.....	26.67	6 atoms.	
Nitrogen,	15.705 2 atoms	.....	15.55	2 atoms.	
	100.		100.		

† Dr. Bostock first endeavoured to show that mucus is a distinct principle, and the French chemists Fourcroy and Vauquelin have admitted his views



It is a viscid colourless liquid, which, when mixed with water, does not coagulate even by a boiling heat, and is not affected by nitro-muriate of tin, corrosive sublimate, or infusion of galls. But subacetate of lead (*Goulard's extract*) occasions an immediate opacity, and afterwards a flaky precipitate. Goulard's extract, however, does not affect gelatine, while tannin, which is a most delicate test of gelatine, occasions no precipitate with mucus. Thus the effects of Goulard's extract and tannin, establish a decided difference between mucus and gelatine.\*

*What is the nature and properties of FIBRIN?*

It forms the basis or chief part of the muscular or fleshy parts of animals, and is left combined with albumen, when all that is soluble in such parts has been washed away by water.† It is solid,

to be correct. Berzelius, however, believes what is called mucus to be a gelatinous fluid, the chemical characters of which vary in different parts of the body, according to the purposes which it is intended to fulfil in the animal economy.—See his *View of Animal Chemistry*, p. 58. Fourcroy and Vauquelin apply the term mucus, in an enlarged sense, to the viscid liquid, which lubricates the mouth, œsophagus, stomach, intestines, and, in general, all the cavities and passages of the body. It differs, they suppose, from vegetable gum, in nothing but in containing a proportion of nitrogen. Dr. Bostock's experiments were made on the *saliva* of the mouth, dissolved in water by agitation.

\* Corrosive sublimate, and ferrocyanate of potassa, on the contrary, which discover very small proportions of albumen, are not affected by either gelatine or mucus.

† It may likewise be procured from blood, by laying the coagulum on a linen strainer, and pouring water upon it, till a white fibrous matter alone remains. Fibrin therefore enters into the composition of blood; it exists also in chyle, and may be regarded as the most abundant constituent of the soft solids of animals.

It is singular that fibrin is found in some vegetables, as well as in animal matters. Vauquelin discovered it in the *papaw* tree. In that tree it exists



white, insipid, without smell, and heavier than water. Cold water has no action on it, but heated with boiling water, it is so changed as to lose the property of softening and dissolving in acetic acid.\* Pure potassa and soda gradually and simply dissolve it in the cold, but with heat they decompose it.

*UREA is a principle peculiar to urine: What are its properties?†*

as a soft solid, of a greasy appearance, which softens in the air, becoming viscid, brown, and semi-transparent. On hot coals it melts, throws out greasy drops, crackles, and evolves the smoke and odour of roasting meat.

\* When moist, fibrin possesses a species of elasticity; by desiccation it becomes yellowish, hard, and brittle. By distillation there is extracted from it much carbonate of ammonia, some acetate, a fetid brown oil, and gaseous products; while there remains behind charcoal, very brilliant, difficult to burn, and which leaves, after combustion, phosphate of lime, a little phosphate of magnesia, carbonate of lime, and carbonate of soda.

Alcohol, of sp. gr. 810, converts fibrin into a kind of *adipocire*, which is soluble in alcohol, and is precipitated by the addition of water. The action of acids on fibrin has been fully described by Berzelius.—See *Medico-Chirurg. Trans.* vol. iii. p. 201. When digested in weak muriatic acid, it evolves a little nitrogen, and a compound is formed, hard, horny, and which, washed repeatedly with water, is transformed into another gelatinous compound. Sulphuric acid, diluted with six times its weight of water, has similar effects. By the action of nitric acid of sp. gr. 1.25, on fibrin, there results a yellow solution, with disengagement of a large quantity of nearly pure nitrogen.

MM. Gay Lussac and Thenard state fibrin to consist of carbon 53.360, nitrogen 19.934, Oxygen 19.685, hydrogen 7.021.

† Dr. Prout's process for procuring urea is the best.—See *Medico-Chirurg. Trans.* vol. viii. p. 529. His process is as follows:—Fresh urine is evaporated to the consistence of syrup, and, when quite cold, pure concentrated nitric acid is gradually added to it, till the whole becomes a dark-coloured crystallized mass, which is to be slightly washed with cold water, and then dried by pressure between folds of blotting paper. To the nitrate of urea, thus procured, a pretty strong solution of carbonate of potassa or soda is added, until the acid is neutralized; and the solution is afterwards concentrated by evaporation, and set aside, in order that the nitre may separate in crystals. The residual liquor, which is an impure solution of urea, is made up into a thin paste with animal charcoal, and is



It crystallizes in four-sided prisms, which are transparent and colourless, with a slight pearly lustre. Its smell is faint and peculiar, but not urinous. It leaves a sensation of coldness on the tongue like nitre. Its specific gravity is about 1.35. It does not affect the colour of litmus or turmeric paper. In a moist air it deliquesces slightly, but otherwise undergoes no change. In a strong heat it melts, and is partly decomposed and partly sublimed without change. It is very soluble in water, and alcohol, at the temperature of the atmosphere, dissolves about 20 per cent.\* The fixed alkalies and alkaline earths decompose it. It is remarkable for being the most azotized of all animal substances.†

allowed to remain in that state for a few hours. The paste is then mixed with cold water, which takes up the urea, while the colouring matter is retained by the charcoal; and the colourless solution is evaporated to dryness at a low temperature. The residue is then boiled in pure alcohol, by which the urea alone is dissolved, and from which it is deposited in crystals on cooling.

\* Boiling alcohol dissolves considerably more than its own weight of urea, from which the urea separates on cooling, in its crystalline form. It unites with the nitric and oxalic acids, forming sparingly soluble compounds, which crystallize in scales of a pearly lustre. This property affords an excellent test of the presence of urea.

Urea has a singular effect on the crystallization of some salts. If muriate of soda be dissolved in a solution of urea, it will crystallize by evaporation, not in cubes, but in octahedra; muriate of ammonia, on the contrary, treated in the same way, instead of crystallizing in octahedra, will assume the cubic form. The same effect is produced, if fresh urine be employed.

† Uric acid is the animal principle which contains most azote or nitrogen next to urea. From the great quantity of nitrogen which these two substances contain, the secretion of urine has been thought, with much probability, to have for its object the separation of the excess of nitrogen from the blood, as respiration separates from it the excess of carbon. Urea, of all animal fluids, appears most readily to undergo decomposition, both from



*We will now advert to ANIMAL OILS or FATS.\*  
How do they differ from vegetable oils?*

Animal and vegetable oils differ very little from one another. The ultimate elements of both are carbon, hydrogen, and oxygen; but the former are very generally solid at the ordinary temperature of the atmosphere, while the latter are mostly fluid.†

spontaneous changes in the arrangement of its elements, and from the action of other substances. According to Dr. Prout's analysis, urea consists of 2 atoms of hydrogen, 1 atom of carbon, 1 of oxygen, and 1 of nitrogen; or in 100 parts, of hydrogen 10.80, carbon 19.40, oxygen 26.40, and nitrogen 43.40.

\* I have enumerated *sugar* as a distinct animal substance. There are two varieties of it, namely, the *sugar of milk*, and the *sugar of diabetes*. The *sugar of milk* is obtained by evaporating whey to the consistence of honey, and then allowing it to cool. It concretes into a solid mass, which is to be dissolved in water, clarified by white of eggs, filtered, and again evaporated to the consistence of syrup. On cooling, a number of brilliant white crystals are deposited, which are the sugar of milk. It has a sweetish taste, but no smell. It differs from common sugar by yielding, when treated with nitric acid, a peculiar acid called saccholactic; in requiring seven parts of cold water, or four of boiling for its solution; and in not being susceptible of the vinous fermentation.

*Sugar of diabetes*, as it is called, is procured by evaporation from the urine of persons labouring under the disease termed *diabetes*. It approaches more nearly than the former to the characters of vegetable sugar, but does not crystallize readily. Its composition appears to be precisely similar to that of vegetable sugar, while sugar of milk is nearly the same as the latter.

† By the term *fat* is to be understood a *solid* oleaginous substance, that is, solid at the ordinary atmospheric temperature.

The animal oils are *whale* or *train oil*, and *sperm* or *spermaceti oil*. *Whale oil* is extracted from the *blubber* of the whale, which is originally a firm solid fat, but on reaching this climate, is found to be mostly resolved into a fluid. The oil is obtained from the blubber by melting it in large copper vessels. *Sperm oil* forms part of the oily substance found in the cranium of the *physeter macrocephalus*, or spermaceti whale. The oil is separated by putting the mass into a woollen bag and pressing it, by which the oil is made to run out, and the solid residue, when washed with a weak



*Is FAT, such as hogslard, suet, tallow, &c. a simple principle?*

No. It is a combination of two principles,\* which may be separated without alteration. One is an *oily substance*, which remains fluid at the ordinary temperature of the atmosphere, and is called *elaine*; the other is a *fatty substance*, which is much less fusible, and is termed *stearine*.† *Elaine* melts at 45°, and has very much the appearance and properties of vegetable oil; *stearine* melts at 100°.‡

alkaline ley, affords spermaceti. This oil is much purer than train oil, and burns away without leaving any charcoal on the wicks of lamps.

*Spermaceti* is called by Chevreul *cetine*. It bears some resemblance to wax, but differs from it in being more fusible (viz. at 112° Fahr.) and less soluble in boiling alcohol, of which it requires 150 times its weight. It is copiously dissolved by boiling ether, and the solution, on cooling, becomes a solid mass. Pure potassa acts on it more remarkably than on wax, and the compound is quite soluble, forming a true soap; the acid then generated is called by M. Chevreul *cetic acid*.

\* *Glycerine* is the *sweet principle* of oils, and was discovered by Scheele.

† For the knowledge of the real constitution of oils and fats, we are indebted to M. Chevreul, a French chemist.—See his *Memoirs* in *Ann. de Chem. et de Phys.* tom. vii. and his *Treatise Sur les Corps Gros*. Chevreul dissolves the tallow in very pure hot alcohol, separates the *stearine* by crystallization, and then procures the *elaine* by evaporation of the spirit. Braconnot has adopted a simpler method. By squeezing tallow between the folds of porous paper, the *elaine* soaks into it, while the *stearine* remains. The paper being then soaked in water, and pressed, yields up its oily impregnation.

‡ There are several peculiar acids generated during the formation of soap by the action of alkalies on oils or fats. The *margaric* (sometimes called simply *margarine*) and *oleic* acids are best prepared from soap made with potash and fluid vegetable oil. *Stearic acid* is a constituent of soap made from hogslard and suet.

*Sebacic acid* is a name given by Thenard to an acid obtained by the distillation of hogslard or suet, and is found in the recipient mixed with acetic acid and fat, partially decomposed. It reddens litmus paper, dissolves freely in alcohol, and is more soluble in hot than in cold water. It melts like fat when heated, and crystallizes in small white needles on cooling.



*What is ADIPOCIRE ?*

It is an animal fat strongly resembling spermaceti, and is the result of certain changes that take place in dead bodies; the fibrin or muscular part disappears, and this fatty matter called adipocire remains. This change was first discovered by M. Fourcroy, in Paris, about 1786.\*

\* This peculiar substance was first noticed by Fourcroy on the occasion of the removal of a very great number of human bodies from the ancient burying place des Innocens at Paris, in which each cavity contained from 1000 to 1500 dead bodies. On opening these pits, and removing the covers from the coffins, the bodies were observed at the bottom, leaving a considerable distance between their surface and the cover, and flattened as if they had suffered a strong compression. The linen which had covered them was slightly adherent to the bodies; and, with the form of the different regions, exhibited, on removing the linen, nothing but irregular masses of a soft ductile matter of a grey-white colour. These masses environed the bones on all sides, which had no solidity, but broke by any sudden pressure. The appearance of this matter, its obvious composition, and its softness, resembled common white cheese; and the resemblance was more striking from the print which the threads of the linen had made upon its surface. This white substance yielded to the touch, and became soft when rubbed for a time between the fingers. No very offensive smell was emitted from these bodies. The grave-diggers asserted that they never found this matter in bodies interred alone; but that the accumulated bodies of the common graves only were subject to this change. They also affirmed, that near three years are required to convert a body into this fatty substance. It is singular that by exposing fibrin (a piece of lean beef or mutton, for example,) to the action of a stream of water for a month, it is converted into adipocire. Muscular fibre, macerated in dilute nitric acid, and afterwards well washed in warm water, likewise affords pure adipocire, of a light yellow colour, nearly of the consistence of tallow, of a homogeneous texture, and of course free from ammonia. This is the mode in which it is now commonly procured for chemical experiments.

*Adipocire* melts like tallow, and, on cooling, becomes crystalline. When exposed to a high temperature, it burns like wax. When put into nitric acid, a fatty matter is separated; and with the fixed alkalis, it gives out the odour of ammonia. The fatty substance produced by acid, has all the appearance of spermaceti, being soluble in hot alcohol, and burning with a bright white flame. With water, adipocire exhibits all the appearance of soap, and affords a strong lather. The fibrin of the muscular fibre was formerly



*What is AMBERGRIS?*

It is an animal substance, supposed to be formed in the intestines of the spermaceti whale. Its colour varies, being either white, black, ash-coloured, yellow, or variegated. It is generally brittle, but on rubbing it with the nail, it becomes smooth like hard soap. Its smell is very peculiar. At  $144^{\circ}$  it melts, and at  $212^{\circ}$  is volatilized in the form of a white vapour.\*

*Enumerate the PRINCIPAL ANIMAL ACIDS?*

They are the *Uric*,† or *Lithic*, *Purpuric*,

thought to be really converted into adipocire; but Gay Lussac and Chevreul maintain that this substance proceeds entirely from the fat originally present in the muscle, and that the fibrin is merely destroyed by putrefaction.

\* Ambergris is found floating on the surface of the sea near the coasts of various tropical countries; and has also been taken out of the intestines of the whale. It has not been found in any whales but such as are dead or sick, and therefore some authors have affirmed it to be the cause of their disease, but the opinion that it is a consequence of such disorder is more general and much more probable. It is found generally in small pieces, but sometimes so large as to weigh 200lbs. When taken from the whale, it is not so hard as it becomes afterwards on exposure to the air. Its specific gravity ranges from 780 to 926. If good, it adheres like wax to the edge of a knife with which it is scraped, retains the impression of the teeth or nails, and emits fat odoriferous liquid on being penetrated with a hot needle. It often contains a considerable portion of benzoic acid, and always a large proportion of adipocire.

I ought to observe here, that there is a peculiar animal substance called *cholesterine*, which is the basis of most of the biliary concretions found in the human subject. It is a white brittle solid, of a crystalline structure and brilliant lustre, very much resembling spermaceti, but appears to be a distinct independant principle. It requires a temperature of  $278^{\circ}$  Fahr. for fusion, and is not convertible into soap, as spermaceti is, when digested in a solution of potassa.

† *Uric* or *Lithic Acid* does not exist in human urine uncombined, but generally in union with ammonia, forming a urate of ammonia. The excrements of the serpent *boa constrictor* consist of pure lithic acid. The urine of the eagle, and other birds of prey, consist almost solely of urate of ammonia, from which it is readily procured in the manner I shall immediately describe. The substance occasionally voided along with human urine, and



*Formic*, and *Rosacic Acids*.\* *Lithic acid* exists in human urine, even in its most healthy state; *Rosacic* † acid is deposited from urine in certain

called gravel, consists for the most part of uric acid; and this acid forms also one of the most common ingredients of urinary calculi. It may be obtained by dissolving a calculus of this kind, reduced to fine powder, in solution of potassa; decomposing the clear solution by muriatic acid added in excess; and washing the precipitate with a large quantity of distilled water. The precipitate may be drained and dried at 212°, a temperature sufficient to deprive it entirely of water. Uric acid, when pure, is without colour, taste, or smell; it is insoluble in alcohol, and almost so in cold water, but dissolves in about 1400 parts of boiling water. It reddens the infusion of litmus, and combines with alkalies, forming salts called *urates* or *lithates*. It does not effervesce with the alkaline carbonates. It dissolves in hot solutions of potassa and soda. When uric acid is dissolved in nitric acid, and evaporated to dryness, it leaves a pink sediment, which forms a good test of the presence of uric acid. No acids act on it, except those that occasion its decomposition.

The atomic constitution of uric acid is not known with certainty, but it contains a very large proportion of nitrogen.

The combination of uric acid with soda constitutes the principal part of the concretions, found about the joints of gouty persons.

*Pyro-uric acid* is a peculiar volatile acid, and is formed when uric acid is exposed to heat in a retort. The carbonate and hydrocyanate of ammonia are formed at the same time. Its properties have been fully investigated by Chevallier and Lassaigne, see *Annals of Philos.* vol. xvi. p. 25.

\* *Purpuric acid* is obtained by digesting pure uric acid in dilute nitric acid, then neutralizing the excess of acid with ammonia, and concentrating the solution by evaporation, when purple crystals of purpurate of ammonia are obtained. From this, the purpuric acid is disengaged by the action of pure potassa, as may be seen in Dr. Prout's paper in the *Philos. Trans.* for 1818. It combines with the alkalies, alkaline earths, and metallic oxides, is a white or yellowish-white powder, has no smell nor taste, and is scarcely soluble in water. Much uncertainty exists with regard to the nature of this acid.

† *Rosacic acid* is so named from its resemblance in colour to a rose, and is supposed to be a peculiar acid found in the *luteitious sediment*, deposited from the urine in certain stages of fever. Dr. Prout is of opinion that this sediment is chiefly composed of purpurate of ammonia, and Proust observes, that rosacic acid differs from the uric in being very soluble in hot water; in having little tendency to crystallize; and in precipitating muriate of gold of a violet colour.



cases of disease, as at the close of gouty attacks, &c. *Formic acid* is extracted from ants.\*

BLOOD, when recently drawn from an animal, is an uniform red fluid, but after standing for a short time, it separates into two distinct parts, namely, a fluid called serum, and a thick red matter, termed *crassamentum*. What are the CHARACTERS OF SERUM?

It is of a greenish-yellow colour, having the taste, feel, and peculiar odour of blood. Its specific gravity varies from 1.020 to 1.030, while that of blood itself is 1.053; it changes vegetable blues to green, owing to the presence of uncombined soda; at 160° Fahr., it coagulates in the same way as white of egg; and if in this state it be cut and pressed, a small quantity of an opaque fluid oozes out, which is called the *serosity*. This coagulation by heat is owing to the presence of a large proportion of albumen. There is no gelatine in blood.†

\* *Lactic acid* has been considered by most chemical writers as a distinct acid, procured from sour milk, &c., but it is now found to be acetic acid disguised by animal matter. Probably several of the other animal, as well as vegetable, acids, now considered as independent substances, will ultimately be found not to be so. Besides the animal acids above noticed, there are the *amniotic acid*, extracted from the liquor of the amnios of the cow, and the *saccholactic*, obtained from gum arabic or sugar of milk by the action of nitric acid.

† Blood usually consists of about 3 parts serum to 1 of *crassamentum*; but the proportion of these parts varies considerably in certain persons or animals, the *crassamentum* being much more abundant in the vigorous and well-fed, than in such as have been weakened by disease or poor living. 1000 parts of *serum* of human blood is composed, according to Berzelius, of



*What are the characters of the CRUOR or CRASSAMENTUM?*

The cruor is resolvable into two parts, that is, into the *colouring matter* or *red globules*, which are soluble, and *fibrin*, which is insoluble in water. The *colouring matter* consists of extremely minute vesicles; it is soluble also in alkalies, acids, and alcohol. The watery solution changes vegetable blues to green.\* The *fibrin* has the properties of fibrin obtained from other sources, which I have already described.

*What is the chief chemical difference between venous and arterial blood?*

Water.....	905.0
Albumen .....	80.0
Muriates of potassa and soda .....	6.0
Lactate of soda and animal matter .....	4.0
Soda, phosphate of soda, and a little animal matter .....	4.1
Loss .....	.9
	<hr/>
	1000.

Dr. Carbonel, of Barcelona, has employed the serum of blood on a large scale in painting. Mixed with powdered quicklime or slaked lime, to a proper consistence, it is easily applied on wood, to which it thus gives a coating of a stone colour that dries quickly, without any bad smell, and resists the action of sun and rain. The wood should be first covered with a coating of plaster, the composition must be mixed as it is used, and the serum must not be stale. It may be used likewise as a cement for water-pipes, and for stones in building under water.

\* Different opinions have prevailed among chemists with respect to the cause of the red colour of blood. Many have considered it to be owing to the iron which it contains, and the recent investigations of Dr. Englehart, a young German chemist, appears to have fully verified that fact. His observations are interesting, and may be read in the *Edinburgh Medical and Surgical Journal* for January 1827.

The proportions of colouring matter and fibrin in 100 parts of crassamentum, are 64 of the former and 36 of the latter.



The difference consists in venous blood being surcharged with carbon, to which it owes its dark purple colour; and the change of the blood in the lungs, from the *purple venous* to the *bright red arterial*, seems owing to the discharge of the carbon.\*

\* During the process of *respiration*, the air which is received into the lungs, and almost instantly expelled, undergoes particular changes, by which its properties are altered; for it is no longer capable of supporting combustion, which was first ascertained by Dr. Black, to be owing to its containing carbonic acid, as is easily proved by blowing, through a tube into lime water. In respiring atmospheric air, a part of its oxygen is applied to the interior of the air-vesicles of the lungs, and combines with the carbon of the venous blood, forming carbonic acid, which, to the amount of about 8 per cent. of the bulk of air inspired, is immediately exhaled. This is the grand change that takes place in respired atmospherical air, namely, the removal of a certain quantity of oxygen, and the substitution of a precisely equal volume of carbonic acid gas. Consequently, if the same portion of air be breathed repeatedly, considerable uneasiness is experienced, arising no doubt from a deficient supply of oxygen, and the increase of the volume of carbonic acid, although the latter cannot be increased beyond 10 per cent.

It is worthy of particular remark, that it is not in the lungs only that the blood exerts an action on atmospherical air, for a similar function appears to belong to the skin throughout the whole body. If the hand be confined in a portion of atmospherical air or oxygen gas, it is found that the oxygen disappears, and is replaced by a portion of carbonic acid. At the same time, a considerable quantity of watery fluid transpires, and may be collected by a proper apparatus.

The proportion of carbonic acid produced in respiration is liable to vary according to the circumstances in which the individual is placed. It is found that less oxygen is consumed, and consequently less carbonic acid formed, at a high than at a natural temperature; but during digestion and exercise, the quantity is greater than natural. Dr. Prout has also shown, in *Annals of Philos.* vol. xiii., that speaking and the depressing passions lessened the quantity of carbonic acid, and Dr. Fyfe found the same effect produced by the use of vegetable food, and spirituous liquors. It appears, likewise, that the quantity varies at different times, being more abundant during the day than at night.

The changes that the blood undergoes during respiration, serve most important purposes in the animal economy. That fluid is thereby freed from what is useless and noxious, and also rendered capable of carrying life and



URINE is one of the most compound fluids of the animal system : What is its composition ?

It is well known to be extremely liable to vary in composition, but the analyses of some able chemist lead us to believe healthy human urine to be composed in 1000 parts of

Water .....	933.00
Urea .....	30.10
Uric acid .....	1.00
Sulphate of potassa .....	3.71
Sulphate of soda .....	3.16
Phosphate of soda .....	2.94
Muriate of soda .....	4.45
Phosphate of ammonia .....	1.65
Muriate of ammonia .....	1.5
Earthy phosphates with fluete of lime .....	1.00
Acetic acid, acetate of ammonia, animal matter soluble in alcohol, and urea .....	17.14
Mucus of the bladder .....	0.32
Silica .....	0.03
<hr/>	
1000. *	

energy to every part. From the blood, all the solids and fluids of the body are derived; even the solid matter of the bones themselves is elaborated from it; this solid matter does not, however, exist in the blood in the state of sub-phosphate of lime or bone earth, but appears to be produced by the powers of life, from the ultimate elements of blood, on the very spot where its presence is required. See page 376. The change which the blood undergoes in the lungs has been thought to be the chief cause also of *animal heat*, or the wonderful power which man and the inferior animals have of preserving their heat above that of the surrounding medium. In consequence of Dr. Crawford's publication on this subject, this theory was not long since almost universally adopted. There are, indeed, many circumstances in its favour, but as the supposed fact of the capacity for heat in arterial being greater than in venous blood, which is the basis of the theory, has been shown to be without foundation, of course the theory falls to the ground. Indeed, of the cause of animal heat we know nothing.

\* There are twenty different substances satisfactorily proved to exist in healthy urine. The urine of inferior animals differs considerably from that above described. In all, it contains urea; but in the herbivorous class, there does not seem to be any uric acid; instead of which, there is a



*Is urine an alkaline or an acid fluid?*

It was formerly supposed to be an alkaline fluid, but is now found to contain an excess of acid, for, when recently voided, it invariably reddens blue vegetable colours.\*

considerable portion of benzoic acid. The urine of the horse is of a white colour, and has a peculiar odour; when exposed to the air, it acquires a crust of carbonate of lime on its surface, and ultimately becomes milky, from the deposition of the carbonate. That of the cow and camel is nearly of the same composition. The urine of the lion and tiger is destitute of uric acid, but abounds with urea. That of birds, particularly those that live on flesh or fish, contain it, and some of them in large quantity. That of amphibious animals is in general solid, and consists almost entirely of uric acid. According to Sir H. Davy, the urine of lizards, which is of a butyraceous consistence when discharged, but soon becomes hard, is of the same composition; and that of the *boa constrictor* contains about 90 per cent. of it.

The colour of urine is well known; its quantity is greatly modified by circumstances. Its average specific gravity is about 1030, water being 1000. In general, urine, as it cools, gradually deposits very minute crystals of a reddish colour, which contain the peculiar acid called *uric*. The deposit varies in different individuals, and even in the same person at different times. After the use of acidulous food or drink, and in those labouring under certain diseases, it is much augmented, forming in the latter case the *lateritious* sediment. This sediment Dr. Prout finds to consist of the phosphate of lime and magnesia, and soda in union with *uric* acid, and also with a minute quantity of *purpuric* acid, which is the cause of the red colour, the intensity varying according to the quantity of purpurates present. A small proportion of nitric acid likewise appears to exist in it.

Urine, after being voided, soon undergoes spontaneous changes, and a fetid ammoniacal odour is exhaled. The decomposition is occasioned by the elements of the peculiar principle, which gives it its particular properties, entering into a new state of combination, and generating ammonia, which causes the deposition of some of the saline matter. Its tendency to putrefaction depends almost wholly on the quantity of gelatine and albumen it contains; in many instances, where these are abundant, it comes on very speedily.

\* Acidification appears to be the chief office of the kidneys, in a healthy state. It is in these organs that the sulphur and phosphorus present in the blood are converted into sulphuric and phosphoric acids, and that a new acid, the *uric*, is generated. In some diseases the acidifying tendency is carried to excess, and nitric and oxalic acids are generated, the former of



*What is meant by a URINARY CALCULUS?*

which probably converts a part of the uric acid into purpuric; and the latter, uniting with lime, composes oxalate of lime. In other cases, the acidifying process is suspended, and unchanged blood or albumen; neutral substances, as sugar or urea; and even alkalies, as ammonia, lime, or magnesia, are abundantly separated, the sulphur and phosphorus at the same time escaping unacidified. When acids are formed in excess, the urine is scanty and high coloured, and the character of the disease is inflammatory. When neutral or alkaline substances are redundant, the urine is pale and copious, and the disease is accompanied with irritation or debility. For further information on this interesting subject, see *Dr. Prout's Treatise on Urinary Disorders*.

The changes produced in urine by disease are very considerable, and of importance to be known, more especially by the medical practitioner. It is of a red colour, small in quantity, and extremely acrid, in *inflammatory* diseases; but deposits no sediment on standing. Corrosive sublimate throws down from it a copious precipitate. Towards the termination of such diseases, it becomes more abundant, and deposits a copious pink-coloured sediment, that is, the *lateritious* sediment, the composition of which I have stated above.

In *jaundice*, it contains a deep yellow colouring matter, capable of staining linen. Muriatic acid renders it green, and this indicates the presence of bile.

In *hysterical* affections it is copious, limpid, and colourless, containing much salt, but scarcely any urea or gelatine.

In *dropsy*, the urine is generally loaded with albumen, and is often coagulated so completely by heat and by acids, as to differ but little from the serum of the blood. In dropsy from diseased liver, however, no albumen is present, and the urine is therefore not coagulable; but it is scanty, high coloured, and deposits a rose, or pink-coloured sediment, which probably contains the *substance rosacée*, or rosacic acid, of Proust.

In *dyspepsia*, or indigestion, the urine often abounds in gelatine, and putrifies rapidly.

In *rickets*, it contains a great deal of a calcareous salt, which is generally considered to be phosphate of lime, but according to Bonhomme it is the oxalate.

In *diabetes*, the urine is sometimes so loaded with sugar, as to be capable of being fermented into a vinous liquor. Upwards of one-twelfth of its weight of sugar was extracted from some diabetic urine by Mr. Cruikshank, which was at the rate of twenty-nine ounces troy a day from one patient. It is said, that in this disease the urine, though always in very large quantity, is sometimes not sweet, but insipid. This is no doubt a possible case, but the instances of it are extremely rare; the presence of saccharine matter in the urine, I believe to be, in general, an essential characteristic of the disease called *diabetes*.



It is a calculus or stone found in the bladder.\*

We must now notice the secretions subservient to the important function of Digestion, and principally the SALIVA and BILE.† What is the chemical composition of SALIVA?

Water constitutes at least four-fifths of its bulk, in addition to which it contains small quantities of mucus, albumen (or a peculiar animal matter,) muriate of soda, and alkaline phosphates.‡

\* The principal *calculi* are, 1. Those composed of uric acid, or urate of ammonia; 2. Those composed chiefly of the ammoniaco-magnesian phosphate; 3. Those consisting of phosphate of lime; 4. Those containing principally carbonate of lime; 5. Those which derive their characteristic property from oxalate of lime, called the *mulberry calculus*; and 6. Those composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide*. For the characters of these different calculi, see Dr. Marcet's *Treat. on Calculous Disorders*.

† Among the secretions subservient to digestion, the *gastric* and *pancreatic juices* hold a chief place.

The *gastric juice* is a fluid secreted upon the inner surface of the stomach, and is possessed of very extraordinary powers as a solvent. It is properly considered as the chief agent in the digestion of food in the stomach. There is a very great difficulty in procuring it sufficiently pure for the purposes of experiment, and therefore its chemical qualities are not fully known. Even out of the body, it appears from experiment to retard the putrefaction of animal substances, and to reduce them to a state somewhat similar to that in which they are found after having been some time in the stomach. From whatever animal it may be taken, it has the power of coagulating milk, which appears to be its characteristic property, but is quite inexplicable on any known chemical principles.

Dr. Prout has shown (*Philos. Trans.* for 1824), that beside the gastric juice, there exists in the stomach a considerable quantity of free muriatic acid, the evolution of which seems to commence almost immediately after the introduction of food. This fact has been confirmed by the experiments of Tiedemann and Gmelin. See their *Tr. sur le Digestion*.

The *pancreatic juice* has not been attentively examined, excepting it be lately by Tiedemann and Gmelin, whose observations may be seen in their work just noticed. They found it to contain, beside water, albumen, a substance like acid, salivary matter, and osmazome, with the same salts that exist in saliva, with the exception of sulpho-cyanate of potassa.

‡ *Saliva* is a transparent colourless fluid like water, but rather more



*What are the chemical characters of BILE ?*

By its greenish colour it changes the blue of turnsole and violets to a reddish-yellow; its specific gravity is about 1.026; it readily unites with water; it is easily decomposed by acids, alcohol, and some of the compound salts. Its taste is bitter and extremely nauseous; and its smell peculiar and something like melted fat.\* Muriatic acid dropped into it throws down a yellow precipitate, consisting of a peculiar *yellow*

viscid. When exposed to the air, it seems to absorb oxygen, and to become thicker. When mixed with water, a flaky matter is precipitated. The acids coagulate it. The alkalies cause it to give the odour of ammonia. Nitrate of silver throws down a precipitate of phosphate and muriate of silver; and oxalate of ammonia precipitates lime. Corrosive sublimate, after some hours, occasions the formation of a light flocculent coagulum. Subacetate of lead throws down a copious precipitate. According to Berzelius, the constituents of saliva are in 1000 parts, water 992.9, peculiar animal matter 2.9, mucus 1.4, alkaline muriates 1.7, lactate of soda and animal matter 0.9, pure soda 0.2. Mr. Brande believes it to contain albumen, and Tiedemann and Gmelin say, that besides the usual ingredients, they have detected in it osmazome and sulpho-cyanate of potassa; the latter being indicated in it by the red colour which it gives to per-salts of iron, a property peculiar to sulpho-cyanates.

Saliva appears to have considerable effect in promoting digestion in the stomach.

The incrustation formed on teeth, and called *tartar*, is supposed to be a deposit from saliva. According to Berzelius, it contains in 100 parts, 79 parts of earthy phosphates, 12.5 of undecomposed mucus, 1. of a peculiar salivary matter, and 7.5 of animal matter soluble in muriatic acid.

\* The bile of the ox has been mostly the subject of experiment. In 1000 parts it is considered to contain 700 parts of water, 24 of resin, 60.5 of picromel, about 3. or 4. of yellow matter, 4 of soda, 2 of phosphate of soda, 3.2 of muriate of soda, 0.8 of sulphate of soda, 1.2 of phosphate of lime, and a trace of oxide of iron.

*Human bile* differs materially from that of the ox. It usually contains a larger proportion of yellow matter than the latter, but a much less quantity of picromel. Indeed, many chemists have not been able to detect any picromel in it. The following are the results of Thenard's analysis of 1100 parts of human bile, viz. 1000 parts of water, from 2 to 10 parts of yellow matter, 42 of albumen, 41 of resin, 5.5 of soda, and 4.5 of different salts.



*matter*, and a little *resin*.\* By the addition of Goulard's extract to bile, the yellow matter and resin are precipitated, and a peculiar substance is left in solution called *picromel*.†

*What is the chemical constitution of the BONES and SHELLS of animals?*

The component parts of *bone* are earthy matter, chiefly phosphate of lime, fatty or oily matter, gelatine, and cartilage,‡ the relative proportions

\* The *resin* is to be considered as the cause of the smell, and, in great part, of the colour and taste of the bile. It is solid; very bitter; and when pure, green, but when melted it passes to yellow. It is soluble in alcohol and in pure alkalies, and is precipitable from the former by water, and from the latter by acids.

The *yellow matter* of ox-bile is thought to be peculiar to the bile, and to possess characters distinct from those of other animal substances. Its presence seems to render the bile putrescent; and it is also the source of the concretions which form in the gall-bladders of oxen. Insoluble by itself, it becomes soluble by the intervention of soda, resin, and picromel; and whatsoever be the solvent, it is precipitated by acids.

† *Picromel* was discovered by Thenard (*Memoirs d'Arcueil*, tom. i.), and is regarded as the characteristic principle of ox-bile. The method of procuring it may be seen in Thenard's Memoir, or in *Dr. Henry's Chem.* vol. i. p. 439. It resembles inspissated bile. Its colour is greenish-yellow; its taste intensely bitter at first, succeeded by an impression of sweetness. It is soluble in water and in alcohol. It is not affected by infusion of galls, but the salts of iron and subacetate of lead precipitate it from its aqueous solutions. It affords no ammonia by its destructive distillation. Hence the absence of nitrogen is inferred, and the peculiarity of picromel. It has the property of rendering the resin of bile easily soluble in water; indeed it is chiefly by its agency that the resin is held in solution in bile, for when united with it, it forms a substance having the peculiar flavour of bile.

*Biliary calculi* are concretions formed in the gall-bladder. Many of them consist almost entirely of a peculiar substance similar to adipocire, and which, indeed, was till lately considered to be adipocire. M. Chevreul, as I have already remarked, has shown it to be a distinct principle, and has called it *cholesterine*.

‡ *Cartilage* is a semi-transparent, elastic, animal solid, resembling coagulated albumen, or white of egg. It forms about one-third the weight of animal bones, and is the primitive paste, so to speak, into which the phosphate and other salts of lime are deposited in the young animal. In the



of which are below.\* *Shells* differ from bones in being composed almost entirely of carbonate of lime (or chalk), cemented by a very small portion of animal matter.†

*Of what are the MUSCLES, TENDONS, and LIGAMENTS of animals composed?*

disease called *rickets*, these earthy matters, which impart solidity and firmness to bones, are either never deposited or withdrawn by diseased absorption, when the bones are found in the state nearly of flexible cartilage. Hence arise the distortions characteristic of this disease. See page 276.

\* Berzelius, who has paid particular attention to animal chemistry, gives the following as the results of his analysis of human and ox bones, and the enamel of teeth.

	Dry Human Bones.	Enamel of Human Teeth.	Dry Ox Bones.	Enamel of Ox Teeth.
Cartilage.....	32.17	—	33.30	3.56
Blood-vessels.....	1.13	—	—	—
Fluate of lime.....	2.0	3.2	2.90	4.0
Phosphate of lime.....	51.04	85.3	55.45	81.0
Carbonate of lime.....	11.30	8.0	3.85	7.10
Phosphate of magnesia.....	1.16	1.5	2.05	3.0
Soda, muriate of soda, } water, &c.....	1.20	2.0	2.45	1.34
	100.	100.	100.	100.

*Human teeth* are composed of the same ingredients as the enamel, and in the same proportion, except that in addition to other ingredients, they contain cartilage.

*Bones* are of great use in the arts. They are not only made into the handles of knives and forks, and into numerous articles of turnery, but when subjected to destructive distillation, they yield ammonia, or volatile alkali (page 203). The coal of bones forms *ivory* or *bone black*.

† The above is the composition of marine shells. Egg shells, and the covering of lobsters, crabs, and other crustaceous animals, differ a little from the preceding in containing also a small proportion of phosphate of lime.

*Horn* differs essentially from both bones and shells. It consists chiefly of gelatine and coagulated albumen, the proportion of earthy matter obtained by its combustion scarcely amounting to  $\frac{1}{300}$ th of its weight.

The *Nails* and *Hoofs* of animals nearly resemble horn in chemical composition. Their basis seems to be a series of membranes composed of coagulated albumen, in which is deposited a quantity of gelatine.



I have already remarked that the *muscles* consist chiefly of *fibrin*, to which is added some gelatine and albumen, and a very small portion of saline matter.\* The *tendons*, or *sinews*, are formed almost entirely of gelatine, and the *ligaments* of gelatine and a small proportion of coagulated albumen.†

\* Lean muscular flesh is composed of nearly three-fourths its weight of fluid, the remainder is fibrin, gelatine, and albumen.

The muscles contain a peculiar substance called *osmazome*, which is of a brownish colour, and has the taste and smell of soup or broth. Thenard, who discovered it, considers that it is the principle which communicates to broth its peculiar odour and taste.

† The *Skin* consists of two distinct parts, namely, a tough white membrane on the outside, which is almost insensible, called the *scarf skin*, and an internal one, distinguished by great sensibility, called the *true skin*. The *scarf skin* resembles coagulated albumen more than gelatine; but the *true skin* is composed almost entirely of gelatine, although under some modification which renders it insoluble in water. As before remarked, it is this substance that adapts the skins of animals for two important uses, that of being converted into leather by the reception of *tan* or the tanning principle, and that of furnishing glue.

*Hair* is a very compound substance, consisting chiefly of an animal matter resembling coagulated albumen, to which are added, an oil of various colours, sulphur, silica, carbonate and phosphate of lime, and oxide of iron and manganese.

*Feathers* appear to agree in composition with hair; but the quill consists of coagulated albumen without any gelatine.



## CHAPTER XIV.

## OF COMBUSTION.

*What is combustion?*

Every one knows what is meant by the term combustion, but the phenomenon may be defined the decomposition of a body at an elevated temperature, accompanied with the evolution of light and heat.

*The Stahlian hypothesis of the nature of combustion is adverted to in almost every book on chemistry: Pray what is it? \**

According to Stahl, a combustible body is a compound, containing fixed fire, or *phlogiston*; and combustion is the disengagement of this

\* Though some of the phenomena of combustion were known from the earliest ages, yet no rational attempt to explain them was made till about the middle of the 17th century. Before that period, it was supposed by alchemists and physicians, that sulphur was the inflammable principle, on which all the phenomena of combustion depended. But Beecher perceiving that sulphur did not exist in several combustible bodies, asserted it was not the principle of inflammability; which he maintained was a different substance, common to sulphur and other combustible bodies: this principle he supposed to be of a dry nature, and called it inflammable earth.

Stahl refined this hypothesis by supposing the inflammable earth of Beecher to be pure fire, fixed in combustible bodies, and constituting an essential part of them; and this view of Stahl is so simple and plausible, that from the year 1736 it was received, though differently modified, all over Europe, until Lavoisier established more correct views on the subject.



phlogiston from a fixed to a free state, attended sometimes with heat and light: when these phenomena cease, the body becomes incombustible; if this calcined body be now heated with charcoal, or any other inflammable substance, capable of giving phlogiston, or fixed fire, it returns again to the class of inflammable bodies.\*

*But this hypothesis is evidently at variance with the fact of bodies, metals for example, increasing in weight after combustion. Therefore a more consistent and probable explanation of the phenomena was sought for, and Lavoisier has the distinguished honour of overthrowing the Stahlian, or phlogistic hypothesis, and substituting in its place what is called the ANTI-PHLOGISTIC theory. What is this theory? †*

It has for its basis the fact, that combustion in general consists in the combination of the combustible material with oxygen.‡ He accounted

\* Independent of this notion of Stahl being at variance with the fact of bodies becoming heavier after combustion and oxigenation, and lighter after reduction, the existence of phlogiston cannot be demonstrated, and is an assumption purely gratuitous.

† According to M. Lavoisier, an inflammable body is nothing but a body which has the property of decomposing vital air, and taking the base from caloric and light, that is to say, the oxygen which was united to them; and that a body ceases to be combustible when its affinity for the oxygen is satisfied, or when it is saturated with that principle; but that it becomes again combustible, when the oxygen has been taken from it by another body, which has a stronger affinity for that principle. When this decomposition of the air is rapid, and, as it were, instantaneous, there is an appearance of flame, heat, and light; when, on the contrary, the decomposition is very slow, and quietly made, the heat and light are scarcely perceptible.

‡ This fact Lavoisier established most satisfactorily. On burning phosphorus in a jar of oxygen, he observed that a considerable quantity of the gas disappeared, that the phosphorus gained materially in weight, and that the increase of the latter exactly corresponded to the loss of the former.



for the production of the heat present, by the doctrine of latent heat, it being conceded that when a substance passes from a rarer into a denser state, it gives out heat; but as an augmentation of temperature often attends chemical action, though the products contain much more latent caloric than the substances from which they are formed, as in the explosion of gunpowder, this opinion cannot be maintained.\*

*Then what is the present theory of combustion?*

Much obscurity still overhangs the phenomena of combustion, but at present they are considered as the result of intense chemical action between any two substances, and not as effected by the union of any one substance with all the others.†

An iron wire was burnt in a similar manner, and the weight of the oxidized iron was found equal to that of the wire originally employed, added to the quantity of oxygen which had disappeared. That the oxygen is really present in the oxidized body he shewed by a very decisive experiment. Some liquid mercury was confined in a vessel of oxygen gas, and exposed to a temperature sufficient for causing its oxidation. The oxide of mercury, so produced, was put into a small retort, and heated to redness, when it was reconverted into oxygen and fluid mercury, the quantity of the oxygen being exactly equal to what had combined with the mercury in the first part of the operation.

\* The *Ann. de Chim. et de Phys.* tom. x., contains some valuable observations on this point from MM. Petit and Dulong, and it clearly appears from their researches, that the quantity of heat developed during the combination of bodies has no relation to the capacity of the elements; and that, in the greatest number of cases, this loss of heat is not followed by any diminution in the capacity of the compounds formed.

† Many facts concur to prove that combustion is not necessarily dependant on the agency of oxygen; that the evolution of the heat is not to be ascribed simply to a gas parting with its latent store of that ethereal fluid, on its fixation or combustion; and that no peculiar substance or form of matter



*Are you acquainted with the NATURE OF FLAME?*

Flame, as I have before remarked, is gaseous matter heated so highly as to be luminous. It is supposed to be a hollow film, or elliptical bubble, filled with volatile matter, the surface of which is

is necessary for producing the effect, but that it is a *general* result of the actions of any substances possessed of strong chemical attractions, or different electrical relations, and that it takes place in all cases in which an intense and violent motion can be conceived to be communicated to the corpuscles of the bodies. We may therefore say, using Dr. Ure's language, *Dict. of Chem.* p. 347, that " whenever the chemical forces which determine either composition or decomposition are energetically exercised, the phenomena of combustion, or incandescence, with a change of properties, are displayed."

It has been lately suggested that the phenomena of combustion may be connected with the electrical energies of bodies; and in confirmation of this view, it has been remarked, that all those bodies which act most powerfully on each other are in an opposite electrical state. It has been proposed as a question worthy of consideration, whether the production of light and heat in combustion is not occasioned by the annihilation of the opposite electricities of the combining substances, just as we see an intense light and heat, produced by bringing together the pieces of charcoal at the end of the wires attached to the opposite poles of the Voltaic battery, cause an annihilation of the opposite states of the electricity.

That the evolution of heat and light is occasioned by the internal motions which accompany the changes in the *mode* of combination, independent of change of *form*, is an opinion which receives much support from the following observations of the celebrated Berzelius:—In 1811, when he was occupied with examining the combinations of antimony, he discovered, accidentally, that several metalline antimoniates, when they begin to grow red-hot, exhibit a sudden appearance of fire, and then the temperature again sinks to that of the surrounding combustibles. He made numerous experiments to elucidate the nature of this appearance, and ascertained that the weight of the salt was not altered, and that the appearance took place without the presence of oxygen. Before the appearance of fire, these salts are very easily decomposed, but afterwards they are attacked neither by acids nor alkaline leys—a proof that their constituents are now held together by a stronger affinity, or that they are more intimately combined. Since that time he has observed these appearances in many other bodies, as, for example, in green oxide of chromium, the oxides of tantalum and rhodium.



formed where the vapour unites with the oxygen of the atmosphere.\*

*Can you prove flame to be hollow?*

Yes. That fact is proved by holding a taper, or a piece of burning phosphorus, within a large flame by the combustion of alcohol. The flame

\* M. Porrett discovered that the luminous portion is surrounded by a flame nearly invisible, which produces heat. The blue bottom is caused by a low temperature, flame being transparent.

I have already observed, that when *pure* gaseous matter is burned, the light is very feeble, the density of flame being proportional to the quantity of solid charcoal first deposited, and afterwards burned. Thus the flame of pure hydrogen is pale blue, and emits very little light; but if we throw into it metallic filings, small pieces of platinum wire, powdered charcoal, or any other solid combustible matter, its light becomes increased by the ignition of these substances. In the flames of candles, lamps, and subcarburetted hydrogen gas, the inflammable element is pure hydrogen; the whiteness and intensity of the light being produced by a quantity of ignited carbonaceous matter, given off by the decomposition of the combustible substances employed, as oil, tallow, &c. The form of flame is conical, because the greatest heat is in the centre of the inflammable mixture. In looking steadfastly at flame, the part where the combustible matter is volatilized is seen; and it appears dark, contrasted with the part in which it begins to burn, that is, where it is so mixed with air as to become explosive. The heat diminishes towards the top of the flame, because in this part the quantity of oxygen is least. When the wick becomes clogged with charcoal, it cools the flame, and prevents a proper quantity of air from mixing with its central part; hence the charcoal thrown off from the top of the flame is only red-hot, and much escapes unconsumed.

The *heat* of flames may be actually diminished by increasing their light, (at least the heat communicable to other matter), and *vice versa*. The flame from combustion, which produces the most intense heat amongst those which have been examined, is that of a mixture of oxygen and hydrogen, compressed in Newman's blow-pipe apparatus. (See page 173). This flame is hardly visible in bright day-light, yet it instantly fuses the most refractory bodies; and the light from solid bodies ignited in it is so vivid as to be painful to the eye. This application originated from Sir H. Davy's discovery, that the explosion from oxygen and hydrogen would not communicate through very small apertures, and he himself first tried the experiment with a fine glass capillary tube. The flame was not *visible* at the end of this tube, being overpowered by the brilliant star of the glass, ignited at the aperture.



of the taper, or of the phosphorus, will appear in the centre of the other flame, proving that there is oxygen even in its interior part.\*

\* The above principle of the increase of the brilliancy and density of flame, by the production and ignition of *solid* matter, admits of many applications. It explains the intensity of the light of those *flames* in which *fixed* solid matter is produced in combustion, such as the flame of phosphorus and of zinc in oxygen, &c. and of potassium in chlorine, and the feebleness of the light of those flames in which gaseous and volatile matter alone is produced, such as those of hydrogen and sulphur in oxygen phosphorus in chlorine, &c.



1.—*Table consisting of Frigorific Mixtures, composed of Ice, with chemical Salts and Acids.*

Frigorific Mixtures with Ice.

MIXTURES.	Thermometer sinks.	Degree of cold produced.
Snow, or pounded ice .. 2 parts Muriate of soda ..... 1	From any Temperature. to — 5° to — 12° to — 18° to — 25°	*
Snow, or pounded ice.. 5 parts Muriate of soda ..... 2 Muriate of ammonia .. 1		*
Snow, or pounded ice.. 24 parts Muriate of soda ..... 10 Muriate of ammonia .. 5 Nitrate of potassa .... 5		*
Snow, or pounded ice.. 12 parts Muriate of soda ..... 5 Nitrate of ammonia .... 5		*
Snow ..... 3 parts Diluted sulphuric acid 2	From + 32° to — 23°	55
Snow ..... 8 parts Muriatic acid ..... 5	From + 32° to — 27°	59
Snow ..... 7 parts Diluted nitric acid.... 4	From + 32° to — 30°	62
Snow ..... 4 parts Muriate of lime ..... 5	From + 32° to — 40°	72
Snow ..... 2 parts Cryst. muriate of lime 3	From + 30° to — 50°	82
Snow ..... 3 parts Potassa ..... 4	From + 32° to — 51°	83

N. B.—The reason for the omissions in the last column of this Table, is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.



2.—*Table consisting of Frigorific Mixtures, combined so as to increase or extend Cold to the extremest Degrees.*

Combination of Frigorific Mixtures.

MIXTURES.	Thermometer sinks.	Degree of cold produced.
Phosphate of soda .... 5 parts Nitrate of ammonia .... 3 Diluted nitric acid ..... 4	From 0° to — 34°	34
Phosphate of soda .... 3 parts Nitrate of ammonia .... 2 Diluted mixed acids .. 4	From — 34 to — 50°	16
Snow ..... 3 parts Diluted nitric acid ..... 2	From 0° to — 46°	46
Snow ..... 8 parts Diluted sulphuric acid .. 3 Diluted nitric acid .... 3	From — 10° to — 56°	46
Snow ..... 1 part Diluted sulphuric acid .. 1	From — 20° to — 60°	40
Snow ..... 3 parts Muriate of lime ..... 4	From + 20° to — 48°	68
Snow ..... 3 parts Muriate of lime ..... 4	From + 10° to — 54°	64
Snow ..... 2 parts Muriate of lime ..... 3	From — 15° to — 68°	53
Snow ..... 1 part Cryst. muriate of lime .. 2	From 0° to — 66°	66
Snow ..... 1 part Cryst. muriate of lime .. 3	From — 40° to — 73	33
Snow ..... 8 parts Diluted sulphuric acid.. 10	From — 68° to — 91°	23

N. B.—The materials in the first column, are to be cooled, previously to mixing, to the temperature required, by mixtures taken from the preceding tables.



## APPENDIX.

### SELECT CHEMICAL EXPERIMENTS.\*

EXPERIMENTS ON SIMPLE AFFINITY. See page 10.

1. POUR into a phial half an ounce of any animal or vegetable oil, (as olive oil,) add to it the same quantity of water, and shake the phial violently. No appearance of combination will take place, for whenever the agitation ceases, the oil will be seen to rise to the surface of the water. Throw in 2 drachms of soda, potassa, or ammonia, and shake the phial again. The case will now be different, for the alkali combining with the oil, forms a soap, which is readily miscible with water, and the whole will have the appearance of thick cream.

*Rationale.* It is evident that no combination took place in the first instance, because there is no affinity existing between oil and water; while the manifest affinity which oils have for alkalies is the cause of the immediate combination that followed the addition of the alkali, in the second case.

*Note.* The attraction or affinity of alkalies for *acids*, is greater than that for oils; consequently the above formed soap may be decomposed by the introduction of any acid, such as diluted sulphuric acid, or common vinegar. In these cases, the alkali will leave the oil, (which will again swim on the top,) and combine with the acid, with which it forms a saline solution.

2. If mercury be poured into a wine glass, its upper surface will be *convex*; that is, a kind of foss or trench will be formed all round the mercury, between it and the edges of the glass. But if the mercury be poured from the glass, into a tin, brass, or other metallic cup, the upper surface will be *concave*.

*Rationale.* The convexity observed in the former instance, is the consequence of no affinity existing between mercury and glass; but the concavity visible in the latter case, results from the attraction which mercury has for other metals, and, of course, its consequent adhesion to them.

3. *Etching or Engraving on Glass.* Take a piece of plate or common window glass, clean it well from grease, and cover

\* Although there are many chemical experiments detailed in the body of this work, I have thought it would still further tend to promote the instruction, as well as serve to the amusement of students, if a few more of the most interesting and striking of such experiments were inserted in the form of an appendix.



one side of it all over either with hard engraver's varnish, called *etching ground*, or with bees-wax. When the coating is dry, trace out upon it, by means of a needle or other sharp-pointed tool, as in common etching, the design intended to be engraven, taking care that every stroke or line be carried clean and smooth through the coat of varnish to the surface of the glass, so that the light may be seen wherever the varnish is cut through. Having done this, take one part of powdered fluor spar, (see pages 182-3,) put it into a leaden bason, add to it two parts of sulphuric acid, and lay the glass, with the engraved side downwards, on the bason, and place the vessel over a spirit lamp for a few minutes, or till white fumes are disengaged abundantly from the mixture; then withdraw the bason, and suffer the glass to be corroded by the action of the white fumes of fluoric acid gas, which will be accomplished in 8 or 10 minutes.

The varnish or wax may be removed by a little oil of turpentine.

*Rationale.* This experiment illustrates the affinity of *fluoric acid* for *silica*, which is a constituent of glass, (see page 369).

*Note.* The present is an example of *elective* affinity, which is that exerted between two substances to the exclusion of a third:—the two substances uniting here are fluoric acid and silica, the excluded substance being the potassa of the glass.

4. To a pint of new milk, in a glass goblet, add half a drachm of diluted sulphuric acid: an immediate change will take place in the whole fluid, by the descent of a white flocculent and abundant precipitate, some parts of which coagulate in masses. This precipitate is called curd, and the supernatant fluid, whey.

*Rationale.* Here the acid combines with the water of the milk, consequently the albumen, gelatine, and oil, are precipitated. A very ready and elegant mode of procuring curds, and also a very pleasant acidulous whey, is by using a solution of the crystallized citric acid; taking care not to add too much.

5. Into a diluted solution of acetate of lead, drop sulphuric acid whilst any white precipitate falls down. This precipitate will be the sulphate of lead, which is an insoluble heavy salt.

*Rationale.* In this experiment the acetic acid quits the metal, which unites with the sulphuric acid. The acetic acid may be collected pure in a cool receiver, if the experiment be performed in a tubulated retort. It is readily known by the pungent odour of vinegar.

*Note.* On the principle of attraction, a drop of sulphuric acid is a good test for the smallest quantity of lead in any transparent liquid. The acetate of lead, on the other hand, is a good test for the presence of sulphuric acid in vinegar, with which the latter is commonly adulterated.



## EXPERIMENTS ON DOUBLE OR COMPOUND AFFINITY.

See page 15.

6. *To produce a beautiful orange yellow pigment.* To a solution of acetate of lead, add a solution of chromate of potassa as long as any precipitation takes place. The precipitate is *chrome yellow*, or chromate of lead, much used by coach painters and others, as a pigment.

*Rationale.* It is evident that a double decomposition is here induced, whereby acetate of potassa is held in solution, and chromate of lead is thrown down.

7. *To produce a beautiful blue pigment, PRUSSIAN BLUE.* Put some solution of sulphate of iron into a tall ale glass, and drop into it a little of a solution of prussiate of potassa, when a very beautiful blue colour will be immediately produced, which may be much heightened by pouring in more of the latter solution, until all the iron is taken up.

*Rationale.* See page 491. Here the prussic acid leaves the potassa, and seizes on the iron, forming prussiate of iron, or *prussian blue*, while the potassa in its turn is taken up by the sulphuric acid, forming sulphate of potassa. In this way, the least portion of iron may be detected in any solution.

8. *Variation of the preceding experiment as a sympathetic ink.* If a letter be written with a solution of sulphate of iron, the inscription will be invisible; but if it be afterwards rubbed over by a feather, dipped in a solution of prussiate of potassa, it will appear of a beautiful blue colour.

9. Place a little white oxide of bismuth on a colourless dish, and pour over it some Harrowgate water. Its fine white colour will be instantly changed to *black*, in consequence of the action of the sulphuretted hydrogen gas of the water upon the metallic oxide.

*Note.* An anecdote is related of the very unexpected influence of this gas on the oxide of bismuth. It is well known that this oxide, under the name of *pearl white*, is used as a cosmetic (p. 424) by some of the fair sex. A lady thus painted was sitting in a lecture room, where chemistry being the subject, water impregnated with sulphuretted hydrogen gas (Harrowgate water) was handed round for inspection. On smelling this liquid, the lady in question became suddenly *black in the face*. Every one was of course alarmed by this sudden *chemical* change, except the lecturer; he explained the cause of the phenomenon, and the lady received no farther injury; probably she profited by this practical lesson to rely more upon natural than artificial beauty in future.

## EXPERIMENTS ON CRYSTALLIZATION. See page 457.

10. *Crystallization of different salts, held in solution by one body of water.* Dissolve in seven different tumblers, con-



taining warm water, half an ounce of each of the following salts, viz. sulphate of iron, copper, zinc, soda, alumina, magnesia, and potassa. Pour them all, when completely dissolved, into a large evaporating dish, and stir the whole with a glass rod; place the dish in a warm place, where it cannot be affected by dust; or where it may not be agitated. When due evaporation has taken place, the whole will begin to shoot out into crystals. These will be interspersed in small groups, and single crystals, among one another. Their colour, taste, and peculiar form of crystallization, will serve to distinguish each separate crystal; and the whole together remaining in the respective places where they were deposited, will display a very pleasing and curious appearance.

11. *Crystallization of salts whose acids and bases are different.* Pour a solution of half an ounce of sulphate of iron, and the same quantity of muriate of soda (common salt), together into an evaporating dish. On due evaporation each set of crystals will be formed.

12. *Crystallization where the salts decompose each other.* Dissolve separately in warm water, half an ounce of muriate of potassa and half an ounce of nitrate of ammonia, and pour both solutions into an evaporating dish. On cooling, two kinds of crystals will be formed; but neither will be like those dissolved; for by double elective affinity (p. 15), the muriatic acid will combine with the ammonia, forming muriate of ammonia, leaving the potassa to be taken up by the nitric acid, to form nitrate of potassa.

13. *Metallic crystallization.* Melt a ladle-full of bismuth, and allow it to cool slowly and quietly, till a thin crust has formed on the surface; and then, by means of a pointed iron, make two small opposite apertures through the crust, and quickly pour out by one the fluid portion, as carefully and with as little motion of the mass as possible, whilst the air enters by the other aperture: there will appear, on removing the upper crust by means of a chisel, when the vessel has become cold, a cup-shaped concavity, studded with very brilliant crystals, more or less regular, according to the magnitude of the quantity or mass employed, the tranquillity and slowness with which it has cooled, and the dexterity with which the fluid portion, at the moment before it commenced to solidify, was decanted from the crystallized part. The same effect will be produced by fusing the substance in a crucible which has a hole in its bottom, lightly closed by an iron rod or stopper, which is to be drawn out when the mass begins to congeal: by this means the superior portion, which is fluid, is made to run off, and a cake studded over with crystal is obtained.



*Rationale.* Crystallization, under whatever circumstances it takes place, is effected solely by virtue of the attraction existing between the integrant atoms of bodies, which tends to bring them together, and make them adhere to each other. And to cause a body to crystallize, it is in the first place necessary to reduce it to the most complete state of disintegration, which, in this instance, is effected by the action of heat. The body being rendered fluid, gives the particles full liberty to move, and then no resistance is offered to a symmetrical arrangement being assumed by virtue of the crystalline power with which the atoms of the body are endued; and as the agency which keeps the atoms of the body at a distance is gradually withdrawn, they have full liberty to exercise their reciprocal attractive power, and to assume a regular symmetrical form, which is different in every different chemical species of crystallizable compound.

14. *Instantaneous crystallization.* Make a concentrated solution of sulphate of soda, or Glauber's salt, by adding portions of it gradually to water kept boiling, till this fluid dissolves no more, ( $1\frac{1}{2}$  ounce of boiling water will dissolve about 2 ounces of the salt): having done this, pour the solution, whilst boiling hot, into common medicine phials, previously warmed, and immediately cork them, or tie slips of wetted bladder over the orifice of the phials, to exclude the access of air from the solution. This being done, set the phials by in a quiet place, without shaking. The solution will cool to the temperature of the air, and remain perfectly fluid; but the moment the cork has been withdrawn, and atmospheric air is admitted, it will begin to crystallize on its upper surface in fine satin-like crystals, which shoot downwards in a few seconds, like a dense white cloud, and so much heat is evolved, as to make the phial very sensibly warm to the hands. When the crystallization is accomplished, the whole mass is usually so completely solidified that on inverting the vessel, not a drop of it falls out.

If the crystallization should not immediately ensue on opening the phial, introducing the point of a needle or pen-knife, dropping in a minute crystal of the same salt, or the slightest agitation, will cause the crystalline process to take place. The same mass of salt will answer any number of times the same purpose; all that is necessary to be done is, to place the phial in boiling water till the salt is again completely liquefied.

*Rationale.* This phenomenon has been attributed till lately to the influence of the atmospheric pressure on the solution of the salt. It is now generally believed that other agencies operate, although they are not fully understood. Dr. Ure says that *agitation is the sole cause* of crystallization under such circumstances, and there are many circumstances in favour of this assertion.



## EXPERIMENTS ON COMBUSTION AND DETONATION.

15. *To set a combustible on fire by the contact of water.* Fill a saucer with water, and let fall into it a piece of potassium of the size of a pepper corn, which is about two grains. The potassium will instantly burst into flame, with a slight explosion, and burn vividly on the surface of the water, darting at the same time from one side of the vessel to the other, with great violence, in the form of a beautiful red-hot fire-ball.

*Rationale.* The combustion here is owing to the *intense* chemical action exerted between the potassium and the oxygen of the water. See p. 311.

16. *Vivid combustion of three metals by simple contact.* Mix a grain or two of potassium with a like quantity of sodium by rubbing them together with the point of a knife. The mixture will take place quietly; but if the alloy of these two metals be brought into contact with a globule of quicksilver, the compound, when agitated, instantly bursts into flame, and burns vividly.

*Rationale.* This combustion during combination appears to be analogous to the apparent combustion of copper filings with sulphur; for neither of the constituent parts of the compound appears to suffer oxidation.

17. *A well of fire.* Add gradually 1 ounce, by measure, of sulphuric acid, to 5 or 6 ounces of water contained in an earthenware bason; and add to it also, gradually, about  $\frac{3}{4}$  of an ounce of granulated zinc. A rapid production of hydrogen gas will instantly take place. Then add, from time to time, a few pieces of phosphorus of the size of a pea. A multitude of gas bubbles will be produced, which take fire on the surface of the effervescing liquid; the whole surface of the liquid will become luminous, and fire-balls with jets of fire will dart from the bottom through the fluid with great rapidity, and a hissing noise.

*Rationale.* The zinc when brought into contact with water, in conjunction with sulphuric acid, decomposes the water. The oxygen of the water unites to the zinc, and forms an oxide of zinc, which is instantly dissolved by the sulphuric acid; the other constituent of the water, the hydrogen, is set free, and dissolves a portion of phosphorus, with which it escapes as phosphuretted hydrogen gas, which takes fire the moment it comes into contact with the common air.

18. *Phosphoric fire bottle.* The phosphoric fire bottle may be prepared in the following manner:—Take a small phial of very thin glass, heat it gradually in a ladle-full of sand, and introduce into it a few grains of phosphorus; let the phial be



then left undisturbed for a few minutes, and proceed in this manner until the phial is full. Another method of preparing this bottle, consists in heating two parts of phosphorus, and one of lime, placed in layers, in a loosely-stopped phial, for about half an hour. Another very simple method is as follows:—Put a little phosphorus into a small phial; heat the phial in a ladle full of sand; and when the phosphorus is melted, turn it round, so that the phosphorus may adhere to the sides of the phial; and then cork the phial closely. To use this bottle, take a common brimstone match, introduce its point into the bottle, so as to cause a minute portion of its contents to adhere to it; if the match be then rubbed on a common bottle cork, it will instantly take fire. Care should be taken not to use the same match a second time immediately, or while still hot, as it would infallibly set fire to the phosphorus or oxide of phosphorus in the bottle.

*Rationale.* The friction on the cork raises the temperature of the phosphorus and sulphur by which they are inflamed.

19. *To render the surface of water luminous.* Wet a lump of fine loaf sugar with phosphorized ether,\* and throw it into a bason of water; the surface of the water will become luminous in the dark, and, by gently blowing upon it, phosphorescent undulations will be formed, which illuminate the air above the fluid to a considerable distance.

In winter it will be necessary to render the water blood-warm. If the phosphorized ether be applied to the hand, or other warm objects (which may be done with safety,) it renders them phosphorescent in the dark.

*Rationale.* The phosphorized ether is decomposed on coming in contact with water, a portion of which unites with the ether, and sets the phosphorus on fire, in the form of a slow combustion, which then exhibits the luminous appearance. If the phosphorized ether be applied to the hands, or any other warm object, the ether instantly evaporates, leaving behind it an extremely minute portion of phosphorus, which forms the luminous appearance, by being acted upon by the oxygen of the air.

20. *To kindle spirit of wine without the contact of fire.* Pour 4 or 6 drachms of spirit of wine into a tea-cup, and add to it 10 or 15 grains of chlorate of potassa. If to this mixture about 6 drachms, by measure, of sulphuric acid be added, it begins to boil, a multitude of small fire-balls, of a vivid blue colour, dart out of the fluid, and the whole bursts into flame.

\* *Phosphorized ether* is prepared, by suffering sulphuric ether to stand, for some weeks, over a considerable quantity of phosphorus in a well-stopped phial.



*Rationale.* The sulphuric acid decomposes the chlorate of potassa, and the nascent euchlorine, or protoxide of chlorine, evolved, inflames the alcohol.

21. *To produce sparks and flashes of fire under water.* Into a tall ale-glass, put 6 drachms, by measure, of nitrous acid; and pour gently over it, down the sides of the glass, 2 or 3 drachms of water, so as to keep the strata of the fluids as distinct as possible; then drop into it a piece of phosphorus of the size of half a pea. If now ten grains of chlorate of potassa be added, a violent action ensues, the phosphorus takes fire and burns with a vivid light at the bottom of the vessel, and brilliant streams of fire dart through the fluid to the surface.

*Rationale.* This is nothing else than a spontaneous combustion of phosphorus in nascent chlorine, furnished by the chlorate of potassa, by virtue of the action of nitrous acid on this salt, which gas inflames the phosphorus.

*Note.* The intensity of the action in this experiment may be regulated by adding more or less water to the acid, and also, by increasing or diminishing the quantity of the ingredients. It should be also observed, that this experiment, though by no means dangerous, requires a little precaution, because the phosphorus is sometimes thrown out of the mixture in a state of combustion, particularly if the vessel be small, which therefore ought not to be held in the hand, but should be placed under a chimney, that the gas which is extricated may be readily carried off.

22. *Gas Light.* Fill the bowl of a tobacco-pipe with rich bituminous coal from the fire, and cover it over with moistened clay, so as to cause the gas issuing from it to escape from the stem; then apply a candle or lighted match to the stem; when the gas will immediately inflame, and continue in a state of beautiful combustion as long as the gas continues to be evolved. The coal in the bowl will afterwards be found converted into a cinder similar to coke.

This experiment may be varied by putting some common coal from the coal scuttle into the bowl of a tobacco-pipe, and after covering it with clay as just described, introducing it into the fire, and heating it gradually. In a few minutes a stream of gas will issue from the stem, which may be kindled by a candle or match.

*Rationale.* The production of the coal gas, or subcarburetted hydrogen (p. 228), is the result of the analysis of coal effected by heat. Some of the carbon of the coal unites with a portion of the oxygen of the water which the coal contains, and produces carbonic acid gas; at the same time, a part of the hydrogen of the water combines with another portion of the carbon, and forms the subcarburetted hydrogen or coal gas.



23. *To produce streams of fire, of a vivid green colour, under water.* Put into a large ale-glass 2 ounces of water, and add first a piece or two of phosphorus about the size of a pea, and then 30 or 40 grains of chlorate of potassa. This being done, pour upon the mass, by means of a tube or funnel with a long neck reaching to the bottom of the glass, 5 or 6 drachms (by measure) of sulphuric acid. As soon as the acid comes into contact with the materials, flashes of fire begin to dart from under the surface of the fluid. When this takes place, drop into the mixture a few lumps (not powder) of phosphate of lime, equal in size to a large pea. This will instantly illuminate the bottom of the vessel, and cause a stream of fire, of an emerald-green colour, to pass through the fluid. By a fresh addition of the same materials, the action may be kept up when it begins to subside.

*Rationale.* The chlorate of potassa yields euchlorine gas (p. 600) by the affusion of sulphuric acid, whilst the phosphuret of lime produces phosphuretted hydrogen gas, which inflaming in the nascent euchlorine, gives the coloured light.

*Note.* This experiment requires a little caution, lest the inflamed phosphorus should be thrown into the eyes.

Oil may also be thus inflamed on the surface of water, the experiment being made with the omission of the phosphorus, and the substitution of a little olive or linseed oil.

24. *Pyrophorus.\** An excellent method of preparing pyrophorus is the following:—Mix together 3 parts of alum and 1 of flour, and heat the mixture to dryness in an iron pot, over a common fire; the black calcined mass thus produced, is to be put into ounce phials of green glass, coated without and within with clay. The phials thus charged are to be lightly stopped with balls of tempered clay, and then set up to their necks in sand in an iron pot; charcoal powder is next to be strewed on to the depth of half an inch, over which is to be placed an earthen cover, luted to the pot. The whole apparatus is now to be placed in a furnace, and kept at a red heat for an hour and a half: at the expiration of this period, being taken out of the furnace and cooled quickly, it is to be unpacked, and the phials containing the pyrophorus are to be placed with their mouths inverted in mercury, in which situation the pyrophorus may be kept for many years without injury.

*Rationale.* The chemical changes that take place during the formation and decomposition of pyrophorus, appear to be the following. First, by being heated below redness in the open

\* The name of *pyrophorus* is given to a powder which takes fire spontaneously on exposure to the air. If a little of this preparation be poured out on any flat surface, it presently diffuses an odour of sulphuretted hydrogen gas, and in a few seconds it becomes red hot, and burns with a lambent bluish flame, leaving a small quantity of ashes.



air, the ingredients enter into fusion, and then mix accurately with each other; then the water of crystallization is driven off from the alum, and of the flour (or sugar, when sugar is employed, as is sometimes the case,) little else than the charcoal escapes volatilization. Secondly, the red heat to which it is exposed in the phial, causes the sulphuric acid of the alum and the charcoal of the flour or sugar to re-act on each other, by which, part of the charcoal is driven off in the form of carbonic acid, and part of the sulphuric acid escapes as sulphurous acid: the blue flame that characterizes the latter part of this process is, in all probability, caused by the volatilization and combustion of a portion of sulphur, more than is requisite to saturate the potash of the alum. Thus the pyrophorus, when prepared, consists of alumina, charcoal, and sulphuret of potassa, in intimate mixture. Thirdly, when this powder is exposed to the air, a rapid decomposition, both of the air itself and of the moisture it contains, takes place; the oxygen of each being absorbed by the sulphuret, while a sufficient quantity of each is disengaged to bring the charcoal and remainder of the sulphur to a state of actual inflammation. Sir H. Davy and Dr. Cox have suggested, that a portion of the potash may be decomposed, and yield potassium.

*Note.* Sometimes, either from a defect in the preparation, or from the air not having been entirely excluded from the phial in which it is contained, the pyrophorus, when poured out, undergoes no sensible change; when this happens, however, the combustion may very often be brought about by breathing on the powder, and thus supplying it with the moisture which seems to be the primary agent in this phenomenon. Pyrophorus made in the above manner, is so very inflammable as to take fire as it is falling from the mouth of the phial.

25. *A powder which takes fire when rubbed in a mortar.* To 5 grains of chlorate of potassa, reduced to a fine powder, add  $2\frac{1}{2}$  of finely pulverized charcoal; mingle them together, by the greatest possible friction, on a piece of paper. If to this mixture 2 grains of sulphur be added, the whole, when forcibly rubbed with a pestle in a mortar, inflames with a rapid flash, like fired gunpowder.

*Rationale.* The friction produces a sufficient increase of temperature to inflame the highly combustibles substances forming this powder.

*Note.* The hand should be covered with a glove or handkerchief in performing this experiment.

26. *A powder which bursts into flame when touched with an acid.* Take 5 grains of chlorate of potassa, reduce it to powder, and mingle it, by trituration, in a mortar, with seven grains of lump sugar. If a drop or two of sulphuric acid be suffered to fall on this mixture, or if it be merely touched with the end of a glass rod moistened with this acid, it takes fire, and burns rapidly.

There is no danger in performing this experiment.



*Rationale.* The charcoal and hydrogen of the sugar are inflamed by being plunged into an atmosphere of euchlorine, disengaged from the chlorate of potassa by the action of sulphuric acid.

#### EXPERIMENTS ON COLOURS.

27. *To produce a carmine-red flame.* The flame of spirit of wine may be coloured, by the addition of various bodies which the spirit holds in solution, or which are mixed with it. And although the real causes which modify the colours of burning bodies are not yet sufficiently known, the phenomena are in themselves sufficiently striking to deserve to be noticed here. The flame of alcohol is tinged red in the following manner: Put into a small iron ladle, one part of muriate of strontia, and pour over it three or four of alcohol; then set it on fire with a candle, or a piece of burning paper, it will burn with a bright carmine-red flame, especially if the mixture be heated, by holding the ladle over the flame of a candle or lamp, to cause the alcohol to boil rapidly.

*Note.* The muriate of strontia left behind, as residue, after being again thoroughly dried, may be used for the same purpose repeatedly. The same remark applies to all the other materials employed for the production of coloured fire, to be presently noticed.

28. *To produce an orange-coloured flame.* Put muriate of lime deprived of its water of crystallization, into an iron ladle, cover it with spirit of wine, and cause it to burn in the manner stated.

29. *To produce an emerald-green flame.* Cause alcohol to burn in a ladle upon nitrate of copper.

30. *To change a blue colour red, green, crimson, or purple.* Put two or three table-spoonfuls of tincture of cabbage, which is of a dark blue colour, into one tall ale-glass, and pour half the mixture into another glass. If a drop of sulphuric acid be added to one of the glasses, the blue will become changed to a lively crimson, and by adding to the other glass a drop of liquid ammonia, or a solution of potassa, soda, baryta, or strontia, the blue will be changed to a bright green: and if you carefully let fall, down the inner sides of the glass, into the green fluid, a single drop of sulphuric acid, crimson will appear in the bottom of the glass, purple in the middle, and green at the top; and by adding a few drops of liquid ammonia, or any other alkali, to the crimson fluid, the colours will present themselves in an inverted order.

*Rationale.* These phenomena prove the important chemical fact, that vegetable blues are changed red by uncombined acids, and green by alkalies. The change of the green fluid



to red, is effected by the excess of acid added, which is then sufficient to neutralize the chemical effect of the alkali, the tendency of which always is to render the colours green; and the reverse is the case when the alkali is again added in excess to the red solution. Tincture of cabbage is therefore a delicate test both for acids and alkalies, and is employed as such in chemical pursuits.\*

31. *To change a blue fluid red, by the air respired from the lungs.* Add to two tea-spoonfuls of water, in a wine-glass, a sufficient quantity of tincture of cabbage to tinge it very slightly blue, and blow with the breath through the coloured water, by means of a quill or tobacco-pipe, dipping into the fluid. The bubbles of air expired, whilst passing through the water, will speedily produce the reddening effect, because the air respired from the lungs contains carbonic acid.

32. *To produce four different coloured precipitates from colourless solutions, by a limpid fluid.* Dissolve 8 or 10 grains of tartrate of antimony and potassa (*emetic tartar*) in a wine-glass half full of water, and drop into the solution, liquid sulphuretted hydrogen (page 267); a bright *orange* coloured precipitate will be obtained, which is a *sulphuret of antimony*.

Add to a solution of arsenic, liquid sulphuretted hydrogen; a *yellow* precipitate will be immediately produced, which is *orpiment*, or *sulphuret of arsenic*.

Let fall a few drops of submuriate of tin, into a wine-glass half full of water; and add to the mixture liquid sulphuretted hydrogen; a *chocolate-brown* precipitate will be produced, which is *sulphuret of tin*.

Add to a wine-glass half full of water, a few grains of acetate of lead, and drop into the mixture a little liquid sulphuretted hydrogen; a *black* precipitate will take place, which is *sulphuret of lead*.

*Note.* It is essential that the liquid sulphuretted hydrogen should be fresh prepared, when employed for this purpose.

\* *Preparation of tincture of cabbage.* Tincture of cabbage is very liable to spoil; it soon undergoes a kind of putrefaction, which destroys its colour. It is obtained by cutting fresh leaves of the red cabbage (*brassica rubra*) into small pieces, and pouring over it boiling hot distilled water, and suffering the whole to macerate for a few hours. The clear fluid being then decanted, and mixed with one-eighth of its bulk of spirit of wine, is fit for use.

The cabbage leaves may be preserved for many years, by drying them in a warm place, at a temperature of about 120° Fahr. having previously cut them into small pieces.

To prepare the test liquor from the dry leaves, let them be digested in distilled water, to which a minute portion of sulphuric acid has been added, which will produce a red tincture. Then let the acid be neutralized by marble powder, the red colour will vanish, and the tincture become blue. This being done, suffer the mixture to become clear by standing, or filter it; and lastly, mingle it with one-eighth of its bulk of spirit of wine.



## EXPERIMENTS ON SYMPATHETIC INKS.\*

33. *A green sympathetic ink, the writing of which is invisible, but appears by heat, and departs by cold.* If letters be traced on paper with muriate of cobalt, the writing is invisible, but by holding it before the fire, the characters speedily assume a green colour, which again disappears as the paper cools. The writing made with this ink may therefore, at pleasure, be made to become visible or invisible successively, by alternately warming and cooling, if care be taken not to expose the paper to a greater degree of heat than is necessary to make the invisible writing legible.

*Note.* Many different theories have been proposed to account for this remarkable change. According to some, it is owing to the moisture of the atmosphere being absorbed, that the colour disappears; and when this is driven off by heat, that is restored. But to this opinion it has been objected, that the same effect is produced, when paper, on which characters have been written with this ink, is entirely excluded from the atmosphere, by being introduced into close vessels. According to others, the sympathetic effect of this ink depends on the iron which is combined with the cobalt. Some chemists suppose, that the concentration of the solution, which takes place by the action of heat, is the cause of the colour appearing; and its dilution, by absorbing moisture from the atmosphere, the cause of its disappearance; while, again, others are of opinion, that it is partially deprived of its oxygen by being heated, and absorbs it again in the cold, when the colour vanishes. The former explanation appears to be confirmed by the fact, that the characters are rendered visible by confining the paper in a vessel with quicklime, or sulphuric acid, either of which attracts humidity powerfully. The green colour cannot, however, be ascribed entirely to the concentration, but is owing to the temperature; for the solution itself becomes green when moderately heated in a close phial, and loses this green colour as it cools, nor is it easy to explain how the temperature does produce this change of colour.

34. *To render an invisible writing visible, by immersing the paper in water.* If characters be formed with a solution of nitrate of bismuth, they will, when dry, be invisible; but, on wetting the paper with water, the writing appears in dense white marks.

*Rationale.* This phenomena is owing to the property which nitrate of bismuth has, to precipitate almost the whole of the metal in the state of white oxide, when diluted with water, the separation of which renders the written characters visible.

35. *To render an invisible writing visible, by exposure to light.* Write on paper with a solution of nitrate of silver, sufficiently diluted, so as not to injure the paper; the characters, when dry, will be perfectly invisible, and remain so, if the paper be closely folded up, or if the writing be in any other way defended from the light; but if the paper is exposed to

\* Sympathetic or secret inks are those fluids, which, when written with on paper, are invisible when dry, but acquire colour by heating the paper, or by applying to the invisible writing another chemical agent.



the rays of the sun, or merely to the common light of day, the characters speedily assume a brown colour, and lastly turn black.

*Rationale.* This change of colour is owing to the partial reduction of the oxide of silver, from the light expelling a portion of its oxygen: the oxide therefore approaches to the metallic state; for when the blackness is examined with a powerful magnifier, the particles of metal may be distinctly seen.

36. *Green sympathetic ink, which becomes blue when held over a liquid, and green again on exposure to air.* Write on paper with a solution of sulphate of copper, when the characters or writing will be of a green colour. When the solution is dilute, the letters are invisible; and if the paper be held over the surface of liquid ammonia contained in a cup or saucer, the writing assumes a blue colour, which departs again on removing the paper near a fire, or by suffering it to be exposed to the open air for some time.

*Rationale.* The vapour of the liquid ammonia combines with the sulphate of copper, and forms with it the triple salt called sulphate of copper and ammonia, which possesses a beautiful blue colour; and this compound is again destroyed when the paper is held near the fire, or on mere exposure to the open air.

37. *A sympathetic landscape.* Draw a landscape on paper with common Indian ink, representing a winter scene, or mere outline: the foliage to be painted with muriate of cobalt (*green*), muriate of copper (*yellow*), and acetate of cobalt (*blue*); all which colours dry in invisible; but on the screen or paper being held near the fire, the gentle warmth will occasion the trees, flowers, &c. to display themselves in their natural colours, and winter is magically changed to spring. As the paper cools, the colours disappear, and the effect may be repeated as often as required.

#### MISCELLANEOUS EXPERIMENTS.

38. *To cause drops of water to roll over paper without breaking.* Rub over the surface of a sheet of writing paper a small quantity of the dust of lycopodium, or puff-ball, (sometimes called club moss,) and then let water fall on it in small quantities. The water will instantly form itself into distinct drops, which touch the lycopodium in a few points only, and will roll over the paper with uncommon rapidity, without breaking. That the drops do touch the lycopodium merely in a few points is obvious, from the copious reflection of white light from their under surface.



*Rationale.* This is an instance of repulsion. The phenomenon is owing to the attraction of cohesion of the particles of the fluid being greater than the attraction of cohesion existing between the fluid and the particles of the lycopodium; hence the former are apparently repelled, and assume, by virtue of their attractive power, a spherical form.

39. *Calico-printing.*—*To produce a scarlet pattern upon a black ground.* Boil a piece of white muslin, or calico, for a few minutes, in a solution of acetate of iron, and dry it thoroughly near a fire. Having done this, rinse it in water, and dye it black, by boiling it for a short time with a few chips of logwood and water; and lastly, clear it of the superfluous dye, by rinsing it in water. Then suffer the dyed cloth to dry again, and sprinkle it over with lemon juice or dilute muriatic acid, or imprint upon it any figure or design by means of lemon-juice, or muriatic acid. It will then be seen, that wherever the lemon-juice is applied, it will turn the dyed stuff of a scarlet colour; and in this manner any pattern may be produced upon a black ground on calico or linen cloth.

40. *To produce white figures upon a black ground.* Boil a piece of white muslin for a few minutes in a solution of sulphate of iron, composed of one part of green sulphate of iron and eight parts of water; squeeze it out and dry it. Then imprint upon it spots, or any other pattern you choose, with lemon-juice, dry it again, and rinse it well in water. If the stuff now be boiled with logwood chips and water, it will exhibit white spots upon a black ground.

41. *Bleaching.* Take one part of chloride of lime, put it into a stone bottle, and pour over it 8 parts of water. Let the mixture stand for 24 hours, during which time it ought to be now and then agitated; afterwards decant the supernatant clear solution of chloride of lime, dilute it with about three or four parts of warm water, and immerse into it a piece of unbleached calico, or any unbleached linen, or cambric article, or household linen, which has acquired a yellow colour by age or frequent washing. If the steeped article, after having been in the bleaching liquor for four or five hours, be then rinsed in water, it will have acquired a beautiful white colour. Spots and stains produced by red port wine, tea, fruit, coffee, become also discharged by the action of this bleaching fluid from white linen and cotton goods.

*Rationale.* On the present theory, part of the water is decomposed, the oxygen of which is imparted to the colouring matter of the cloth, while the hydrogen passes to the chlorine and composes muriatic acid, which remains behind with the lime, as muriate of lime.



42. *To fill soap bubbles with hydrogen gas.* Fill with hydrogen gas a bladder furnished with a stop-cock, and adapt to this a brass tobacco-pipe made to fit the stop-cock. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles. These bubbles, instead of falling to the ground, like those commonly blown by children, will rise rapidly into the air, from the great levity of the hydrogen gas.

43. The preceding experiment may be varied by filling the bladder with a mixture of two parts of hydrogen gas and one of oxygen gas, which may be conveniently done by making the mixture in a jar, and adapting to it a bladder (with a stop-cock,) by means of a connecting piece. Bubbles blown with this mixture take fire on the approach of a lighted candle, and detonate with a loud report. It is proper not to set them on fire till they are completely detached from the bowl of the pipe.

*Rationale.* This is a case of rapid combustion. Oxygen combines with the combustible body, light and caloric are evolved, and the result of this action and combination is one of the products of combustion, namely, water.

44. *Twisting of ropes and raising of heavy burdens by capillary attraction.\** If we suspend perpendicularly a rope 10 or 12 feet long, and affix to its lower extremity a heavy weight to stretch it as much as possible; the rope, when wetted, will be shortened, and if its length be such only as to allow the weight to touch the ground, the weight will be raised from the ground when the rope is wetted with water.

*Rationale.* The water, by introducing itself within the cord, makes the fibres of it twist, and become situated obliquely; it therefore produces between them such a separation as causes the cord to thicken or swell, and, by a necessary consequence, to shorten, by virtue of the capillary attraction existing between the water and the fibres of the rope.

*Note.* The anecdote respecting the famous obelisk erected by Pope Sixtus V. before St. Peter's at Rome, is well known. The chevalier Fontana, who had undertaken to raise this monument, was, it is said, on the point of failing in his operation, just when the column was about to be placed on its pedestal. It was suspended in the open air; and as the ropes had stretched a little, so that the base of the obelisk could not reach the summit of the pedestal, a man cried out, "Wet the ropes." This advice was followed, and the column, as if of itself, gradually rose to the required height, to be placed upright on the pedestal prepared for it.

\* By *capillary attraction* is meant, that which takes place in minute or capillary tubes.



A

## VOCABULARY

OF

## CHEMICAL TERMS.

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- ACETIC ACID.** A distinct vegetable acid. Vinegar is an impure acetic acid. See page 528.
- ACETOMETER.** An instrument for estimating the strength of vinegars.
- ACIDS.** A most important class of chemical compounds, the characters of which are almost universally known.
- ARSENIOUS ACID.** The common white arsenic of the shops.
- ACONITA.** The poisonous alkaline principle of the *aconitum napellus*, or wolfsbane. See page 540.
- ACTINOLITE.** A mineral.
- ADIPOCIRE.** A peculiar fatty substance resembling spermaceti, obtained from animal matter under particular circumstances. See page 570.
- ADOPTER.** A vessel with two necks placed between a retort and a receiver, and serving to increase the length of the neck of the former.
- AEROMETER.** An ingenious instrument invented by Dr. M. Hall for making the necessary corrections in pneumatic experiments, to ascertain the mean bulk of the gases.
- ALABASTER.** See page 485.
- ALBUMEN.** A proximate principle of animal substances. See page 564.
- ALCARRAZAS.** A species of porous pottery made in Spain.
- ALCHEMY.** The mystical art of the adepts of the dark ages, who professed to find the philosopher's stone.
- ALCOHOL.** Rectified spirit of wine. See page 555.
- ALEMBIC or STILL.** A chemical apparatus used for distilling.
- ALKALI.** Alkalies are those bodies which combine with acids so as to neutralize or impair their activity, and produce salts. The *mineral* alkali is soda, the *vegetable* alkali is potassa, and the *volatile* alkali is ammonia.
- ALLUVIAL FORMATIONS.** These are recent deposits in valleys or in plains, of the *detritus* of the neighbouring mountains.
- ALMANDINE.** Precious garnet.
- ALUMINA.** One of the primitive earths. See page 351.
- AMADON.** A variety of the *boletus igniarius*, found in old ash and other trees.
- AMALGAM.** A combination of mercury with other metallic substances.
- AMIDINE.** A peculiar substance produced from starch.
- ANALYSIS.** The separation of the component parts of bodies.
- ANHYDROUS.** Destitute of water.
- ANNEALING.** The art of rendering substances which are naturally hard and brittle, soft and flexible. Thus glass is annealed by cooling it very gradually.
- AQUA REGIA,** A strong acid, composed of a mixture of nitric and muriatic acids.



**ARGAL.** Crude tartar, as taken from wine vessels.

**ARGENTINE FLOWERS OF ANTIMONY.** The deutoxide of antimony, or the antimonious acid.

**ARGILLACEOUS EARTH.** Alumina.

**ASBESTOS.** A peculiar mineral substance, which is indestructible by fire, or the strongest acids.

**ASPHALTUM.** A bituminous substance. See page 548.

**ASSAY.** The operation of determining the quantity of valuable or precious metal contained in any mineral or metallic mixture, by analyzing a small part thereof.

**ATMOMETER.** An instrument invented by Professor Leslie, to measure the quantity of exhalation from a humid surface in a given time.

**ATOMIC THEORY.** The theory of chemical equivalents. See page 27.

**ATTRACTION or AFFINITY.** See page 10.

**AZOTE.** Nitrogen gas. See page 184.

**BARIUM.** The metallic basis of the earth barytes.

**BARILLA.** Impure soda, imported from the Levant.

**BASE or BASIS.** A term usually applied to alkalies, earths, and metallic oxides, in their relations to the acids and salts. Thus, potassa is the base of sulphate of potassa, and sulphur the base of sulphuric acid.

**BASSORINE.** A peculiar substance extracted from the gum resins.

**BITUMEN.** An inflammable mineral substance, of which there are several varieties. See page 547.

**BLACK JACK.** An ore of zinc, sometimes also called blende, or mock lead.

**BLACK WADD.** One of the ores of manganese.

**BLEACHING POWDER.** Chloride of lime.

**BORAX.** The bi-borate of soda.

**BORON.** The base of boracic acid.

**BOYLE'S FUMING LIQUOR.** Hydroguretted sulphuret of ammonia.

**BRASS.** A compound of copper and zinc. See page

**BRITISH GUM.** A substance procured by exposing starch to a temperature of 600° or 700°.

**BROME or BROMINE.** A new elementary body of the same class as oxygen. See page 138.

**BUTTER OF ANTIMONY.** See page 424.

**CAFEINE.** A peculiar principle in coffee. See page 541.

**CALAMINE.** A native carbonate of zinc.

**CALCAREOUS SPAR.** Crystallized carbonate of lime.

**CALCINATION.** The exposure of substances to heat, by which some of their constituents are driven off; thus chalk is calcined, and converted into lime, by driving off its carbonic acid and water; and carbonate of magnesia is calcined, and converted into pure magnesia.

**CALX.** The old name for metallic oxide.

**CALCIUM.** The metallic base of lime.

**CALORIC.** The agent or matter of heat. See page 40.

**CAMELEON MINERAL.** See page 389.

**CAOUTCHOUC.** Elastic gum, or Indian rubber.

**CAPUT MORTUUM.** The coaly residuum left at the close of a distillation or sublimation.

**CASE HARDENING.** Communication of a surface of steel to iron utensils by heating charcoal in contact with the surface. It scarcely differs from the making of steel, except in the shorter duration of the process.

**CAUSTICITY.** The property of corroding the skin, &c.



**CERASIN.** The name given to those gummy substances which swell in cold water, but do not readily dissolve in it.

**CERITE.** The siliciferous oxide of cerium.

**CERUSE.** White lead.

**CETINE.** The name given by M. Chevreul to spermaceti.

**CHALYBEATE.** Impregnation with iron.

**CHLORATES.** Compounds of chloric acid with the salifiable bases.

**CHLORIDES.** Compounds of chlorine with different bodies.

**CHLOROUS and CHLORIC OXIDES.** The protoxide and deutoxide of chlorine.

**CHOLESTERINE.** The name given by Chevreul to the pearly substance which constitutes the principal part of human biliary calculi. See page 570.

**CINCHONIA.** The vegetable alkali extracted from *pale* Peruvian bark.

**CINNABAR.** A sulphuret of mercury.

**CLARIFICATION.** The process of freeing a fluid from heterogeneous matter or feculencies, which is accomplished chiefly by the use of albumen, gelatine, or blood.

**CLAY (pure).** Alumina.

**COKE.** An impure charcoal obtained from coal.

**COHOBATION.** The continuous redistillation of the same liquid from the same materials.

**COLOCYNTHINE.** The peculiar bitter principle of colocynth, in which its purgative property resides.

**COLOPHONY.** It is the resinous residuum left after the distillation of the light oil, and thick dark reddish balsam, from turpentine. It is sometimes called *black resin*.

**COMBUSTIBLE.** An inflammable substance.

**COPPERAS.** Sulphate of iron.

**CORROSIVE SUBLIMATE.** Bi-chloride of mercury. See page 428.

**CREAM OF TARTAR.** Bi-tartrate of potassa.

**CRUCIBLE.** A vessel of a peculiar structure in which substances are placed to sustain the action of fire. They are of different materials, but chiefly of platinum, silver, porcelain, and plumbago.

**CRYOPHORUS.** An elegant instrument invented by Dr. Wollaston. See page 93.

**CUPEL.** A shallow vessel, made of bone-ash, or phosphate of lime, somewhat resembling a cup, and used in assays wherein the precious metals are fused with lead, which becomes converted into glass, and carries the impure alloy with it.

**CUPELLATION.** The process of refining or purifying of gold or silver by alloying it with lead or bismuth, and submitting it to intense heat, with a free current of air.

**CYANOGEN.** Carburet of nitrogen or azote.

**DECOCTION.** The operation of boiling.

**DECOMPOSITION.** The separation of the component parts or principles of bodies from each other.

**DECREPITATION.** The crackling noise which several salts make when suddenly heated.

**DEFLAGRATION.** The vivid combustion produced by exposing some substances, as nitre and chlorate of potassa, to a red heat.

**DELIQUESCENT.** Applied to salts, the act of becoming moist by the attraction of water from the atmosphere.

**DEPHLOGISTICATED AIR.** Oxygen gas.

**DESTRUCTIVE DISTILLATION.** The process of exposing organized substances, or their products, to distillation, until the whole has suffered all that the furnace can effect.



**DETONATION.** A sudden combustion and explosion.

**DIGESTION.** The slow and regular action of a solvent on any substance.

**DUCTILITY.** The property of being drawn out into *wire*.

**EFFERVESCENCE.** The commotion produced in fluids by some part of the mass suddenly taking the elastic form, and escaping in numerous frothy bubbles.

**EFFLORESCENCE.** Spontaneous conversion into a dry powder. In saline bodies, it is almost always occasioned by the loss of the water of crystallization.

**ELAÏN.** The oily principle of solid fats. See page 520.

**ELASTIC BITUMEN.** Mineral caoutchouc. See page 549.

**ELECTIVE ATTRACTION.** See page 14.

**ELECTRO-MAGNETISM.** See page 131.

**ELEMENTARY PRINCIPLES.** See page 505.

**ELUTRIATION.** The process of washing, which carries off the lighter earthy parts, while the heavier metallic parts subside to the bottom.

**EMPYREUMA.** A term applied to denote the peculiar smell produced by a considerable heat upon vegetable or animal substances in closed vessels, or when burned under circumstances which prevent the access of air to a considerable part of the mass, and, consequently, occasions an imperfect combustion, or destructive distillation, of the parts so covered up by the rest of the mass.

**EQUIVALENTS (Chemical).** The doctrine of definite proportions. See page 26.

**ETHIOPS MINERAL.** The black sulphuret of mercury.

**ETHIOPS PER SE.** The black oxide of mercury.

**EUCHLORINE.** The protoxide of chlorine.

**EUDIOMETER.** An instrument for determining the purity of atmospheric air, or rather the quantity of oxygen contained in any given bulk of elastic fluid. See page 187.

**EVAPORATION,** The loss of volatile matter or vapour. See page 91.

**FARINA.** Another name for starch. See page 511.

**FECULA.** Starch or farina.

**FERROCYANATES.** Ferroprussiates.

**FIBRIN.** A peculiar organic compound found in animals. See page 566.

**FIRE DAMP.** Subcarburetted hydrogen gas.

**FIXED AIR.** Carbonic acid gas.

**FIXITY.** The property by which bodies resist the action of a great heat, so as not to rise in vapour.

**FLUORINE.** The unknown base of fluoric acid. See page 159.

**FLUX.** A substance or mixture added to assist the fusion of minerals.

**FULMINATION.** Synonymous with detonation.

**FUSION.** The act of fusing.

**GALENA.** The native sulphuret of lead.

**GAS.** A permanently elastic fluid or air, as oxygen, hydrogen, &c.

**GELATINE.** Jelly. See page 565.

**GLAUBER'S SALT.** Sulphate of soda.

**GLIADINE.** One of the two principles into which, according to M. Taddey, the gluten of wheat may be divided.

**GLUTEN.** A peculiar proximate principle of vegetables. See page 515.

**GOULARD'S EXTRACT.** Subacetate of lead. See page 528.

**GOUTY CONCRETIONS.** Sometimes called chalk stones. They consist of urate of soda.

**GRANULATION.** The method of dividing metallic substances into grains or small particles.



**GRAVITY.** Weight or density. **SPECIFIC GRAVITY** means the comparative weight of a body. See page 6.

**GREEN VITRIOL.** Sulphate of iron.

**HÆMATITES.** An ore of iron.

**HARTSHORN** (Spirit of). Ammonia.

**HEPAR SULPHURIS.** An old name for alkaline and earthy sulphurets.

**HONEY-STONE.** A variety of bitumen. See page 547.

**HORN SILVER.** Chloride of silver.

**HYDRATES.** Compounds, in definite proportions, of metallic oxides with water.

**HYDROCYANIC ACID.** Prussic acid. See page 242.

**HYDRO-GUINETTED SULPHURET.** Sulphurets, which by acting on water, decompose it, and are thus transmuted.

**HYDROSULPHURETS.** Compounds of sulphuretted hydrogen with the salifiable bases.

**HYDRURETS.** Compounds of hydrogen with metals.

**HYPEROXYMURIATES.** Salts now called *chlorates*.

**IGNIS FATUUS.** A luminous appearance, or flame, frequently seen in the night in different places. It seems to be mostly occasioned by the extrication of phosphuretted hydrogen gas from rotting leaves and other vegetable matters.

**INCINERATION.** The combustion of vegetable or animal substances, for the purpose of obtaining their ashes or fixed residue.

**INTEGRANT.** An integrant part of any substance is one which may be separated by mechanical division.

**KALI.** Potash.

**KAOLIN.** The Chinese name of porcelain clay.

**KELP.** An impure soda obtained by the incineration of sea-weeds.

**KERMES MINERAL.** Hydrosulphuretted oxide of antimony. See page 426.

**LABORATORY.** A place properly fitted up for the performance of chemical operations.

**LAMINÆ.** Fine plates or leaves of any substance.

**LAPIS INFERNALIS.** Caustic potassa.

**LAPIS LAZULI.** Azure-stone.

**LEVIGATION.** Reducing to a fine powder or paste, by means of a stone, called the muller, on a marble slab, &c. Some fluid is always added in this process. The advantage of levigation with a stone and muller, beyond that of triturating in a mortar, is, that the materials can more easily be scraped together, and subjected to the action of the muller, than in the other case to that of the pestle; and, from the flatness of the two surfaces, they cannot elude the pressure.

**LITHIA.** A new alkali.

**LITHIC ACID.** Uric acid. See page 572.

**LIXIVIATION.** The separation, by means of water, of the soluble saline part from the fixed residues of bodies.

**LUNAR CAUSTIC.** Nitrate of silver.

**LUTE.** A substance with which the joinings of vessels are perfectly closed.

**MACERATION.** The steeping of a body in a cold liquor.

**MAGISTERY OF BISMUTH.** White oxide of bismuth.

**MALLEABILITY.** The property of being beaten into thin leaves.



**MASSICOT.** Yellow oxide of lead. See page 441.

**MENSTRUUM.** A solvent.

**MINIUM.** Red oxide of lead.

**MORPHIA.** A new vegetable alkali, extracted from opium, of which it forms the active narcotic principle.

**MOTHER WATER.** When sea-water, or any other solution containing various salts, is evaporated, and the crystals taken out, there always remains a fluid containing deliquescent salts, and the impurities, if any are present. This is called the mother-water.

**MUFFLE.** A small earthen case or oven, made and sold by the crucible manufacturers, to receive the cupel, protecting from the ashes, &c. and yet allowing the heated air to act on the alloy.

**NAPHTHA.** A bituminous liquid, which contains no oxygen.

**NATRON.** Native carbonate of soda.

**NEUTRALIZATION.** When acid and alkaline matter are combined in such proportions that the compound does not change the colour of litmus or violets, they are said to be neutralized.

**NICOTIN.** The active principle of tobacco. See page 544.

**OCHRE.** An ore of iron.

**OIL OF VITRIOL.** Sulphuric acid.

**OLEFIANT GAS.** Carburetted hydrogen gas. See page 238.

**ORPIMENT.** Sulphuret of arsenic.

**OSMAZOME.** A peculiar animal principle existing in muscular fibre, and having the taste and smell of soup.

**OXIDATION.** The process of converting metals and other substances into oxides, by combining with them a certain portion of oxygen. It differs from *acidification* in the addition of oxygen not being sufficient to form an acid with the substance oxidized.

**OXIDE.** A substance combined with oxygen, short of or without being in the state of an acid.

**OXYGENATION.** A word of more general import than oxidation, as every union with oxygen, whatever the product may be, is an oxygenation; but oxidation takes place only when an oxide is formed.

**OXYMEL.** A compound of honey and vinegar.

**PEARL ASH.** An impure potash.

**PHLOGISTON.** The supposed general inflammable principle of Stahl. See page 585.

**PHOSGENE GAS.** Chlorocarbonous acid.

**PICROMEL.** The characteristic principle of bile. See page 580.

**PLUMBAGO.** A carburet of iron. See page 118.

**POTASSIUM.** The metallic base of potassa.

**PRECIPITATE.** The insoluble portion thrown down from any solution, by a test or re-agent.

**PRUSSIC ACID.** Hydrocyanic acid, which see.

**PYRITES.** Native compounds of metal with sulphur.

**PYROMETER.** An instrument for measuring intense degrees of heat.

**QUINA, or QUININA.** A vegetable alkali, extracted from the *yellow* bark.

**RADICAL.** Similar in meaning to the word base, but mostly confined in its application to acids; thus sulphur is the base of sulphuric acid.



**RE-AGENT.** A test or substance by which the quality of the component parts of bodies is ascertained.

**REALGAR.** Native sulphuret of arsenic. See page 442.

**RECEIVER.** A vessel used to collect, receive, and contain the product of distillation.

**RECTIFICATION.** Increasing the strength of spirit, &c. by a second or third distillation.

**REDUCTION.** The revival or restoration of metals to their metallic state, after they have been deprived of this by combustion, or union with some heterogeneous matter.

**REGULUS.** The name formerly given to metallic matters when separated from other substances by fusion.

**RETORT.** A chemical vessel used in many operations. It is a kind of bottle with a capacious elliptical belly, and a long neck, so bent that it makes with the belly of the retort an angle of about 60 degrees.

**SAL AMMONIAC.** Muriate of ammonia.

**SAL CATHARTICUS AMARUS.** Sulphate of magnesia.

**SAL DE DUOBUS.** Sulphate of potassa.

**SAL DIURETICUS.** Acetate of potassa.

**SAL GEM.** Native varieties of soda.

**SAL MARTIS.** Green sulphate of iron.

**SAL MIRABILE.** Sulphate of soda, or Glauber's salt.

**SAL POLYCHREST.** Sulphate of potassa.

**SAL PRUNELLA.** Nitrate of potassa, cast into flat cakes or round balls, after fusion.

**SALIFIABLE BASES.** The alkalies, and those earths and metallic oxides which have the power of neutralizing acidity entirely or in part, and producing salts.

**SALT (AMMONIACAL, FIXED).** Muriate of lime.

**SALT (AMMONIACAL, SECRET).** Sulphate of ammonia.

**SALT (COMMON TABLE).** Muriate of soda. See page 321.

**SALT (FEBRIFUGE) OF SYLVIUS.** Muriate of potassa.

**SALT (FUSIBLE).** Phosphate of ammonia.

**SALT (MICROCOSMIC).** Triple phosphate of soda and ammonia.

**SALT (NITROUS AMMONIACAL).** Nitrate of ammonia.

**SALT OF LEMONS (ESSENTIAL.)** Superoxalate of potassa.

**SALT OF SORREL.** Superoxalate of potassa.

**SALT OF TARTAR.** Subcarbonate of potassa.

**SALT (SPIRIT OF)** Muriatic acid.

**SALTPETRE.** Nitrate of potassa.

**SATURATION.** A fluid which holds in solution as much of any substance as it can dissolve, is said to be saturated with it.

**SILICA.** One of the primitive earths—the base of sands and flints.

**SPECIFIC GRAVITY.** Comparative weight. See page 6.

**SWEET SPIRIT OF NITRE.** The *spiritus etheris nitrici* of the Pharmacopœia.

**STEARINE.** The solid principle of fats. See page 570.

**STRYCHNIA.** The vegetable alkali found in *nux vomica*. See page 545.

**SUBLIMATION.** Volatilization of a substance by heat, and its subsequent condensation in a solid form; thus arsenic, sulphur, &c. are sublimed.

**SUGAR OF LEAD.** Acetate of lead—formerly called superacetate of lead, or *cerussa acetata*.

**SULPHATES.** Definite compounds of sulphuric acid with the salifiable bases.

**SULPHITES.** Definite compounds of sulphurous acid with the salifiable bases.



**SUPERSALT, or BISALT.** A compound of an acid and base, in which the acid is in excess.

**SYNTHESIS.** The re-union or composition of a substance from its constituents, as of muriate of lime by the combination of muriatic acid and lime. It is the reverse of analysis.

**TAN, or TANNIN.** A proximate principle of vegetables. It is their *astringent principle*. See page 516.

**TARTAR EMETIC.** The tartrate of antimony and potassa.

**TELLURETTED HYDROGEN.** A gas formed by the union of the metal tellurium with hydrogen gas.

**TEST.** Same as Re agent.

**THERMOMETER.** An instrument for measuring relative degrees of heat, when not above 212 degrees, or the boiling point of water.

**TINCAL.** Crude borax, as it is imported from the East Indies

**TURBETH MINERAL.** The yellow deutosulphate of mercury.

**TRITURATION.** Rubbing in a mortar, or any similar vessel.

**UREA.** One of the constituents of human urine. It is remarkable for the large proportion of nitrogen it contains. See page 577.

**URIC ACID.** One of the constituents of urine.

**VAPOUR.** See page 4.

**VERDIGRIS.** A crude acetate of copper.

**VERMILION.** The red sulphuret of mercury. See page 432.

**VITAL AIR.** Oxygen gas.

**VITRIFICATION.** The assuming a glassy consistency.

**VITRIOLIC ACID.** Sulphuric acid.

**VOLATILE ALKALI.** Ammonia.

**VOLATILITY.** The property of assuming the gaseous state, or form of vapour.

**WATER OF CRYSTALLIZATION.** See page 458.

**WATER (OXYGENIZED).** Deutoxide of hydrogen.

**WELDING.** See page 411.

**ZERO.** A point in Fahrenheit's thermometer, marked 0, being the beginning of that scale, and 32° below the freezing point of water.

**ZIMOME.** One of the two principal substances into which the gluten of wheat may be divided.

THE END.







