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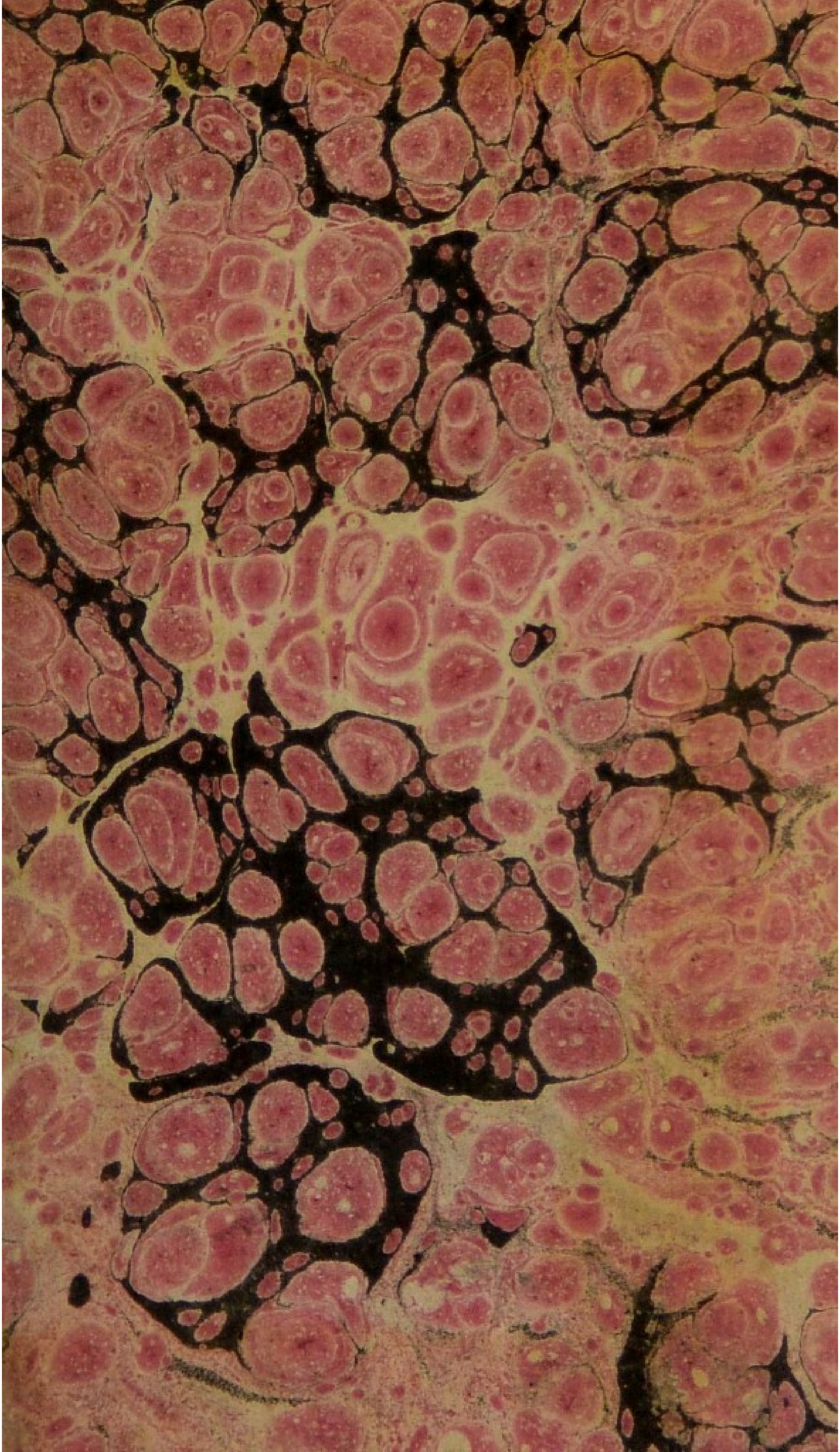

THE
RUDIMENTS
OF
CHEMISTRY.

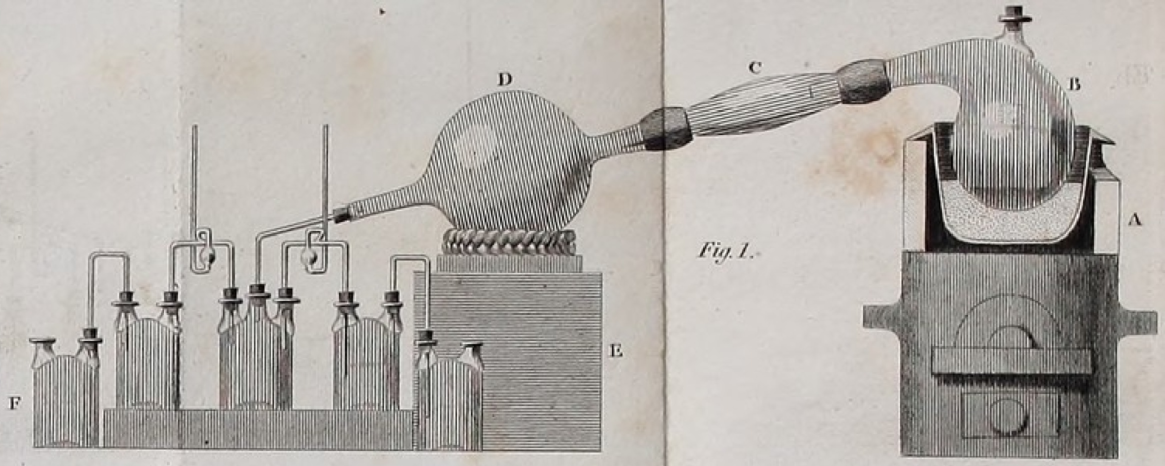

Fig. 1.

Fig. 2.

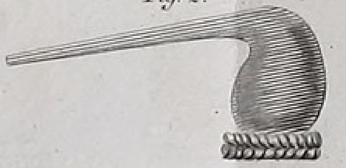

Fig. 3.

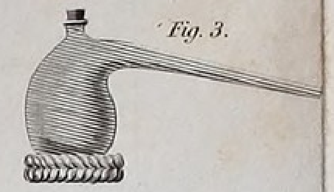

Fig. 4.

Fig. 5.

Fig. 6.

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THE
RUDIMENTS
OF
CHEMISTRY;

ILLUSTRATED BY EXPERIMENTS,
AND
COPPER-PLATE ENGRAVINGS OF
CHEMICAL APPARATUS.

BY
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AUTHOR OF
THE CHEMICAL CATECHISM, THE CHEMICAL ESSAYS,
&c. &c.

THE THIRD EDITION,
*Carefully Corrected, and adapted to the Present State of
Chemical Science.*

LONDON:
PRINTED FOR BALDWIN, CRADOCK, AND JOY.

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PRINTED BY RICHARD TAYLOR,
SHOE-LANE.

PREFACE

TO THE FIRST EDITION.

THE Author of the following pages had often been requested to compose an Elementary Treatise on Chemistry, which, while it possessed the simplicity and perspicuity at which he aimed in composing the "Chemical Catechism," might, by a reduction of its size, be afforded at a much lower price: but a variety of avocations had induced him to decline this proposal, until the applications became too numerous and respectable to be refused. He has however now entered on the proposed task; and, having made the Chemical Catechism the basis, he has taken pains to accommodate that system to the improved state of chemical knowledge; in hopes that this little volume may not only be acceptable to those masters of seminaries, and other friends, at whose particular solicitation it was at first projected, but also have some claim to general patronage.

In pursuing the plan of the Chemical Catechism, this work is also divided into Thirteen Chapters; and it has been the Author's endeavour to draw up the whole in such language as might be easily comprehended by any capacity.

The principal chemical facts are here printed in a larger type, and numbered progressively. These should be considered as axioms to be treasured up in the mind of the student, as a foundation for the superstructure of all his future chemical attainments; they should therefore be read first without any attention to the smaller type; for, as one position frequently arises as it were from others that precede it, the connexion of the whole will be more readily perceived by this method, and the facts remembered with more certainty.

All the illustrations and experiments are given in a smaller letter, which distinguishes these sufficiently from the axioms. They are printed immediately under the respective axioms which they serve to elucidate; and, being thus connected, the rationale of each example will be at once understood by the student. This part of the plan is the most striking feature peculiar to this book, in which it differs essentially from the Chemical Catechism, where the experiments stand unconnected with the work; in order that the student might exercise his ingenuity and memory, to discover the different laws of Nature by which they are governed.

To render the work still more instructive, a very large addition has been made to the number of the experiments, besides a collection of copper-plate engravings, containing some of the more approved and useful chemical implements.

The Author hopes therefore, that, while the Chemical Catechism is better calculated for the more advanced students, this small essay will be found suitable to those who are just entering on the study of this science; and that, where the young people are encouraged by the preceptor to perform the experiments alone, and make themselves thoroughly acquainted with the chemical principles on which they are founded, their progress must ultimately be correct, rapid, and pleasing.

ADVERTISEMENT

TO THE THIRD EDITION.

THE motives which induced me to undertake this little work, and the reasons which determined me to adopt the peculiar plan on which it is arranged, have been so fully explained in the preface, that very little need be added on presenting a new edition to the public. To those who are already in possession of the Rudiments of Chemistry it will be obvious that this is printed on a larger and better paper, and that the new matter which has been added since the publication of the first edition, has enlarged the volume full one-fourth beyond its original size.

In preparing for this impression, the whole work has been carefully examined, and a great part of it re-written, in order to adapt it to the present state of chemical science. The Vocabulary of Chemical Terms has also been enlarged and corrected, and a considerable expense has been incurred in engraving new Plates.

Neatness as well as utility having been thus studied in the publication of this edition, I flatter myself that not only the Tyro, but the more advanced student, may find it a convenient pocket volume, and be induced to use it as a kind of vade-mecum, or *memoranda chemica*, on all occasions.

LONDON,
October 28, 1822.

DIRECTIONS TO THE BINDER.

Plate 1.	To face the Title.	*Plate* 5.	To face page 151.
2.	To face page 19.	6.	To face page 144.
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4.	To face page 358.	8.	To face page 353.

CONTENTS.

DESCRIPTION

OF

THE PLATES.

Plate I.

Fig. 1. Represents an apparatus useful for many kinds of distillation. A the furnace, B a tubulated retort containing the materials to be distilled. D a glass balloon, supported by the stand E, to receive the first products of the distillation. C is an adopter for connecting the retort with the receiver, so as to keep the latter at a sufficient distance from the heated materials. F a series of tubulated glass bottles, connected together by bent tubes, and forming what is usually called a Woulfe's apparatus.

Fig. 2. represents a common glass retort; an instrument much used in chemical laboratories for various purposes.

Fig. 3. is a tubulated retort, that is, an instrument like the latter, with an orifice at the bend and with a ground stopper to fit it. This is the most useful kind of retort, as materials may be put in through the tubulure during an operation.

Figs. 4. 5. and 6. are crucibles of various descriptions. They may be made of metal, of black-lead, or of any refractory argillaceous earth. Those made of baked and raw clay, and of the shape marked fig. 4. are usually called *Hessian* crucibles; fig. 5. is the common shape of the black-lead crucible; and fig. 6. is commonly called a *melting-pot*.

Plate II.

Fig. 7. is a glass-bell to be inverted over water and

filled with oxygen gas, for the combustion of phosphorus, iron wire, &c.

Fig. 8. a bent funnel, with Welter's tube of safety. A glass funnel of this description is extremely convenient, as, on account of the curvature in the stem, any acid or liquid may be affused upon other ingredients, while no vapour or gas is suffered to escape out of the vessel; and this, in many chemical processes, is often essentially requisite.

Fig. 9. is an apparatus for obtaining hydrogen gas, and may be thus described. C an iron barrel passed through the furnace B, so as to be made red-hot. A is a bent funnel for conveying water very gradually into the heated tube. In this way the water becomes decomposed, and the hydrogen, now converted to hydrogen gas, and passing along the tube D, is collected within the glass jar E which stands inverted in a bason of water to receive it.

Fig. 10. represents a glass matrass standing on a common wreath or cushion of straw. This vessel is very useful for making digestions, as from the length of its neck it more readily prevents any loss from an unexpected ebullition of the materials within it. In a great variety of experiments, however, nothing answers better than a common oil-flask.

Fig. 11. A bladder-gas-receiver. This may be furnished either with a metallic tube and stop-cock as here represented, or fixed on a piece of common tobacco-pipe, which, if firmly inserted in the cork of the jar, will often be sufficiently accurate. The bladder should first be moistened, and the common air pressed out previously to the admission of any other gas.

Plate III.

Fig. 12. an apparatus for collecting gas from coal for lighting mines, manufactories, &c., and which may be seen described at some length, with an account of the

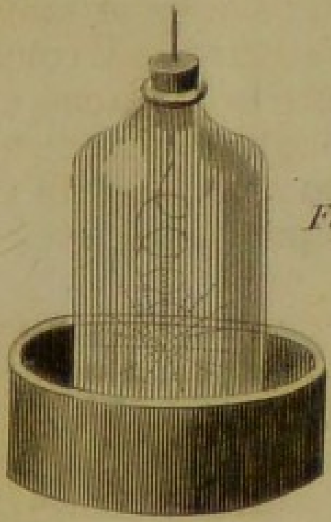
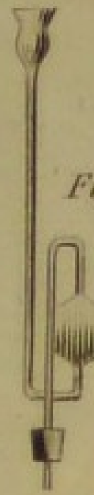


Fig. 7.



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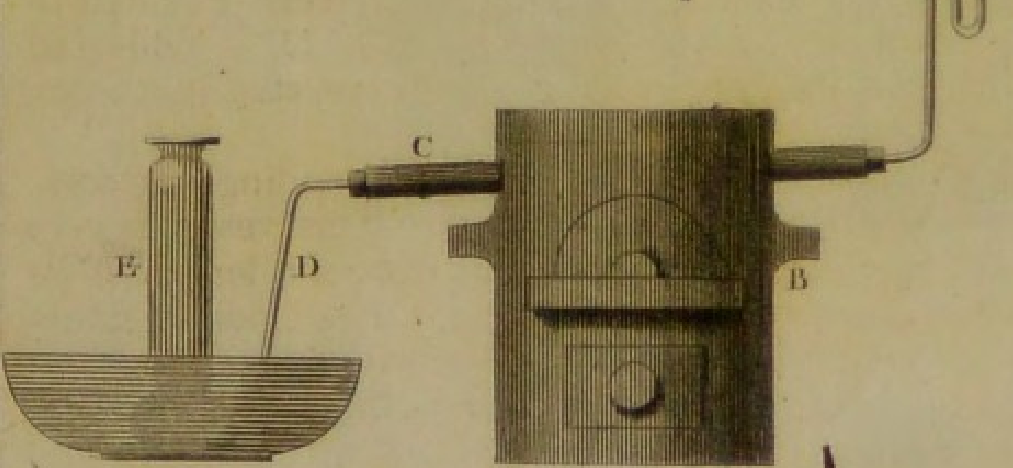
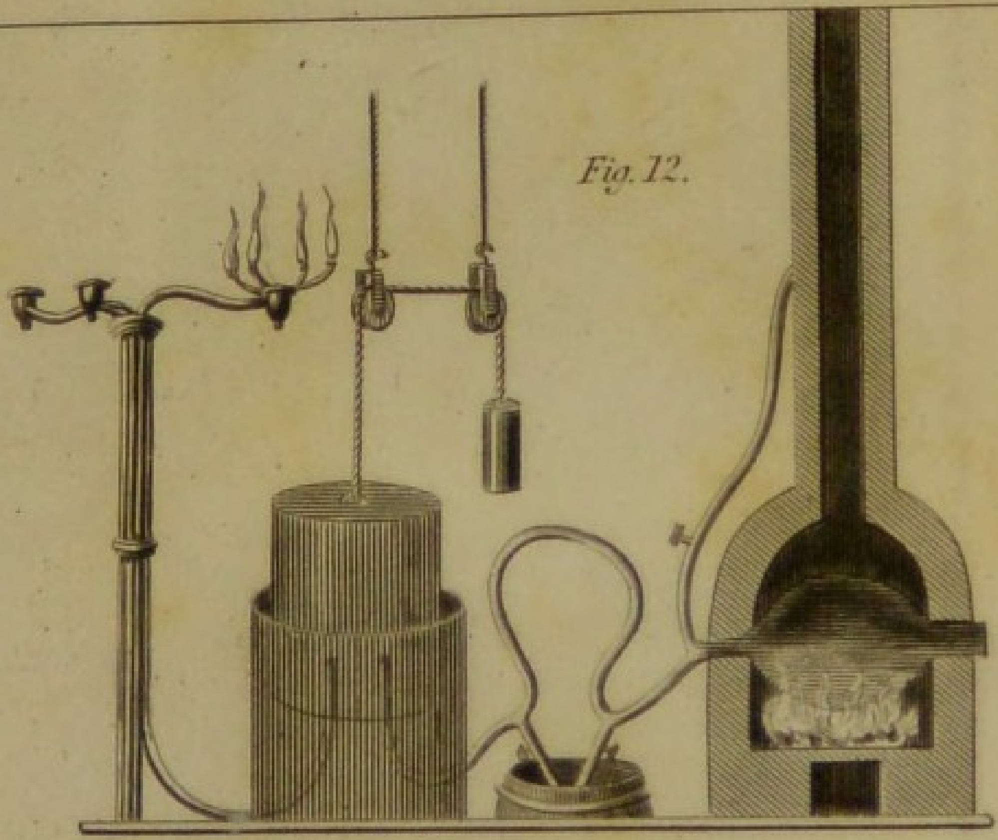


Fig. 9.

Fig. 10.

Fig. 11.



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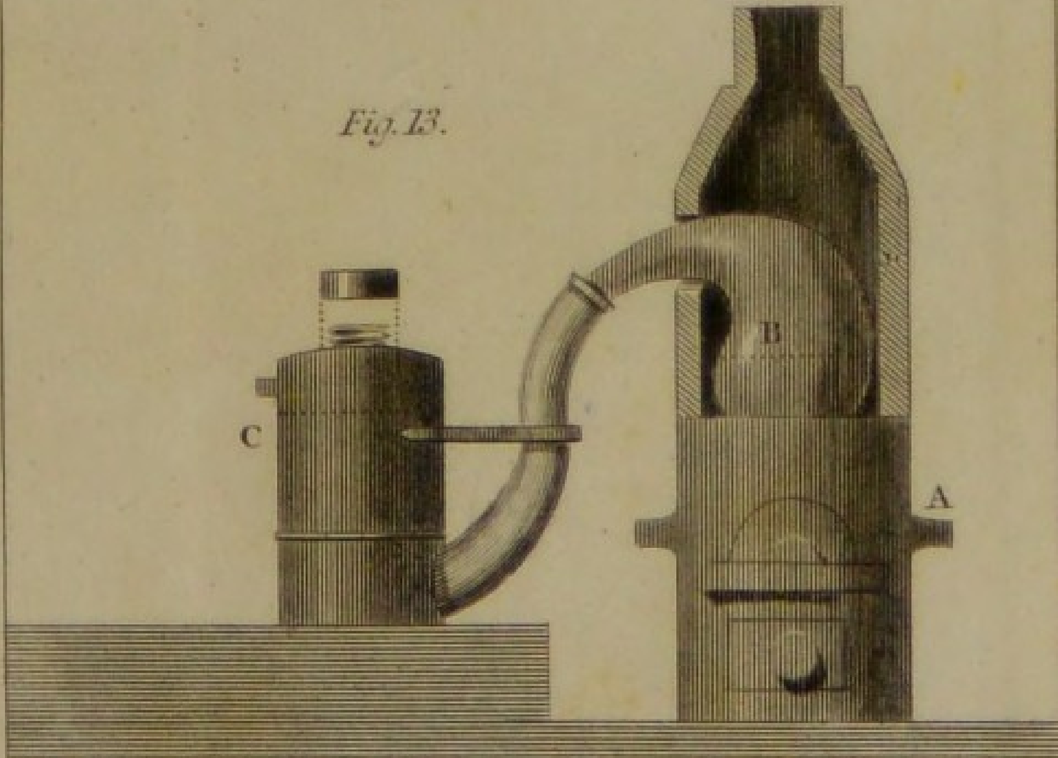
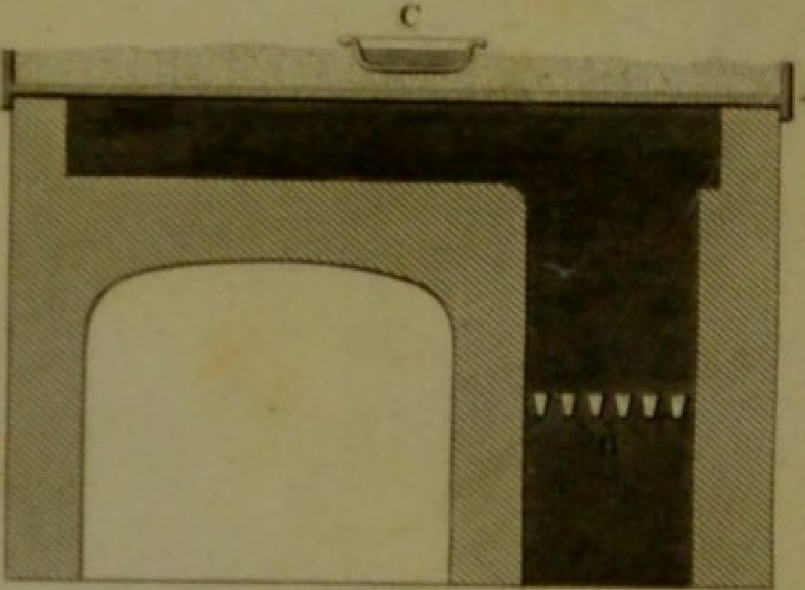


Fig. 13.

Fig. 14.



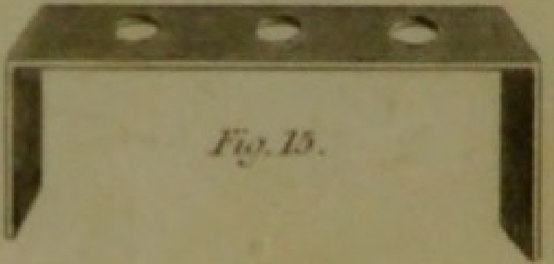


Fig. 15.

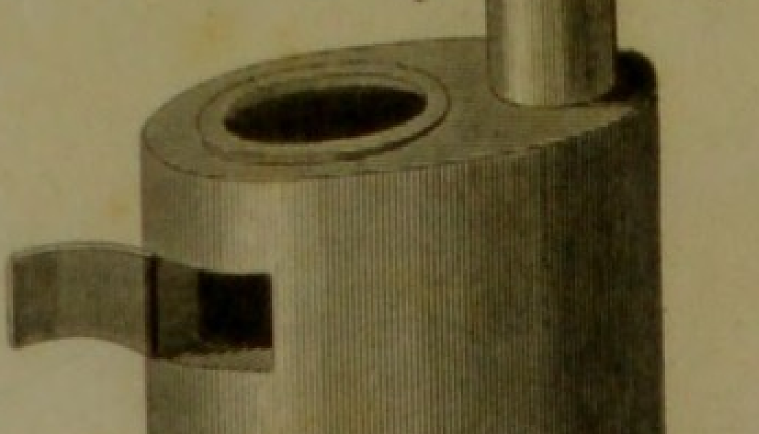
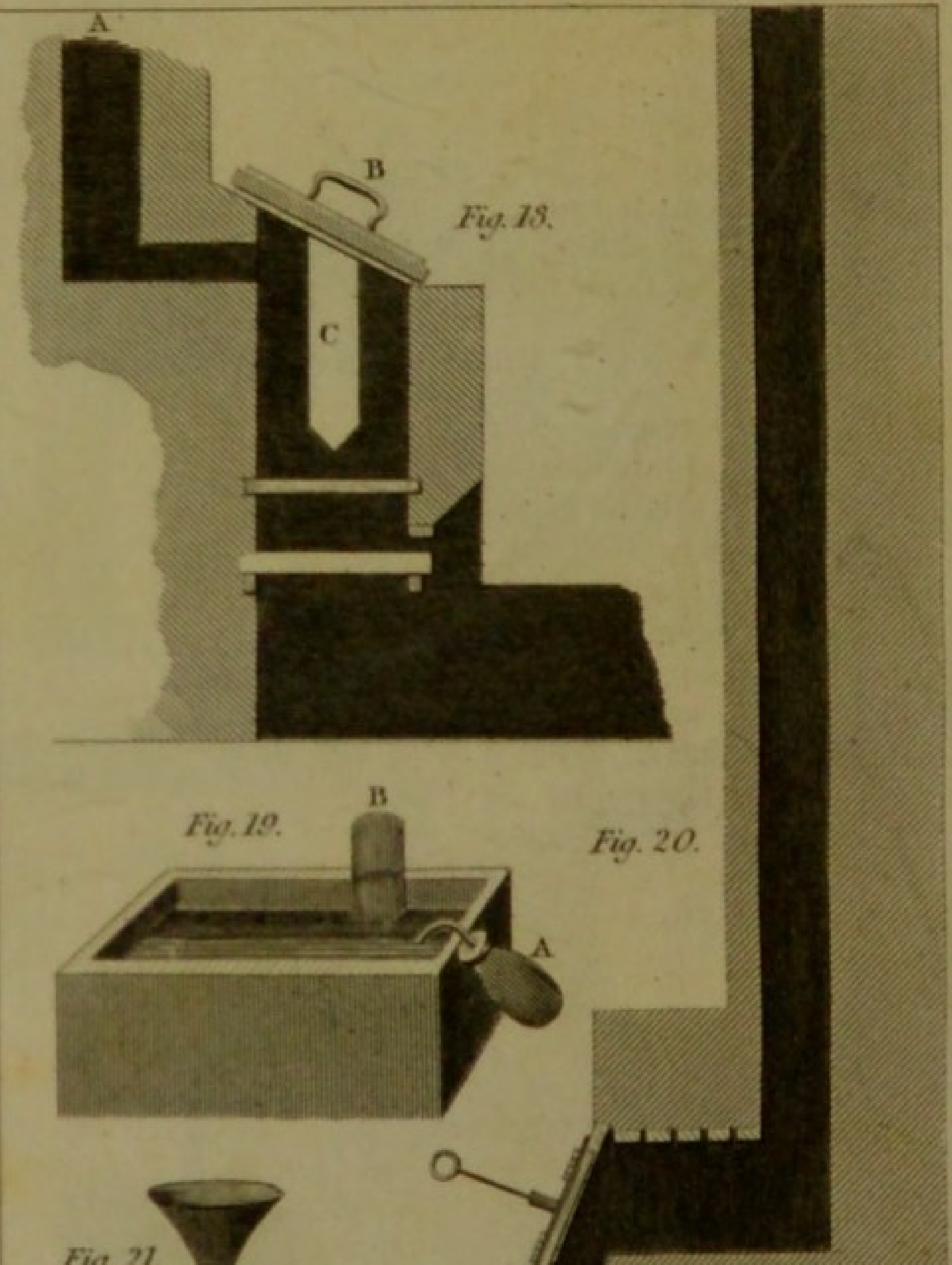


Fig. 16.


A
B
Fig. 18.
C
B
Fig. 19.
Fig. 20.
A
Fig. 21.
Fig. 22.

method of employing the gas, in the 3d edition of the *Chemical Catechism*, page 539.

Fig. 13. an apparatus for the distillation of phosphorus from phosphoric glass. A is a section of the furnace. B an earthen retort, C a vessel with a long neck and partly filled with water, to receive the phosphorus as it comes over from the retort.

Plate IV.

Fig. 14. represents a sand-heat constructed with several flat iron plates rabbeted together and secured by a fire lute. A is an iron rim for holding the bed of sand. B the bars of the fire-place, C a flat vessel of glass or earthenware for containing the liquor to be evaporated, several of which may be arranged on the same bed of sand.

Fig. 15. a small wooden stand for the support of funnels, the feet of which should be high enough to admit of vessels standing underneath to receive the liquors as they pass through.

Fig. 16. Dr. Black's portable furnace, very useful in various operations of chemistry.

Plate V.

Fig. 18. of this plate, and fig. 34 in Plate VII. represent different views of a furnace invented by Mr. Knight. These furnaces, which have some advantages peculiar to themselves, are sold by the inventor, in Foster-lane, Cheapside, and a particular description of them may be seen in Henry's Epitome of Chemistry.

Fig. 19. a pneumatic trough filled, and a jar B placed on the shelf:—this jar, for some purposes, may be close at the top, as represented in the figure, or, if open, the neck should be so contrived as to admit either a glass stopper, or a stop-cock; thus with great ease any gas, collected in this jar, may be readily transferred into another vessel, or into the bladder receiver, fig. 11.

Plate II. The bottle A, which hangs by its bent tube to the side of the trough, is the same as the gas-bottle, fig. 27. Plate VII. designed for the extemporaneous formation of elastic fluids, which, as they are evolved, pass through the tube to the inverted jar on the shelf of the pneumatic trough.

Fig. 20. represents a wind furnace employed by the refiners of gold and silver, for melting the metal in crucibles, after it has undergone the operation of parting.

Fig. 21. a glass funnel made with small channels on its surface to allow of the passage of air from the vessel, while the liquid drops in and supplies its place.

Fig. 22. an utensil of cast iron, called a *plumber's pot*, useful for many purposes, and particularly to form a sand-heat for a single retort.

Plate VI.

Fig. 23. is a representation of another variety of Woulfe's apparatus, being more simple than that described Plate I. fig. 1. A is a small moveable lamp; B the retort to be heated by the lamp A. C a glass receiver standing on a wreath of straw. DD are the connecting tubes to convey the gas from one vessel to another, as the contents of each become saturated; EE are tubulated bottle receivers; and FF tubes of safety which dip into the liquor sufficiently to make the apparatus air-tight, and yet not far enough to prevent the escape of gas whenever there might otherwise be a danger of explosion.

Fig. 24. a hydrostatic balance for ascertaining the specific gravity of solid substances. The solid is here represented as immersed in a jar of distilled water.

Fig. 25. represents a glass jar, inverted over the flame issuing from the combustion of hydrogen gas. In this case the oxygen of the atmosphere combines with the hydrogen, and water is formed, which will evidently appear attached to the inside of the inverted jar.

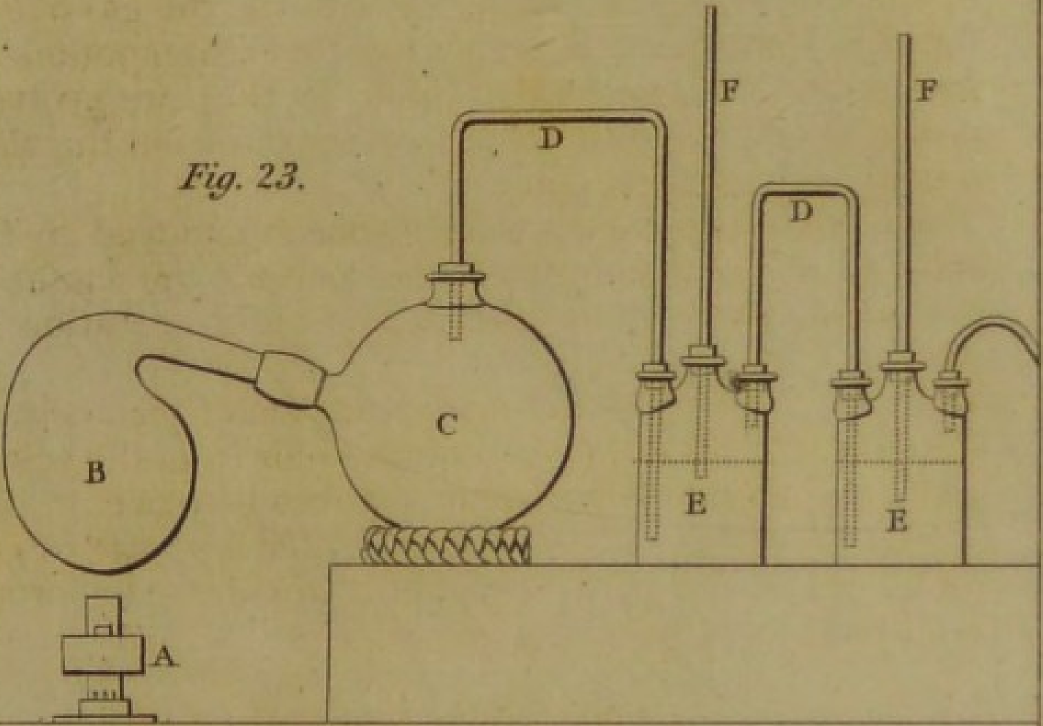


Fig. 23.

Fig. 24.

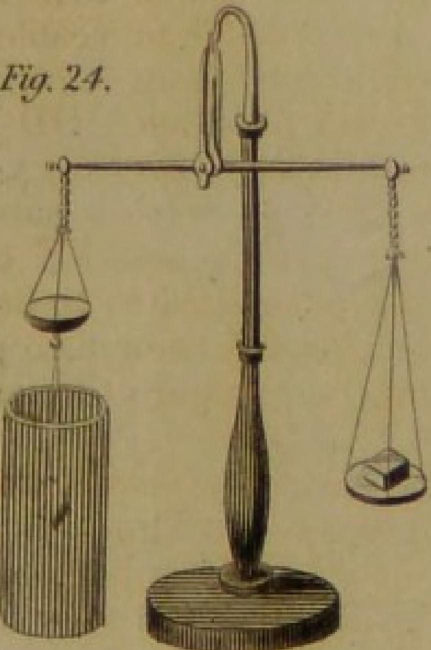


Fig. 25.

Fig. 26.

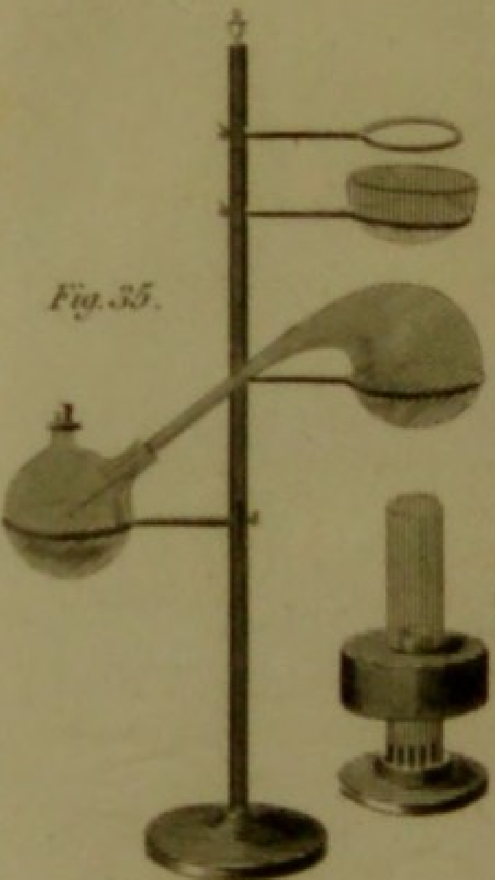


Fig. 35.

Fig. 37.

Fig. 36.

Fig. 38.

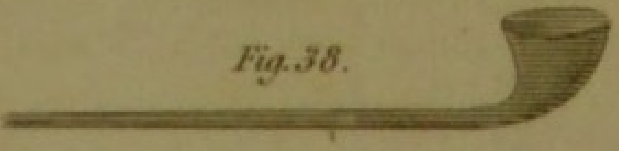
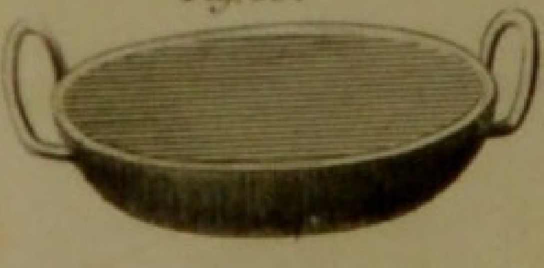


Fig. 39.



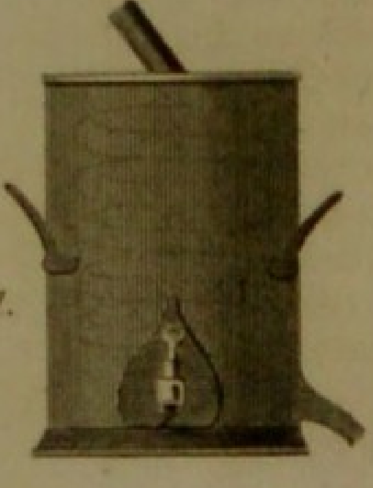


Fig. 41.

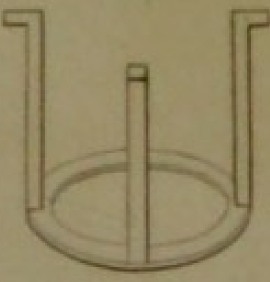


Fig. 40.

Fig. 26. a dish for evaporating small quantities of any fluid. Such utensils are made of glass, earthenware, silver or platinum. For many purposes, however, nothing answers better than a common watch glass.

Plate VII.

Fig. 27. is a gas-bottle the same as that described at fig. 19. Plate V.

Fig. 28. an adopter of earthenware or glass, for connecting a retort with a receiver, as shown in Plate I. fig. 1.

Fig. 29. a gravity-bottle for ascertaining the specific gravity of any kind of fluid, when compared with that of distilled water. By having the neck of the bottle very small, and always filling it to a certain mark on the neck, the specific gravity of any liquid may be found very accurately.

Fig. 30. a glass utensil for dropping liquids regularly. By immersing it in any fluid, and then emptying it of air by the mouth, it will be filled by the pressure of the atmosphere to any height that may be wished; and then by placing the thumb on the larger orifice, the liquor may be preserved within it, and on removing the thumb the liquor issues out in regular drops at pleasure.

Fig. 31. a glass-jar with a tube firmly luted into one of its tubulures, for the purpose of forming the philosophical candle.

Fig. 32. an alembic. The whole of this may be made either of glass, porcelain-clay, silver, or platinum. The head, which is moveable, may be luted on with putty, or any other suitable lute, during an operation. It may be seen that the head is hollowed in such a way, that whatever condenses there and trickles down must collect in the interior current and pass on through the spout into a receiver.

Fig. 33. a pair of tongs for removing crucibles or melting-pots, &c. from the furnace.

Fig. 34. another representation of Mr. Knight's furnace, described fig. 18. Plate V.

Plate VIII.

Fig. 35. a distilling apparatus. The retort and its receiver are placed on the same stand; the receiver has an opening on one side fitted with a glass stopper, and its tubulure is inclined so as to receive the beak of the retort, to which it is to be luted. When things are thus prepared for an operation, an Argand's lamp may be placed beneath the retort to give it the required heat.

Fig. 36. a common blow-pipe.

Fig. 37. a self-acting blow-pipe, the globular part of which contains alcohol, the vapour of which is made to pass through the flame of the lamp by which it is raised into vapour.

Fig. 38. a retort funnel. The use of this instrument is to fill a retort after it is fixed in a sand-heat, or when its beak stands in a horizontal position.

Fig. 39. a copper utensil employed for evaporation or digestion.

Fig. 40. an iron ring for suspending a retort within a furnace, whenever we wish to expose it to the direct action of the fire. This ring is itself supported above the fuel, by means of the three small projections which appear in the drawing.

Fig. 41. is a refrigeratory, or worm-tub for condensing the fluid products of distillation. The outer vessel for containing the cold water may be made of wood, earthenware, or metal, but here it is supposed to be formed of japanned tin. The curved tube or worm which passes through the water, is usually made of fine tin or pewter.

Fig. 28.

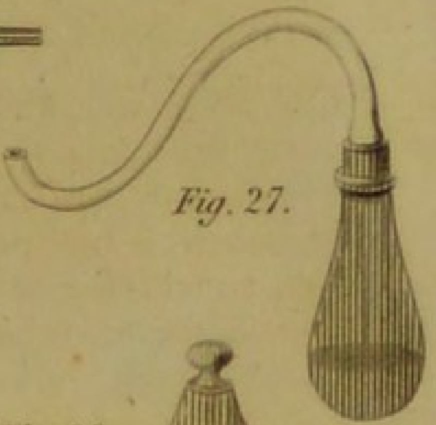


Fig. 27.

Fig. 30.

Fig. 29.

Fig. 32.

Fig. 31.

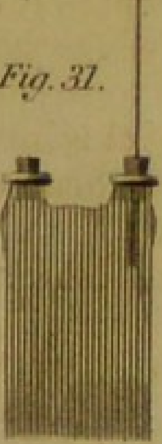
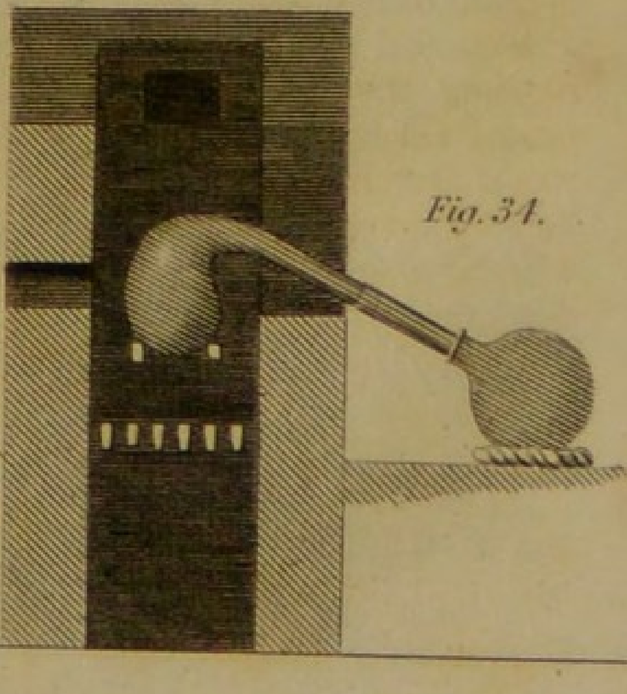


Fig. 33.

Fig. 34.



THE

RUDIMENTS

OF

CHEMISTRY.

CHAPTER I.

INTRODUCTION.

1. CHEMISTRY is the science which enables us to discover the peculiar properties of all natural bodies, either in their simple or compound state.

The following was Dr. Black's definition of chemistry. "Chemistry (said he) is the study of the effects of heat and mixture, with the view of discovering their general and subordinate laws, and of improving the useful arts."

2. The chemical examination of bodies is in general effected by producing a change in the *nature* or *state* of the body under examination.

This change is frequently effected by the addition of some substance which can form a combination with a part of the substance under examination, and leave the other part in a detached state. On this principle reagents, or chemical tests, are employed.

Experiment.—Epsom salt is composed of sulphuric acid and magnesia. If some of this salt be dissolved in water, it will form a transparent solution; but the moment a little of the solution of *caustic* soda is poured in, the sulphuric acid will unite with the soda, and the magnesia will be precipitated in the form of a white powder.

3. A change in the qualities or state of any substance is generally effected by means of *heat*, or by the *mixture* of some other matter with the matter intended to be examined.

Heat has a tendency to separate the particles of all bodies from each other.

Exp. 1.—If water be poured into a solution of camphor in spirit of wine or alcohol, the camphor will be immediately precipitated.

Exp. 2.—When the whole of the camphor has fallen down, pour the fluid into a small retort, and apply a gentle heat. By this means the alcohol may be raised in the form of vapour, condensed in the recipient and thus separated from the water, which will remain in the retort.

4. By these means we effect the *decomposition* of a compound body, and thus acquire a knowledge of the nature of its ingredients.

This is also called analysis, and is distinguished by chemists into the *simple* and the *complicated* analysis.

Exp.—Take a few grains of citric acid, and twice as much dry carbonate of potass, or of soda, both in powder; mix them, and put them into a dry glass. Whilst the mixed powders remain in this state no chemical change will take place in either of these salts; but the moment water is poured upon them, an effervescence will ensue; affording an instance of the necessity of water to promote some chemical decompositions.

5. In chemical language, decomposition means the art of dividing a body into its simple elements.

By various processes water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

6. The matter which constitutes this lower world is usually divided by philosophical writers into four classes; viz. solid, liquid, aëriform, and imponderable.

When cohesive affinity between the particles of a body is strong, that body is a solid; when this affinity is considerably diminished by heat, the body becomes fluid; but when sufficient heat is applied to destroy the cohesion altogether, the particles of the body then begin to repel each other, and thus a vapour or a gas is formed.

7. Solidity is that quality of bodies whereby their parts cohere firmly, so as to resist impression.

8. Liquid substances are those whose parts do not cohere firmly, but readily yield to any impression, and have free motion among themselves. They also assume, when in small masses, the spherical form, as may be observed in detached portions of mercury, and

are incapable, by any common mechanical force, of being compressed into a smaller compass.

We have no reason to suppose that fluidity is an essential property of any liquid substance whatever; but rather that solidity is the natural state of all bodies, for we are able to reduce most substances to a state of fluidity by means of heat.

On the contrary, the greatest number of liquid substances take a *solid* form by reduction of temperature. As in the instance of water, which, when deprived of a certain portion of its heat, congeals and forms ice.

9. All elastic fluids, usually called vapours and gases, belong to the class of aëriform substances.

These aëriform substances are called *elastic*, because they are all capable of being reduced into a smaller compass by pressure, and of expanding again to their usual volume whenever the pressure is removed.

10. The imponderable bodies with which we are acquainted, are only four; viz. light, caloric, electricity, and magnetism. They are also sometimes denominated unconfinable, or ethereal substances.

In this introductory chapter, it has been found most convenient to treat only of the solid and liquid state of bodies; the aëriform and imponderable states of matter will be considered hereafter.

11. It must be recollected that liquid substances are merely solids converted into liquids by heat, a certain increase of which

would convert any liquid into an elastic vapour.

Fluidity is owing to the matter of heat being interposed between the particles of the fluid; which heat would dissipate all fluids into the air, were it not for the pressure of the atmosphere, and the mutual attraction which subsists between those particles.

Exp. 1.—A little bees' wax placed near the fire will show that heat alone is sufficient to render the solid wax a fluid.

Exp. 2.—A little lead melted in the bowl of a tobacco-pipe would furnish a familiar instance of the *metals* becoming fluid by heat.

12. Liquids are likewise called fluids: we call the air a fluid.

13. The air is called a fluid, because it flows like a fluid; because, like a fluid, it presses in every direction; and because light substances will swim in it.

The facility and rapidity of the motions of atmospheric air cannot be explained on any principle but its fluidity. Some of the winds move at the rate of 3000 feet in a minute. The air is also known to be a fluid, by the easy conveyance which it affords to sound.

Exp.—To show that the air presses in every direction, fill a wine-glass with water, and place a moistened card upon it; if the glass be then carefully inverted, the water will not escape, as the pressure of the atmosphere upon the outside of the card will enable it to support the water.

14. It is an established law of nature, that all substances will swim in fluids which are specifically heavier than themselves.

If a cork be placed at the bottom of a bason of water, it will rise immediately to the surface, because it is specifically lighter than the fluid in which it is immersed; whereas a stone, being heavier than water, would sink if placed on its surface.

15. Not that the stone is heavier than the *whole* of the water in the vessel; for, if it be heavier than a portion of water of its own bulk, it must sink.

16. Every substance which *swims* on water, displaces so much of the water as is exactly equal to its own weight; whereas, when a substance *sinks* in water, it displaces water equal to its bulk.

Exp.—Take a piece of hard wood, balance it accurately in a pair of scales with water, and then place it gently on the surface of water in a vessel exactly filled with that fluid, and it will displace a portion of the water, which will flow over the top of the vessel. If the wood be now taken out with care, it will be found that the water in the scale will exactly fill the vacancy left by the wood.

17. The term made use of to express the relative weight of bodies, is *specific gravity.* Thus the specific gravity of one body may be much greater than that of another, though their absolute weights be the same.

The specific gravity of bodies is denoted in chemical writings by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Hence if a substance be five tenths heavier than water, it is denoted thus, 1.500. The specific gravity of all bodies is noted in the same way, throughout this little volume.

18. When one body is larger, or takes up more room, than another of the same weight, the first is said to be *specifically* lighter than the other, and *vice versa.*

In order to ascertain the specific gravity of any solid, it is necessary first to weigh it in common scales in air, and then by means of an hydrostatic balance in water, (see Plate VI. fig. 24.) and calculate from the difference in its weight when weighed in these two media. For more particular directions, see *The Chemical Catechism*, Tenth Edition, page 24, &c.

19. A pint measure of hydrogen gas weighs little more than half a grain, whereas a pint of atmospheric air weighs nearly nine grains, and the same measure of pure water weighs upwards of one pound avoirdupois.

The measure here alluded to is the common *wine* pint. From this one may deduce by calculation, that a cubic foot of atmospheric air weighs nearly one ounce and a quarter, and a cubic foot of water 1000 ounces, avoirdupois.

20. If the specific gravity of water be so much greater than that of atmospheric air, it may be asked, how is water retained in the atmosphere? When bodies change their state, their specific gravity is generally altered.

Water exists in the atmosphere in abundance even in the driest seasons, and under the clearest sky. There are substances which have the power of absorbing water from the air at all times, such as the fixed alkalies and sulphuric acid; the latter of which will soon absorb more than its own weight of water from the air when exposed to it.

21. The water which is taken up by the atmosphere is not in an aqueous state, but is converted into vapour by the matter of heat.

Exp.—By inverting a glass goblet over a cup of hot water, the vapour will be seen to rise into it, to condense upon the cold glass, and then to run down its inside; which will show that steam is *real* water, and will, when the caloric is abstracted, become water again.

Here the pupil may be informed that water not only becomes converted into steam by heat, but that, when it is received into the atmosphere, if the air be warm it becomes so far changed by its union with the matter of heat as to be perfectly invisible. In this state it occupies a space 1400 times greater than its ordinary liquid state.

The vapour arising from boiling water is visible only in consequence of its being partially condensed by a cold atmosphere, as may be demonstrated by causing water to boil in a Florence flask over a lamp; for in this case, the steam within the neck of the flask will be found to be entirely invisible.

22. This principle of evaporation is of very general utility: it is subservient to many natural and artificial processes, and is of perpetual use to man in every occupation of life.

The effects of evaporation are of eminent importance to the practical chemist. By this means fluids are separated from solids and one salt from another in various operations of the laboratory. Sometimes artificial and at others spontaneous evaporation is employed for these purposes.

Whenever fire is used to separate the water from aqueous solutions, it is called *artificial* evaporation; when this is effected by exposing the mixture to the action of the sun and air, it is called *spontaneous* evaporation. In separating common salt from sea water, both these methods are adopted.

A little consideration would convince any one of the importance of this principle of evaporation even in the common affairs of life. Innumerable instances of its use might be adduced: suffice it to say, that without it neither grass nor corn could be sufficiently dried to lay up for use. Our clothes when washed could not be dried; neither could a variety of the most common operations be carried on, which conduce much to our comfort and convenience.

CHAPTER II.

OF ATMOSPHERIC AIR.

23. The air is that very light fluid which surrounds us every where: it is the medium in which we live, and without which we could not exist.

24. This great body of air is called the atmosphere.

25. The obvious properties of atmospheric air are fluidity, elasticity, expansibility, and gravity.

26. If atmospheric air be compressed into

a small compass, it has the property of recovering its former state, as soon as the pressure is removed; which is called its elasticity.

Atmospheric air may be compressed into about the 128th of its usual volume. It is now generally supposed that the air owes its elasticity to *caloric;* and that if it could be entirely deprived of the matter of heat, it would lose its elastic form.

Exp.—If a bladder be tied up with a very small quantity of atmospheric air within it, and put under the receiver of an air pump, it will be seen to inflate gradually as the receiver is exhausted, till it attains its full size; owing to the *elasticity* of the small quantity of air within the bladder, which dilates in this manner, as the atmospheric pressure is removed.

27. The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space than it would at a lower temperature.

It has been calculated, that the air which is disengaged in the firing of gunpowder is rarefied by the heat, so as to occupy a thousand times the space of the whole of the gunpowder employed.

Exp.—If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder, by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

28. The atmosphere is necessary for the support both of animal and vegetable life.

It has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for atmospheric air. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them.

29. The atmospheric air is indispensable in all the common processes of combustion.

Exp.—Light a small taper, place it upon a plate, and having poured a little water upon the plate, invert a glass jar over it. In this situation the taper will burn for some time; but when the air within the jar is consumed, the taper will be extinguished.

30. It gives buoyancy to the clouds, and enables the feathered creation to transport themselves with ease from one part of the earth to another.

This fact affords a fresh instance of the harmonies of nature, and of the suitableness of every creature to the medium in which it was designed to live. The density of the air, neár the surface of the earth, we see is exactly what was requisite for the residence of the feathered race; and the specific gravity of every individual, of every species, is just sufficient to enable it to occupy that element, and to move within it at all times with ease and safety.

31. The atmosphere extends several miles above the surface of the earth.

If the atmosphere were of the same density throughout, its height might be known by its effect in raising a column of mercury in a tube; but as it increases in rarity the higher it ascends, we cannot possibly tell how far it may extend. This, however, has been estimated by the length of our twilight; and it is now supposed to be about 45 miles high.

32. It is this great extension of the atmo-

sphere which occasions its *weight;* and the pressure of such a weight produces many important effects in the economy of nature.

Exp. 1.—Invert a tall glass jar in a dish containing a little water, and place a lighted taper under it as directed No. 29. As the taper consumes the air in the jar, its pressure becomes less on the water immediately under the jar; while, the pressure of the atmosphere on the water *without* the circle of the jar remaining the same, part of the water in the dish will be forced up into the jar, to supply the place of the air which the taper has consumed. Nothing but the pressure we are speaking of could thus cause a part of the water to rise within the jar, above its own level.

Exp. 2.—The reality of atmospheric pressure may be explained and demonstrated by a common barometer, merely by showing how it acts upon that instrument.

"In tubes of glass mercurial columns rise,
Or sink, obedient to the incumbent skies."

33. It is owing to the weight of the atmosphere that we are enabled to raise water from beneath the surface of the earth, by the common pump, and to perform many other useful operations.

The atmosphere presses equally upon the whole surface of the water in the well, until the rod of the pump is moved; but, by forcing the rod down, the bucket compresses the air in the lower part of the pump tree, which being elastic forces its way out of the tree through the valve; so that, when the bucket is again raised, that part of the pump tree under the bucket is void of air; and the *weight of the atmosphere* pressing upon the body of water in the well, forces up a column of water to supply its place; the next stroke of the pump rod causes another column of water to rise: and so long as the bucket fits the pump tree close enough to produce a vacuum, a constant stream of water may be drawn from below.

> "Press'd by the incumbent air, the floods below,
> Through opening valves, in foaming torrents flow,
> Foot after foot in lessen'd impulse move,
> And rising seek the vacancy above."

On the tops of very high mountains, water will boil much sooner than on the plains, where the atmosphere is heavier; at the top of Mont Blanc it has been known to boil at the temperature of 187° of Fahrenheit; and it has been observed that many spirituous liquors, such as ether and spirits of wine, lose the best part of their qualities when exposed at such heights.

34. If we had little or no atmosphere, we should have no water; for the waters on the face of the earth would all evaporate at a very inferior temperature.

Exp.—The quick evaporation which would take place if we had no atmosphere, may be shown by a common instrument, invented by Dr. Franklin, called a pulse glass. It is a small tube with a bulb at each end, exhausted of air, and containing a small quantity of spirits of wine. If this instrument be held sloping, with one end in the palm of the hand, the heat of the hand will quickly cause the spirit to boil; but the vapour rising to the other end becomes condensed as soon as it comes in contact with the cold glass. This simple experiment shows that a very small degree of heat would be sufficient to evaporate most of our fluids, if we had no atmosphere.

35. The weight of the atmosphere, pressing on the water, binds it down as it were,

and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour.

Exp.—That the waters on the face of the earth would be dissipated in vapour by a small degree of heat, if we had no atmosphere, may be shown by the following easy experiment:—Procure a common oil flask, let this be about one third filled with water, and heat it over a lamp. When the water boils, remove the flask, cork it closely so as to exclude the air, and plunge it for a moment into cold water, nearly up to the mouth of the flask. This will not only cool the hot water in some measure, but it will entirely condense the vapour which occupied the upper part of the flask, and occasion so great a vacuum, that the water which had been thus partially cooled, will be seen to recommence its boiling with great violence. This effect can be attributed to nothing but the vacuum which has been formed in the upper part of the flask, and to the cork preserving the water from the pressure of the atmosphere. In like manner, water which has been cooled many degrees below boiling will begin to boil again, if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air.

36. Each square foot of the earth's surface sustains about 2160 pounds of atmospheric air. A column of air an inch square weighs about fifteen pounds.

It has been computed that the weight of the air which presses upon the whole surface of the earth, is equal to that of a globe of lead sixty miles in diameter.

It is necessary to remark that the air presses upwards, downwards, and sideways, in every direction; and that it is owing to this equal pressure that we are not injured by the vast weight of the atmosphere; for the equal pressure on all sides resists as much as it is resisted.

Exp.—Whenever I hold my hand out in this fluid, I feel no weight upon it, because the pressure under and above my hand is equal; but if I lay my hand on a hollow cylinder of glass, placed on the plate of an air pump, and exhaust the cylinder of air, I become immediately conscious of something that presses it so forcibly to the glass, that I cannot endure it. The prop is now gone; I have no pressure under my hand; a column of air 45 miles high forces it down by its weight, and I must let in the air under it before the hand can be withdrawn.

37. This immense atmosphere is composed of oxygen and nitrogen, two different airs, which are intimately mixed in certain definite proportions.

It has been determined that the air of Europe, Asia, Africa, and America, differs very little in the proportion of its ingredients.

Atmospheric air is not a chemical *compound* of nitrogen and oxygen, but a mere *mixture* of those gaseous substances, with a small proportion of carbonic acid gas. The uniformity of this mixture has been accounted for by Mr. Dalton in a very satisfactory manner. This gentleman discovered that the gases act as vacuums to each other; and that if two jars of different kinds of gas are placed one above the other, and the lighter gas be placed uppermost, with a proper connexion between the two vessels, a portion of the lighter gas will soon be found to have descended through the heavier gas, and part of the heaviest gas will also be found to have ascended through the lighter one; and this interchange will continue to go on until an uniform mixture of the whole is produced.

38. Atmospheric air contains also about one part in every thousand of carbonic acid gas, and several adventitious substances.

It has been calculated that the absolute quantity of carbonic acid gas, dispersed throughout the atmosphere, amounts to more than one hundred millions of hundred millions of pounds avoirdupois. For an account of the *uses* of this enormous quantity of carbonic acid gas in the atmosphere, consult Chem. Catechism, Tenth Edit. page 249–254.

Exp.—If an acid be poured upon a pure alkali, no effervescence will be perceived; but take a little of the same kind of alkali and expose it to the air for a few hours, it will then effervesce by the addition of an acid; which shows that it has absorbed carbonic acid from the atmosphere.

39. Besides carbonic acid gas, it holds a portion of water in solution; and sometimes contains hydrogen and carburetted hydrogen gases.

Upon an average, atmospheric air contains about 1 per cent. of water in the state of elastic vapour, and it is remarkable, that whenever aqueous vapour is united to atmospheric air, an augmentation of volume is the consequence, and damp air is always specifically lighter than dry air.

40. When solid substances are rendered permanently aëriform by heat, the air thus produced is called a gas, to distinguish it from those aëriform substances which return

to the solid or fluid state when the heat is abstracted.

All the gases are compounds of solid matter and caloric. It is caloric which separates the particles, and gives to the whole a gaseous form.

The simple gases are elastic, transparent, and permanently aëriform, unless condensed by chemical combinations. Few of them possess any colour.

The permanency of the gases appears to be owing to the strength of the affinity existing between caloric and their bases, which affinity resists every reduction of temperature.

41. By the operation of different agents, the several gases may be separated from each other, and the quantity of each ascertained.

A pneumatic trough is generally employed for collecting gases, and for transferring them from one vessel to another. See Plate V. fig. 19.

42. With respect to the proportions of these gases, there are 21 parts of oxygen gas, and 79 of nitrogen gas, in every 100 measures of atmospheric air, or 23 of the former and 77 of the latter, (fractions omitted,) if the calculation be made by weight.

Exp.—The pupil may be satisfied of the truth of these proportions in various ways;—the following is the easiest: A lighted taper will not burn in nitrogen gas a moment; if immersed in oxygen gas, it burns with a splendour too great for the eye to endure; but if four measures of nitrogen gas and one of oxygen gas are put into a jar inverted over water, and a lighted taper put into such mixture, it will burn exactly the same as it does in atmospheric air.

43. These gases are of different and opposite qualities.

They are of such opposite qualities, that the one is sometimes called *vital air;* while the other, from its causing the death of those who breathe it, has been called *azotic gas.*

44. The oxygen gas in atmospheric air is the principal supporter of combustion, and the vehicle of heat; and is, as was before mentioned, absolutely necessary for the support of animal life.

Exp.—Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.

An account of a melancholy accident which happened to two men in consequence of their being deprived of atmospheric air, may be seen in the Chemical Catechism, Tenth Edition, page 48.

It has been asserted that oxygen is necessary to promote the vigour of plants as well as that of animals.

> "LEAVES, LUNGS, and GILLS, the vital ether breathe
> On earth's green surface, or the waves beneath."

45. Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the most rapid combustion of all combustible substances; so that it is the most energetic and powerful agent that we are acquainted with.

Exp. 1.—It is an interesting experiment to place a glow-worm within a jar of oxygen gas, in a dark room. The insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert. As the luminous appearance depends on the will of the animal, this experiment probably affords an instance of the stimulus which this gas communicates to the animal system.

Exp. 2.—Attach a piece of common sulphur about the size of a small bean, to the end of an iron wire, and set fire to it. It will burn with a slow combustion; but if it be plunged in an ignited state into a jar of oxygen gas, it will then burn with a splendour almost too strong for the eye to endure. The jar made use of should be similar to that employed for burning iron wire. See Plate II. fig. 7.

46. Oxygen gas is a little heavier than atmospheric air, and about 750 times lighter than water.

At the temperature of 60° when the barometer stood at 30° it was determined by Messrs. Allen and Pepys that 100 cubical inches of oxygen gas weigh 33.82 grains. Sir Humphry Davy states it at 34 grains.

Oxygen gas is plentifully procured from nitre, or from the black oxide of manganese.

47. Nitrogen gas, or azote, is chiefly distinguished by certain *negative* qualities, such as its being incapable of supporting combustion and animal life. It is uninflammable, and somewhat lighter than atmospheric air.

Nitrogen forms a part of all animal substances. It is also the base of ammonia, and of the nitric acid. It appears to be favourable to plants, as they grow and vegetate freely in this gas.

Exp.—Take a few iron filings, mix them with a little sulphur, and moisten the mass with water. Put this mixture into a large glass jar, and cork it close. In a few days the oxygen will be absorbed by the mixture from the air which was previously in the glass, and the residuum will be found to be nitrogen gas. It may be procured also by digesting pieces of flesh or the muscular fibre in very dilute nitric acid.

48. Nitrogen gas has the effect of neutralizing, in some measure, the properties of oxygen gas, and rendering it fit for respiration and combustion.

Though nitrogen gas is, by itself, so noxious to animals, it answers an important end when mixed with oxygen gas in atmospheric air. Were it not for this large quantity of nitrogen in the atmosphere, the blood would flow with too great rapidity through the vessels; the consequence of which would be, that the life of man would not be protracted to the length that it now is.

"From Nature's chain whatever link you strike,
Tenth, or ten thousandth, breaks the chain alike."

49. The atmospheric air which is produced by this mixture, supports animal life by giving out its oxygen and caloric to the blood.

The blood in the veins is purple, approaching to black; but when it arrives at the lungs, having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries; the source of animal heat; and the cause of sensibility, irritability, and motion.

Black venous blood, exposed to the air, becomes red on its surface; and air, remaining confined over venous blood, loses its oxygen, so that what remains is found to be unfit for combustion. These facts prove that the vermilion colour of the blood is owing to the inhalation of oxygen gas.

"The internal surface of the lungs, or air vessels, in man, is said to be equal to the external surface of the whole body; it is on this *extended* surface that the blood is exposed, through the medium of a thin pellicle, to the influence of the respired air."

50. Caloric is the name which modern chemists have given to fire, or the matter of heat; a large portion of which is intimately combined with atmospheric air.

This name was given by the framers of the new nomenclature to the matter of heat, which they always distinguish from the effect. Caloric is applied to fire, or the substance which produces the sensation we call heat, but never to the sensation itself, or the effect produced by fire. In this case it is said that caloric raises the temperature of bodies, or, on the contrary, that the temperature is lowered by the loss of caloric.

51. Animal heat is preserved chiefly by the inspiration of atmospheric air. The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body.

A man generally consumes 32 ounces troy of oxygen gas in 24 hours; that is, the lungs separate this quantity of oxygen gas from the air which he respires in that time.

Nature has provided for those animals which do not breathe, such as fishes and insects, by giving them a bodily temperature but little superior to the medium in which they live. The temperature of other animals is in proportion to the quantity of air which they breathe in a given time.

52. As the temperature of the atmosphere in this climate is always inferior to the animal temperature, clothes are necessary to prevent the sudden escape of that heat from the surface of the body which the lungs have separated from the atmosphere.

Clothes keep the body warm in consequence of the air which they infold within them; all confined bodies of atmospheric air being non-conductors of heat. It is on this principle that double windows preserve the warmth of apartments at an equable temperature, and that light spongy substances, such as furs and down, afford the warmest clothing.

53. With regard to the nitrogen that is combined with atmospheric air, the greatest part of that is thrown out of the lungs at every respiration; and being somewhat lighter than atmospheric air, it rises into the atmosphere to await fresh combinations.

It may be remarked, that the interval which there is between every inspiration seems to have been designed, to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed. How provident has the Almighty been, in thus foreseeing the operation of those laws which were designed to promote the welfare of every species of animated beings!

54. The loss of that vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere, would soon render the air unfit for those purposes, if nature had not made provision for its restoration.

Exp.—Take a bladder with a stop-cock similar to that described in Plate II. fig. 2, and folding the lips carefully round the end of the pipe, begin to draw the air out of the bladder into the lungs, and immediately return it into the bladder by respiration. Thus continue to breathe the same air for some minutes, and then close the stop-cock. If the air be now removed from the bladder into a pneumátic glass jar, and a lighted taper immersed within it, it will at once be seen that the process of respiration has rendered the air unfit for supporting combustion.

55. The leaves of trees and other vegetables give out during the day a large portion of oxygen gas, which uniting with the nitrogen thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere.

The *upper* side of the leaf is the organ of respiration; hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night.

Exp.—To show the production of oxygen gas from the leaves of plants, fill a glass bell with water, introduce leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. In like manner a sprig of mint, corked up with a small portion of carbonic acid air and placed in the light, renders it again capable of supporting life. The plant purifies what the animal had poisoned.

CHAPTER III.

OF CALORIC.

56. HEAT is the well-known sensation which we perceive on touching any substance whose temperature is superior to that of the human body.

The sensation of heat and cold arises from the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body, and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

57. Chemists have agreed to call the matter of heat *caloric*, in order to distinguish it from the sensation which this matter produces.

In order to give precision to chemical language, it was necessary to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes fixed in a body, it loses its property of affording heat.

58. Caloric is every where indispensable to the existence of man. "It is with fire that, in every country, he prepares his food, that he dissolves metals, vitrifies rocks, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require."

59. There are six sources from whence we procure caloric; viz. from the sun's rays, by combustion, by percussion, by friction, by the mixture of different substances, and by means of electricity and galvanism.

60. The sun is the chief fountain which furnishes the earth with a regular supply, and renders it capable of supporting the animal and vegetable creations.

Caloric, it is said, comes to us from the sun at the rate of 200,000 miles in a second of time; but Dr. Herschel has proved, that the solar rays which occasion heat, are distinct from those which illuminate and produce vision.

It is now a prevailing opinion, that the sun is not the original source of heat, but that the earth, and each planet belonging to this system, is furnished with the necessary portion of caloric, and that the rays of the sun impinging upon the earth and the other planetary bodies, elicit the native caloric which is inherent in them, and occasion what is called heat.

Exp.—That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If in the midst of winter a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere.

61. The second source we have mentioned is combustion: in this process the oxygen gas of the atmosphere is decomposed, and caloric, one of its component parts, is set at liberty.

For a more particular account of this curious natural phænomenon, see the whole of Chapter XII.

62. The heat produced by percussion is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric.

As evaporation produces cold, condensation always occasions heat: that is, caloric is always evolved from those bodies which have undergone any degree of condensation. In one case caloric is absorbed, in the other it is set at liberty.

By the collision of flint and steel so much caloric is disengaged, that the metallic particles which are struck off are actually melted thereby. This is evident, from their being always found in a spherical form.

Exp. 1.—Mix three grains of sulphur with nine grains of dry nitrate of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a *cold* hammer, the sulphur will inflame, but no detonation will ensue. This is an instance of a metallic salt being decomposed and a combustible substance inflamed by percussion.

Exp. 2.—If the experiment be repeated, and the mass be struck with a *hot* hammer, the mixture detonates, and the silver is reduced.

63. It is not known how friction produces caloric, unless we suppose it to be a succession of percussions.

The original inhabitants of the New World, throughout the whole extent from Patagonia to Greenland, procured fire by rubbing pieces of hard wood against other very dry pieces, till they emitted sparks, or kindled into a flame. Some of the people to the north of California had the method of inserting a kind of pivot in the hole of a very thick plank, and by its circular motion produced the same effect.

Instances have occurred, where whole forests have been burnt down, by fires kindled from the violent friction of the branches against each other by the wind.

Exp.—Having a common phosphorus box, take out a small portion of its contents on the point of a brimstone match, and rub it briskly on the cork. In this case a sufficient quantity of caloric will be evolved by friction to occasion the phosphorus to burst into flame.

64. By the discharge of an electrical battery, or by the galvanic apparatus, a more intense degree of heat may be obtained than by any other means whatever.

By means of an electrical battery metals may be suddenly fused, and gases united, which we are unable to combine by any other mode.

Exp. 1.—If fine metallic wire be made part of a powerful galvanic circle, it will be melted in an instant, and give out the most beautiful coruscations of light, of various colours, according to the nature of the metal employed.

Exp. 2.—Submit a little gold or silver leaf to the action of a galvanic battery: either of which will burn with great splendour, and afford a beautiful spectacle.

Exp. 8.—If a piece of charcoal, from hard wood, be inflamed by galvanism, the light produced seems to vie with that of the sun, being too intense for the eye to endure.

65. When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form; for neither water nor any other fluid can acquire an increase of density without giving out a portion of its latent caloric.

Whenever two gases or liquids unite *chemically*, the compound has greater density than the mean density. Thus the vapour of water, at the heat of ebullition, occupies much less space than the hydrogen gas and oxygen gas, which compose it, would have occupied at the same temperature.

Exp. 1.—Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong sensation of heat will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water.

Exp. 2.—Put a little fresh calcined magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sulphuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be completely ignited.

66. Mixture does not uniformly produce heat. The mixture of some substances produces an intense cold.

Whenever substances become more condensed by mixture, heat is evolved; when they expand, cold is produced; or, in other words, the compound has a greater or less capacity for caloric than the separate ingredients. The mixture of crystallized muriate of lime and snow produces the greatest degree of cold yet known.

Exp.—Take a small phial containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a sensation of cold will be immediately felt.

67. Caloric is uniform in its nature; but there exist in all bodies two portions of caloric, very distinct from each other.

How the same substance may exist in a body in two distinct states, may easily be explained by the familiar example of a piece of common bread which has been dipped in water. This bread will contain two portions of water very distinct; one of them is in a state of combination, and forms a constituent part of the bread; the other is only interposed between the particles of the bread, and may again be forced out by pressure.

68. The one is called *sensible* heat, or free caloric; the other *latent* heat, or combined caloric.

Exp. 1.—Wrought iron, though quite cold, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of this species of caloric, which by the percussion of hammering is now evolved and forced out as *sensible* heat.

Exp. 2.—If a little sulphuric acid be mixed with about an ounce of the strongest nitrous acid, and the mixture be poured into oil of turpentine, the whole will burst into flame. This is owing to the compound having less capacity for caloric than these separate fluids.

The phial containing the mixed acids should be fixed to a rod, and its contents poured at armslength and as quickly as possible upon the oil in a cup. The cup containing the oil of turpentine should be placed in the open air, or under a large chimney, to prevent any accident from the sudden combustion.

69. *Sensible* caloric is the matter of heat disengaged from other bodies, or, if united, not *chemically* united with them.

Some writers have called the matter of heat when in this state *interposed* caloric.

70. *Latent* caloric is that portion of the matter of heat which makes no *sensible* addition to the temperature of the bodies in which it exists.

Caloric, as it penetrates bodies, frequently forms a chemical combination with them, and becomes essential to their composition. This is always the case when a solid is converted to a liquid, or when a liquid passes to a gaseous state. But if caloric be superadded to a body when it is in a state of saturation, it merely traverses its surface, and passes from it, in the form of sensible heat, to some of the adjacent bodies.

Exp.—If a pan of snow be hung over a large fire, the snow will receive a great accession of caloric from the fire without being at all sensibly warmer. The caloric, as it enters the snow, becomes chemically combined with it, and the fire will not in the least alter its temperature, till the whole becomes fluid.

71. Caloric in a latent state exists in all substances that we are acquainted with.

Caloric pervades all bodies; this is not the case with any other substance we know of—not even light.

Whenever caloric quits its latent state, how long soever it may have lain dormant and inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

72. Caloric combines with different substances in very different proportions; and for this reason one body is said to have a greater *capacity* for caloric than another.

Exp.—The propriety of this term may be shown to a pupil by dipping a lock of wool and a piece of sponge in water, and directing him to observe how much more water the sponge is capable of taking up than the wool. Hence sponge may be said to have a greater *capacity* for water than wool has.

73. The same bodies have at all times the same capacity for caloric, unless some change takes place in the state of those bodies.

Whenever a body changes its state, it either combines with, or separates from, caloric.

74. When gaseous substances become liquid, or liquid substances become solid, they lose in a great measure their capacity for caloric.

The caloric which is evolved during the slaking of quicklime, escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. The same effect is produced in making butter. When the cream changes from a fluid to a solid, a considerable degree of heat is produced.

Exp. 1.—If when the air is at 22° we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole rises to the freezing point; so that the water has acquired 10° of caloric in an instant.

Exp. 2.—If a small thermometer be placed in a glass vessel containing about an ounce of a solution of soda; on adding a sufficient quantity of muriatic acid to saturate the soda, the mercury in the thermometer will expand; affording an instance of heat being produced by the formation of a salt.

Exp. 3.—Let the last experiment be repeated with *carbonate* of soda, instead of pure soda; the mercury will now sink in the thermometer. Here, though the same kind of salt is formed, *cold* is produced. This must be attributed to the *evaporation* of the carbonic acid.

Exp. 4.—Charge a small glass retort with strong muriatic acid, and insert its beak into a tubulated receiver containing a little water; then into this receiver insert two small thermometers, the one immersed in the water, the other suspended above it. By applying the heat of a lamp to the retort, muriatic acid gas will be disengaged in abundance; and if the thermometers be examined, that which is suspended in the gas will be found to have risen only a few degrees, while that which was immersed in the cold water has acquired a boiling heat.

75. When solid bodies become liquid or gaseous, their capacity for caloric is proportionately increased.

By the solution of some salts water may be deprived of so large a portion of its caloric as to be frozen in the midst of summer.

Exp. 1.—Dissolve five drachms of muriate of ammonia and five drachms of nitre, both finely powdered, in two ounces of water. A thermometer immersed in the solution will show that the temperature is reduced below 32°. If a thermometer tube, filled with water, be now suspended within it, the water will soon be effectually frozen.

Exp. 2.—Dip the bulb of a thermometer in melted rosin so as to coat the glass with it, and suffer it to cool completely. If the flame of a taper be now applied to the bulb so as to melt the rosin, the mercury in the thermometer will not rise at the approach of the taper, but will actually be seen to contract as the rosin becomes liquid.

76. Whenever a body has its capacity for caloric thus increased, it requires a larger portion of the matter of heat to raise it to a given temperature, than another body does which has a less capacity for caloric.

If equal weights of water and mercury, cooled down to the same point, be afterwards separately heated to the heat of boiling water, the water will be found to have required more than three times the quantity of caloric that the mercury did to bring it to that temperature.

The difference in the capacity which different bodies have for caloric, is owing to one substance having a chemical affinity for caloric superior to that of another. See this fully explained by Dr. Henry in the fifth volume of the *Manchester Memoirs*.

Exp.—This property may be shown more readily by the following experiments.—Take 1 lb. of water at 100°, and mix it with 1 lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1 lb. of mercury, at 100°, and 1 lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury has not therefore so great a *capacity* for caloric as water.

77. The portion of caloric necessary to raise a body to any given temperature is called the *specific* caloric of that body.

This term is always used in a *comparative* sense, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be 1, that of water may be said to be 3, as noted in an experiment just related.

78. An instrument called a *calorimeter* is used for ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for caloric.

The substances to be tried are heated to the same temperature, and then placed in this machine surrounded with ice. By observing how much ice each of them melts in cooling down to a given point, the specific caloric which each of them contained is determined.

Ice has the property of absorbing all the caloric with which it comes in contact, and communicates no part of it to the surrounding bodies till the whole of the ice is melted; therefore the specific caloric of bodies may easily be calculated by its means.

79. The instrument which is in common use to measure the temperature of bodies is called a thermometer.

80. The thermometer consists of a glass

tube containing a portion of mercury, with a graduated plate annexed to it. The glass is usually sealed hermetically, to preserve the metal and the inside of the tube from the action of dust or moisture.

Thermometers are made by putting mercury into small glass tubes with bulbs, and heating these bulbs till the mercury boils. This ebullition forces out the air, and the tubes are hermetically sealed while the mercury is boiling. They are afterwards graduated by a correct scale.

81. When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and the height at which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied.

Though mercury has a capacity for caloric inferior to that of many liquids, it has such an attraction for it that it absorbs sufficient to keep it in a fluid state in the common heat of our atmosphere. Owing to this affinity, it expands very readily by every addition of the matter of heat. It is also equally affected by equal increments of heat at every temperature between its freezing and boiling points; which is not the case with some other fluids, such as water, ardent spirit, &c.: hence it is the most proper substance for thermometers.

To measure the degrees of heat in high temperatures, Mr. Wedgwood contrived a very useful instrument, which he called a pyrometer, including a range of nearly 32,000 degrees of Fahrenheit.

82. The thermometer will not show the absolute caloric in all substances; for it cannot measure that portion which is latent, or chemically combined with any body.

Every substance requires its own quantity of caloric to raise it to a given temperature; but when raised to that temperature, every *further* addition of caloric is precisely shown by the thermometer.

83. Thus fluids require a certain portion of caloric to keep them in a state of fluidity; which portion is not indicated by the thermometer.

Exp. 1.—If a quantity of snow be placed in a bason before a fire, and a thermometer be plunged in it, the thermometer will stand at 32°; if the thermometer be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the same temperature, though it has all along been receiving an accession of caloric; but the moment that the *whole* of the snow is melted, the thermometer will begin to rise.

Exp. 2.—If a piece of ice cooled 20° below the freezing point be exposed to a fire with a thermometer stuck in it; the thermometer will rise very uniformly until it comes to the freezing point 32°, and there make a full stop till the ice is all liquefied, as though the fire had lost its faculty of heating: but the instant that all the ice is melted the thermometer will begin to rise again, and will continue to rise gradually till the water becomes heated to 212°, the boiling point.

84. Notwithstanding this, all fluids operate upon the thermometer in the same manner as solids; for, whatever sensible caloric be con-

tained in any liquid, that portion may be measured by the thermometer.

Exp.—If we plunge a thermometer ever so often into boiling water, it will always stand at the same point, provided the pressure of the atmosphere be the same. Melting snow will always show the same degree upon the thermometer, in whatever state the atmosphere may be.

85. That portion of caloric which is a necessary part of fluids, is called the caloric of fluidity; but different fluids require different portions of it to preserve them in the state of fluids.

The caloric of fluidity of water is 140°. That is, water reduced to 32° must lose 140 degrees more of caloric before it becomes ice, and still its temperature will be 32°.

Exp. 1.—If four parts of sulphuric acid and one part of ice, both at the temperature of 32°, be mixed together, the ice melts instantly, and the temperature of the mixture rises to 212°, the heat of boiling water. But if four parts of ice and one of the same kind of acid at 32° be mixed, the temperature sinks to about —4°. In the first of these experiments, as the ice and acid combine, they become more dense than their *mean* density; consequently they both give out a part of their caloric of fluidity, and retain only the caloric of fluidity which is necessary for the new compound. In the other case, the ice, assuming a liquid form, requires a large dose of caloric to give it fluidity; and the sudden fall of the thermometer is owing to the suddenness with which the ice absorbs the caloric from the acid, and which it requires before it can become liquid.

Exp. 2.—Take an amalgam of lead and mercury, and another amalgam of bismuth, let these two solid amalgams be mixed in a mortar by triture, and they will instantly become fluid.

86. The *general* effects of caloric are to increase the bulk of the substances with which it unites, and to render them specifically lighter than they were before; but in whatever quantity it is accumulated in bodies, it never adds to their absolute weight.

Some bodies are much more dilatable by heat than others; thus iron is more dilatable than wood, and wood is more dilatable than a stone. Of the metals, platinum dilates the least, and lead and zinc the most, by increase of temperature.

Exp. 1.—In order to be convinced that solids increase in bulk by combination with caloric, procure a piece of iron wire, of anexact length to slip lengthways within a ring, or within some metallic box; then if the wire be heated, it will be found increased in length so as not to pass through the ring or box.

Exp. 2.—Fill a Florence flask with water to about the middle of the neck, mark the place to which it rises, and then immerse it in boiling water; when it will be seen to expand in the glass till it nearly runs over the neck of the flask.

87. Caloric favours the solution of salts, and promotes the union of many substances.

Exp.—If two ounces of sulphate of soda (Glauber's salt), in powder, be put into a tea cup holding two ounces of cold water, the water will dissolve only a portion of it; but if a boiling heat be applied, the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot again into crystals. This little experiment will also have its use as an example of crystallization.

88. In other cases it serves to separate bodies already united; so that in the hands of chemists it is the most useful and powerful agent we are acquainted with.

This is the case in distillation, whereby the most subtile parts of a compound body are dissolved by caloric, and separated from the mass in the state of gas or vapour. Every kind of distillation may be performed in a common retort, (see Plate I. fig. 2. and fig. 3.) with common receivers attached to it, similar to the apparatus, fig. 23, Plate VI. For strong heats, Wedgwood's retorts are preferable to glass.

Caloric promotes also the decomposition of bodies, by reason of its counteracting the attraction of cohesion which exists in all bodies. For a more particular explanation of the effects of caloric in chemical processes, consult the article *Repulsion* in Chapter XIII.

Exp. 1.—Ice and soda have no more action on each other than soda and silica; but raise the temperature of the ice, and it unites to the soda.

Exp. 2.—Potash and silica if mixed have no action whatever on each other; but if submitted to a great heat, the potash melts, and attracts the silica, which melts with it into a substance that may be dissolved in water; or, if the silica be in proper proportion, the compound will be glass.

89. It is the cause of fluidity in all substances which are capable of becoming fluid, from the heaviest metal to the lightest gas.

Let it be remembered that *all* fluids are formed from solids by an addition of caloric; and that, by abstracting this caloric, solids would be reproduced.

90. It insinuates itself among their particles, and invariably separates them in some measure from each other. Thus ice is converted into water, and by a further portion of caloric into steam.

Though the temperature of steam be no more than that of boiling water, or 212°, yet it has been demonstrated by some very ingenious experiments of Mr. Watt, that it contains nearly 1000° more caloric; and that this keeps it in the form of steam.

Exp. 1.—The expansion of volatile bodies by heat may be shown by the following experiment:—Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

Exp. 2.—Fill a small oil flask with any kind of coloured water, having previously put in a few tea-spoonfuls of *ether:* then invert the flask in a shallow vessel of the same kind of coloured water, and by degrees pour boiling water upon its bulb. By the sudden accession of heat the ether will be changed into vapour; which will force out the coloured water, and fill the whole of the vessel. If cold water be now poured on the flask, the vapour will be condensed, and the coloured water will again rise within it.

91. We have reason to believe that every solid substance on the face of the earth might

be converted to a fluid, or even to a vapour or a gas, were it submitted to the action of a very high temperature in peculiar circumstances.

Sir James Hall has succeeded in fusing chalk, limestone, marble, and even common coal, by means of a pressure sufficiently strong to prevent the escape of the more volatile parts of the substances which he submitted to the experiment.

When a very intense heat is required, it is sometimes procured by collecting the sun's rays by means of a double convex lens, or a concave mirror.

92. Calorific rays, or rays which elicit caloric, are transmitted to us from the sun accompanied with light: these are perpetually thrown off from that immense body with astonishing velocity, in every direction.

Whether caloric itself is in any degree transmitted from the sun, is now considered to be extremely doubtful. See Note, No. 60.

Since the discoveries of Dr. Herschel, we have reason to believe the sun to be an *opaque* body, probably a habitable world; and that the light and heat we receive from it are owing to an atmosphere which it has, of elastic fluids of a phosphorescent nature, by the decomposition of which, light is evolved, and heat produced in the planetary bodies.

93. As caloric passes with such velocity from the sun, it would never be retained by those substances which receive it, were it not for its affinity for those bodies, or rather their mutual affinity for each other.

Caloric (like light) moves at the rate of 200,000 miles in a second; therefore it never could be accumulated in any body, were it not retained by its *affinity* for that body, but would pass through it with the rapidity of lightning.

The rays of the sun seem to afford heat, only when they meet with an *opaque* substance, and not when they pass through a transparent one, as air or water; or when they are reflected by a white or polished one. The air is not heated immediately by the rays of the sun passing through it; but on their meeting with an opaque body, as the earth for instance, heat is elicited, and is thence gradually communicated to the surrounding atmosphere. Hence, the further we remove from the earth's surface the greater is the degree of cold.

94. The chemical affinity of bodies for caloric, is notwithstanding one of the weakest of all known affinities.

It is worthy of remark, that this was wisely and kindly ordered by the Creator; for, owing to this, organized bodies have no difficulty in separating a sufficient quantity of caloric from the substances around them, and of securing to themselves the quantity necessary for their wants. It is obvious how dreadful would have been the consequences, if caloric had had as strong an affinity for bodies, as some simple substances have for each other. A *small* deviation from the present order of things would probably occasion infinite mischief.

95. This is evident from the facility with which heated bodies part with their caloric to all surrounding bodies.

The facility with which caloric passes from one body to another may be owing to the repulsion which is known to exist among the particles of caloric. This repulsion gives it a tendency to fly off in every direction.

96. It is one of the laws of nature, that heated bodies should give out part of their free caloric to the neighbouring bodies at a lower temperature, till the whole become of an equal degree of temperature.

Water however affords a curious exception to this law of nature; this fluid having a very slight tendency to conduct caloric *downwards.* Had it been otherwise, the ocean and other large bodies of water would have operated very unfavourably on the temperature of the atmosphere.

Exp. 1.—Take a glass of cold water, pour a little sulphuric ether upon its surface, and inflame it by a slip of lighted paper. The ether will burn for a considerable time and produce a large volume of flame, but when extinguished the water will be found not to have increased in temperature. The design of this experiment is to show that water is a bad conductor of caloric, and that when we wish to heat water, the heat ought not to be applied at its surface.

Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass is a better conductor than wood. Hence the use of wooden handles to metallic tea-pots and other utensils.

Exp. 2.—I take a piece of iron in one hand, and a piece of wood in the other; the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. How is this? The iron has a stronger affinity for caloric than wood, and conducts it from the hand much swifter than the wood, and hence gives me a more lively sense of cold.

97. Thus, when the temperature of the atmosphere is reduced below 32°, water gives out its superabundant caloric by degrees, till at length the cold atmosphere robs it of its caloric of fluidity also, and it becomes ice.

The quantity of heat given out in freezing, occasions the progress of congelation to be extremely slow. The constant emission of caloric from the freezing substances operates favourably; for thus the severity of the frost is mitigated, and its progress retarded. This accounts for its often feeling warmer after a great fall of snow.

98. By this change the ice becomes specifically lighter than the subjacent water, and is thus enabled to swim upon its surface.

Ice is lighter than water, owing to air bubbles produced in the ice while freezing: but Monsieur de Mairan attributes the increase in the bulk of water in freezing to a different arrangement of its particles: ice being a crystallization composed of filaments, which are found to be uniformly joined at an angle of 60°, and by this disposition occupy a greater volume than if they were parallel.

Exp. 1.—Drop small pieces of ice into a tall glass full of hot water; as the ice melts, bubbles of air will be seen to rise from it, and burst at the surface of the water.

Exp. 2.—If hot water be poured into a glass jar of cold water, it will remain on the *surface;* but if cold water be poured upon hot water, it will sink to the *bottom* of the vessel. This experiment may be rendered more obvious by colouring that portion of the water which is poured in. The design of this experiment is to show the change of the specific gravity of the *same* body, merely by the agency of caloric.

Exp. 3.—Fill a thermometer tube with tepid water, and immerse it in a glass vessel of water of the same temperature, containing a mercurial thermometer. If the whole be now placed in a bed of snow, or in a frigorific mixture, the water in the tube will suffer a progressive diminution of volume, until it arrives at about 40°; it will then begin to expand gradually, until it becomes solid. This shows how ice is enabled to swim on the surface of water.

Exp. 4.—Another example on this subject may be shown. Fill a thermometer tube with cold water, at about 32°, and immerse it in a vessel of warm water. In this case, the water in the tube will contract in volume till it arrives at about 42°, when it will appear for a time nearly stationary. If the heat be now continued, the effect will be reversed, for the water in the tube will *expand* as its temperature is increased. This is a curious instance of a chemical anomaly.

99. Substances usually become more dense by the loss of caloric; but the freezing of water is a striking *exception* to this general law of nature, and is a memorable instance of the wisdom and provident care of the Almighty, when he established the laws of the universe.

In general, all bodies, whether solid or fluid, contract their dimensions and become of more specific gravity in cooling; but *water* affords a remarkable and striking exception. Water as it cools below 42°.5, instead of contracting and becoming of greater specific gravity, actually becomes increased in bulk, and its specific gravity continues to lessen as it cools. How admirable the wisdom, how skilful the contrivance, that, by subjecting water to a law contrary to what is observed by other fluids, the water as it freezes becomes specifically lighter, and, swimming upon the surface, performs an important service by preserving a vast body of caloric in the *subjacent* fluid from the effects of the surrounding cold, ready to receive its own accustomed quantity upon the first change of the atmosphere!

CHAPTER IV.

OF WATER.

100. WATER is a compound consisting of hydrogen and oxygen.

Water was always considered to be a simple substance, and chemical philosophers were for a long time unwilling to allow of its being otherwise. Its compound nature was however fully proved, in the year 1784, by Mr. Cavendish.

101. It is found in four states, viz. solid or ice; liquid or water; vapour or steam; and in a state of composition with other bodies.

Water is said to be in a state of *composition* with other bodies, because in many cases it becomes one of their component parts and unites with them only in a definite proportion. By this union it occasions the transparency of crystallized salts, and in other cases it unites with bodies and forms what are called hydrates.

Exp. 1.—Take an ounce of sulphate of soda in dry powder, dissolve this in as small a portion of *hot* water as is necessary for its solution. If it be then suffered to remain at rest until the solution is perfectly cold, crystals of sulphate of soda will be found in the vessel. On weighing these crystals it will be perceived that the ounce of dry sulphate of soda has produced more than two ounces of the crystals of that salt. The water which is thus become united with the salt, is known by the name of *the water of crystallization.*

Exp. 2.—If a little fresh burnt lime be carefully slacked with water and suffered to remain until the whole becomes a perfectly *dry* powder, and then weighed, it will be found that every 100 grains of the lime have united with more than thirty grains of water. This dry compound is called a *hydrate* of lime.

102. The most simple state of water is that of ice.

103. The difference between liquid water and ice, is merely that water contains a larger portion of caloric.

Exp. — Take any quantity by weight of ice or snow at 32°, and mix it with an equal weight of water heated exactly to 172°. The snow instantly melts, and the temperature of the mixture is still only at *thirty-two* degrees. Here the water is cooled 140°, while the temperature of the snow is not increased at all; so that 140° of caloric have disappeared. There can be no doubt, then, but water owes its fluidity to its latent caloric. See *Exp.* 1, at N° 85.

104. Vapour is water, combined with a still greater quantity of caloric.

However long we boil a fluid in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated.

Exp.—Those who have an air-pump may easily see that water requires a vast portion of caloric to convert it into steam; for, if a cup of *hot* water be put under the receiver, and the pump be set to work, the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat.

105. Owing to the large quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold.

An animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him. Its evaporation would shortly carry off the whole of his vital heat. Water thrown on hot bodies acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives these bodies of a great portion of the caloric they contain.

Exp. 1.—Take a glass thermometer tube, fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will presently be frozen, even in summer.

Exp. 2.—If the student be in possession of an air-pump, the following experiment may be easily performed:—Let him fix a small tin cup of *ether* within a large watch-glass containing a little water, and place both under the receiver of the air-pump. The exhaustion of the receiver will cause one of the fluids to boil, and the other to freeze, at the same instant.

106. Vapour, owing to the large quantity of caloric which is combined with it, takes a

gaseous form, and acquires great expansive force.

Water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice-cold water to a boiling heat, and occupies a space 800 times greater than it does when in the form of water.

The expansive force of steam is found by experiment to be much greater than that of gunpowder. Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to this power of steam; the water of the sea finding its way to subterraneous fires.

107. These properties of steam render it capable of supporting enormous weights, and of becoming an useful and powerful agent for raising water from deep pits, and for other important purposes.

The invention of the steam engine was a vast acquisition to the arts. There is reason to believe that, in time, steam may be applied to many useful purposes of which at present we have no idea. In America vessels have long been navigated by steam, and of late years such vessels have become very common in several districts of Great Britain.

108. Water is composed of 88 parts by weight of oxygen, and 12 of hydrogen, in every 100 parts of the fluid.

Both these terms are derived from the Greek language; the former signifies to *generate acids*, the latter to *generate water*.

Water is found to be a compound of 1 part hydrogen and $7\frac{1}{2}$ parts oxygen by weight: this will give, in the 100 parts, the proportions of nearly $11\frac{3}{4}$ of hydrogen and $88\frac{1}{4}$ of oxygen. If the gases are estimated by their volume, water will be found to be composed of two measures of hydrogen and one of oxygen.

Exp.—Put a little alcohol in a tea-cup, set it on fire, and invert a large bell glass over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell, which by means of a dry sponge may be collected, and will be found to be pure water.

109. Several methods have been contrived whereby water may be decomposed, and the exact proportion of its constituent parts ascertained.

This was discovered by Mr. Cavendish, in the year 1781. Dr. Priestley had previously combined the two gases by combustion; but Mr. Cavendish was the first who drew the proper conclusion from the Doctor's experiment.

110. It may be done by forcing it through a tube over red-hot charcoal, by passing repeated electrical shocks through it, and also by means of the galvanic apparatus.

"Water cannot be decomposed without a combustible body," or the agency of electricity or galvanism, "as the hydrogen requires a very large dose of caloric to put it in a gaseous state. This appears from the lightness of hydrogen gas compared with water. A cubic foot of water weighs $62\frac{1}{2}$ pounds, whereas a cubic foot of hydrogen gas weighs less than 40 grains."

Exp.—When two wires from the opposite extremities of a galvanic battery are placed in a tube containing water, so that they are distant from each other $\frac{1}{4}$ or $\frac{1}{2}$ an inch, a stream of gas issues from each wire—from the positive wire oxygen, from the negative, hydrogen gas; and these are in the proportions which when exploded, either by galvanism or electricity, re-form water.

111. Nature also decomposes water in many of her operations, particularly by means of every living vegetable.

See Axiom 55, and the Notes.

112. Likewise fish in general, and all cold-blooded amphibious animals, we have reason to think, are endowed with the same faculty of decomposing water.

Among other cases, we read of a fish that was kept three years in a vessel and fed only with water, and that at last it became too large to live any longer in the vessel. Whence this increase of animal substance, if we deny it the power of decomposing water? Rondelet *de Piscibus*, lib. i. cap. 12.

113. Vegetables, in decomposing water, combine part of its hydrogen, as well as of its oxygen, with the carbon of the atmosphere and of the soil, to form the vegetable compounds oil, wax, gum, resin, sugar, &c.; while the superfluous oxygen is abundantly evolved by the leaves.

It should always be recollected that the oil found in vegetables is produced by this process of vegetation. The oils, bitumens, &c. in minerals, must all have had a vegetable origin.

In China, vegetable wax is extracted from plants by maceration in boiling water, and employed in the manufacture of candles.

Bees' wax is doubtless a vegetable product. The bees extract it unaltered from the leaves of trees and other vegetables.

114. Oxygen is the basis of vital air, as well as one of the constituent parts of water; it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms.

Nature, in economizing the primary materials of the universe, has constituted *oxygen* the basis both of the atmosphere which surrounds the earth, and of the water which forms its seas and oceans:

"For mark how oxygen with azote gas
Plays round the globe in one aërial mass,
Or, fused with hydrogen in ceaseless flow,
Forms the wide waves which foam and roll below."

115. Hydrogen, the other constituent part of water, is the base of the gas which was formerly called inflammable air, and is, when in the aëriform state, the lightest of all ponderable things.

Hydrogen gas, from its great levity, has generally been used to fill air-balloons. This gas can be procured pure only from water, which in all cases must suffer a decomposition. See a further account of hydrogen and its compounds in chap. xi.

Exp.—Put a quantity of filings of zinc into a vessel which has a glass tube adapted to it; then pour upon them sulphuric acid diluted with 6 or 8 times its quantity of water; an effervescence will immediately take place, the water will be decomposed, the oxygen of it will become united to the metal, and the hydrogen gas will be disengaged, and may be conveyed by the glass tube into any proper receiver.

116. Several methods have been discovered of forming water artificially by a mixture of oxygen and hydrogen, so that the composition of this fluid is now ascertained beyond all doubt.

Exp. 1.—Add gradually one ounce of sulphuric acid to four ounces of water in a large phial containing a few iron filings. The temperature of the mixture will be so much raised by the union of the water with the acid, as to enable the iron to decompose a part of the water. If a hole be neatly made through a cork which fits the mouth of the phial, and a piece of tobacco-pipe with a very small orifice be fitted into it, and the whole cemented into the phial with a mixture of resin and bees' wax, the hydrogen gas as it is separated from the water will pass in a continued stream through the pipe, and may be set on fire by the flame of a candle brought in contact with it.

Exp. 2.—That water may be re-formed by the combustion of this gas, may be shown by holding a glass bell over the flame of the gas: as the hydrogen burns, it unites with the oxygen of the atmosphere, and the union of the two gases produces water, which will soon be seen to deposit itself like dew on the inside of the glass. *It is advisable to fold a cloth round the bottle to prevent any injury from the fragments of glass, in case of an explosion, which sometimes will happen during this experiment, if atmospheric air be left in the phial; or let the gas burn for a moment, before the cork and pipe are fixed into the neck of the bottle.*

117. Thus, if a mixture of oxygen and hydrogen gases, in proper proportion, be fired,

the inflammation will unite the bases of the two gases, without separating the whole of their caloric, and water will be the product.

M. Biot has succeeded in forming water from hydrogen and oxygen, by *compression* only, independently of the electric spark. The compression, by bringing the particles of gas into intimate union, makes them throw out heat sufficient to set the hydrogen on fire; and the product of the combustion is water.

118. It is even probable that the torrents of rain which generally accompany thunder storms, may arise from a sudden combustion of hydrogen and oxygen gases.

This combustion is probably occasioned by lightning.

The aurora borealis may be owing to the existence of a stratum of hydrogen gas in the higher regions of the atmosphere. The vulgar entertain strange conceits about this curious phenomenon of nature.

119. Hydrogen gas is only one-fourteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination.

120. Hydrogen is continually emanating from vegetable and animal matters during their decay, and is a certain consequence of their putrefaction; it is also evolved from various mines, volcanoes, and other natural sources.

The ignis fatuus, or will-o-wisp, originates from decayed vegetables, and the decomposition of pyritic coals; it consists generally of hydrogen combined with carbon; and, perhaps, occasionally with phosphorus or sulphur.

121. A wine-pint measure of water weighs rather more than one pound; and a cubic foot of water weighs about 1000 ounces, or 62½ lbs. avoirdupois.

It is very necessary for the student to bear in mind the specific gravity of water, because this is always taken for unity in the measure of the specific gravity of every other substance. An accurate wine-pint holds 7272 grains of distilled water, which is 272 grains more than one pound avoirdupois.

According to the last experiments of Sir George Shuckburgh, when the barometer is at 30 inches and the thermometer between 50° and 60°, water is 825 times heavier than atmospheric air.

122. The atmosphere, when its temperature is sufficiently low, deprives the water of a certain portion of its caloric; crystallization then ensues, and the water solidifies and becomes ice.

Water in freezing crystallizes in filaments, which are uniformly joined at angles of 60 and 120 degrees. The word *crystal* originally signified ice.

It is owing to the *expansion* of water in freezing, that rocks and trees are often split during intense frosts. According to the calculations of the Florentine academicians, a spherule, or little globe of water, only one inch in diameter, expands in freezing with a force superior to the resistance of 13½ tons weight.

It may be remarked, that though fresh water freezes when reduced to the temperature of 32°, sea water does not freeze till cooled down to 28.5°.

123. By crystallization is understood the concretion of certain substances into regular

forms, occasioned by the loss of a portion of their caloric; but the term is generally applied to compound bodies of the saline kind, and to their separation in regular and peculiar figures, from the water in which they were dissolved.

124. Near the poles water is eternally solid: there it is similar to the hardest rocks, and may be formed by the chisel of the statuary, like stone.

Near Hudson's Bay there are islands of ice which are immersed above 100 fathoms beneath the surface of the sea, and which measure three or four miles in circumference.

"There can be no doubt but that the quantity of ice at the north pole is the principal source of the coldness of our winters, which is occasioned by the regions of air blowing from the north at that season."

"Where, for relentless months, continual night
Holds o'er the glittering waste her starry reign."

"It is related that at the whimsical marriage of Prince Gallitzin, in 1739, the Russians applied ice to the same purposes as stone. A house consisting of two apartments was built with large blocks of ice; even the furniture of the rooms was made with ice; and the icy cannon, which were fired in honour of the day, performed their office more than once without bursting."

125. The great solidity of ice at the poles is occasioned by the very low temperature of the circumambient air; for in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

We need not look for any cause for the conversion of water into ice, but the loss of its caloric; for in the Grotto of Besançon water is frozen during the heats of summer. In this singular place the variation of the thermometer between winter and summer is very inconsiderable.

126. Water becomes still more solid in the composition called mortar and in cements, having parted with more of its caloric in that combination than it does in the act of freezing.

Though water takes a solid form in its various combinations, such as with lime and saline crystals, it was thought impossible to compress it when in a fluid state. The Florentine academicians filled a globe of gold perfectly full of water, and submitted it to a very powerful press; but could not perceive that they were able to make it occupy less space than it did at first. They gave it such a degree of pressure, that at length the water exuded through the pores of the metal.

127. Water is also combined in a state of solidity in marble, in crystals, in spars, in gems, and in many alkaline, earthy and metallic salts, both natural and artificial, to all of which substances it imparts hardness, and to most of them transparency.

Most stones and salts lose their solidity and transparency by being deprived even of a part only of the water which they contained, and generally become pulverulent.

If water be thrown on quick-lime, it will be retained by it with such force that nothing less than an intense *red* heat will separate it. Saussure has proved that alumina, when mixed with water, retains a tenth of its weight of that fluid at a heat which would melt iron.

Exp. 1.—Take some ground plaster of Paris fresh calcined, and mix it up with a little water. The affinity of the plaster for the water is so great, that in a few minutes the whole of this pulverulent matter will be converted to a solid.

Exp. 2.—Boil a few copper filings in concentrated sulphuric acid to which a small portion of nitric acid has been added, and when the copper is dissolved dilute the mixture with a little water, and then leave it where it can cool gradually. If the mixture be thus suffered to remain undisturbed a few hours, beautiful crystals of blue vitriol will be found at the bottom of the vessel, as hard as some minerals. It is the water which gives them their solidity.

CHAPTER V.

OF THE EARTHS.

128. The earths are incombustible bodies, and in general are unalterable in the fire. Till lately they were thought to be unsusceptible of decomposition; they are insoluble in water, or nearly so, when combined with carbonic acid; and are of a specific gravity never exceeding five times that of water.

Baron Born, many years ago, was of opinion that the earths were compound bodies. Sir H. Davy has now succeeded in decomposing most of them; and from his experiments we have reason to suspect that they are all metallic oxides.

The insolubility of the earths in water, when combined with carbonic acid, forms a striking distinction between this class of bodies and the carbonated fixed alkalies, which are very soluble in water.

129. There are nine distinct earths known at present, viz. silica, alumina, zirconia, glucina, yttria, barytes, strontites, lime, and magnesia.

Notwithstanding the varied appearance of the earth under our feet, of that of the furrows of the field, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths; and as three of these occur but seldom, the *variety* which is produced by the other *six* becomes the more remarkable.

To give a still greater variety to the works of Nature, these earths are endowed with an affinity for acids and metallic oxides, whence arise the spars, gems, and precious stones of every colour and every species.

Besides the nine earths here enumerated, we have now *thorina*, which is a rare earthy substance, lately discovered by Berzelius in a species of gadolinite. Its properties are at present but little known, yet it is presumed to be, like the other earths, a metallic oxide.

130. Barytes, strontites, and lime, are called alkaline earths, because they agree with the alkalies in taste, causticity, solubility in water, and in their effect upon vegetable colours. Magnesia agrees with the alkalies in the latter property only.

Barytes, strontites, lime, and magnesia, are found in nature always combined with acids. None of the combinations are very hard, as either of them may be scratched with a knife. The acids, which are found united by nature with these alkaline earths, are generally the carbonic, the sulphuric, the fluoric, the boracic, and the phosphoric.

131. Silica, or pure flint, is a white, inodorous and insipid earth; it is insoluble in water, and in every acid except the fluoric; it endures the strongest heat without alteration; but, when mixed with soda or potash, becomes fusible in a strong fire into glass. Its specific gravity is 2.65.

Some properties that are common to all the earths, do not pertain to silica; among others, it has no attraction whatever for carbonic acid, nor does it form a *regular salt* with any other acid.

Sir H. Davy has not yet succeeded in exhibiting the base of this earth in a separate state, though from the result of his experiments there is great reason to believe that silica, like the other earths, is a metallic oxide. *Elem. Chem. Philos.*, part i. page 362.

132. Silica is found in almost all solid mineral substances, particularly in gravel, sand, quartz, and flint, of which it forms nearly the whole substance. It is also the chief ingredient of those rocks which constitute the most bulky material of the solid parts of our globe.

Pure silica may be procured for chemical experiment, by fusing common flint stones with three or four times their weight of potash, dissolving the product in water, and then taking up the alkali by the addition of an acid, which will precipitate the silica, which is to be well washed for use. The siliceous stones should be previously heated red in a crucible, and plunged in that state into cold water. This will render them brittle, so that they may easily be reduced to powder before they are mixed with the potash.

There is a granite mountain, about 30 miles from the Cape of Good Hope, which rises out of the ground to the height of 400 feet, is half a mile in circumference, and is formed of a single block of granite.

133. Silica has such various uses in the arts, that it is one of the most valuable earths that we are acquainted with.

134. It is the most durable article in the state of gravel for the formation of roads; it is a necessary ingredient in earthen-ware, porcelain, and cements; is the basis of glass, and of all vitreous substances; and is an indispensable article in many of our chemical furnaces and utensils.

The manufacture of glass was known very early; but glass perfectly transparent was reckoned so valuable, that Nero is said to have given a sum equal to 50,000*l.* for two glass cups with handles.

The manufacturing of *pastes*, or artificial gems, is a branch of the art of glass-making. The basis of these is a very hard and pure silica, obtained by melting pounded quartz with an alkali, with the addition of borax, nitre, and oxide of lead, different metallic oxides being added to imitate the colour of the different gems.

135. In making glass, silica is the chief ingredient. It is rendered fusible by a due mixture of alkali, which acts as a flux to the silica, and renders the whole transparent.

Glass cannot be made without great heat, as the alkali retains the last portions of carbonic acid and water with singular obstinacy, and it is only at a very high temperature that the alkali fuses, and then it prefers the silica; for it is one of the laws of nature, (to which there are few exceptions,) that, in order that two bodies may become *chemically* united, one of them must be in a state of fluidity.

136. Alumina, or pure clay, is an earth whose specific gravity is 2.0.

Pure alumina may be procured by decomposing common alum with carbonate of ammonia. It has not been found native in a state of purity any where, except at Halle in Germany.

137. This earth is soft to the touch; adhesive to the tongue; emits a peculiar odour when moistened; forms a paste with water; has great affinity for colouring matter; will unite with most acids; and acquires great hardness, and contracts in the fire. Like silica, it is soluble in caustic potash, or soda.

Common clay is a mixture of alumina and silica. It frequently contains metallic oxides, chalk, and other earths. Alumina united to the oxides of iron is plentifully procured in Staffordshire and Derbyshire; in which state it is called raddle, an article very useful in colour-making. Fuller's earth is alumina combined with very fine silica.

138. Alumina is distributed over the face of the earth in the form of clay, and from this circumstance acquired the name of *argil.*

139. It is found also in a state of crystalli-

zation in the sapphire, and other precious stones, and is united to the oxides of iron in the ochres. It obtained the name of *alumina* from its being the base of the salt called alum.

140. Alumina, on account of its aptitude for moulding into different forms, and its property of hardening in the fire, is employed in various ways, such as for making bricks, crucibles, &c.; but the alumina which is made use of for these purposes is always impure.

141. Aluminous earth is employed for various purposes by the dyer and the calico-printer, especially in its combination with acetic acid as a mordant for fixing madder reds and some other colours on calico; and upon the continent it is artificially combined with sulphuric acid, in order to form alum.

In England it is not necessary to form alum by art, as the alum-slate is found in great abundance, and it is only requisite to add potash, ammonia, or salts containing either of these bases, in order to complete the process.

Exp.—If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the alumina, or base of the salt, will attract the colouring matter, forming an insoluble compound, which in a short time will subside, and may easily be separated.

142. Alumina, mixed with silica, is used by the potter in the manufacture of porcelain and earthen-ware.

Earthen-ware, according to the Old Testament, was known at an early period to the Jews; and the potter's wheel, there spoken of, was probably the same simple machine as is used at the present day to form round vessels with plain surfaces.

Alumina is of inestimable value for securing the bottoms and sides of canals and reservoirs of water, and composes in a great measure those tenacious earths called *arable* soils.

143. In making earthen-ware a due proportion of both these earths is necessary; for if alumina alone were used, the ware could not be sufficiently burnt without shrinking too much, and even cracking; and a great excess of silica would lessen the tenacity, and render the ware brittle.

144. Stone-ware, like other pottery, is chiefly composed of alumina and silica, but a certain quantity of old pottery finely ground is generally introduced into its composition. The difference, however, between this and common earthen-ware, chiefly consists in the burning and glazing; stone-ware being always submitted to a much higher degree of heat, and in its being glazed with muriate of soda instead of the oxide of lead.

145. On account of the superior strength of stone-ware, its very compact texture, and

the wholesome nature of its glaze, it is greatly to be wished that its use were considerably extended, and that every article for culinary purposes were to be manufactured with it.

146. Porcelain is not esteemed good, unless it be very compact, quite white, and semi-transparent; indeed, it is chiefly the last quality that constitutes the principal difference between earthen-ware and porcelain, for *earthen-ware* is always opaque.

147. Barytes occurs chiefly in combination with sulphuric acid; it was first discovered by Scheele in a mineral called ponderous spar, afterwards terra ponderosa. It is chiefly found in this state in England, and in other parts of the globe. In Derbyshire it is known by the popular name of cauk.

Barytes is always found united either with the sulphuric or the carbonic acid.

Bergman gave it the name of *barytes* from the Greek word *barys* (*heavy*), this being the most ponderous of all substances except the metals and the earth called yttria.

Exp.—Dissolve the carbonate of barytes in very weak nitrous acid, by which means the carbonic acid will be expelled, and then in the usual way, by proper evaporation, crystals of nitrate of barytes will be formed. By exposing this salt to a strong heat, the nitric acid will be dissipated, and pure barytes will be procured.

148. It has also been found, combined with carbonic acid, in several parts of the British

empire, particularly in Northumberland, Cumberland, and Lancashire; and in France, in combination with the oxide of manganese.

149. Barytes when pure is of a greyish white colour; like the alkalies it changes the vegetable blues to a green; has a pungent caustic taste; has the property of enabling oil to unite with water; and is in all its combinations, excepting that of the sulphuric acid, a violent poison.

Pure barytes changes quickly when exposed to the air; it swells like quick-lime, and like it falls into a white powder; but this slacking is much more violent and speedy than that of lime. It combines intimately with water, and the water becomes solidified in the barytic earth.

150. Barytes is a non-conductor of electricity; and may be known from the other earths by its solubility in water, by its forming an insoluble compound with sulphuric acid, and by its imparting to flame a yellow colour. Its specific gravity is 4.00.

Barytes is soluble in about 20 parts of water at the temperature of 60°; but boiling water will dissolve half its weight of this earth, part of which will crystallize on cooling.

The most singular property of this earth is the tenacity with which it holds the sulphuric acid when combined with it. It has such an affinity to it, that it will not part with it even to pure alkalies. The solution of this earth in water, and in various acids, furnishes excellent tests for chemical analysis.

Exp. 1.—Into a solution of pure barytes pour some solution of sulphate of soda, both solutions being previously clear and transparent. The barytes will instantly quit the water and attach itself to the sulphuric acid. Pure soda will now remain in the supernatant liquor, and sulphate of barytes be deposited in a white powder.

Exp. 2.—Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived; pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of sulphate of barytes will be produced.

Exp. 3.—Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of barytes use nitrate of lead. In this case sulphate of lead will be precipitated.

Exp. 4.—If a spoonful of good alcohol and a little pure barytes be stirred together in a tea-cup, and then set on fire, a brilliant yellow flame will be produced.

151. Barytes forms some of the most useful chemical tests, whether in its pure state, dissolved in water, or combined with particular acids. It is capable of making a very tenacious cement, but has not yet been used much in the arts, except by limners as a most excellent water colour.

This is the only *white* for water painting that never changes.

152. Strontites was discovered by Dr. Hope about the year 1791 in a mineral brought from the lead-mine of Strontian in

Argyleshire. That mineral, which is a *carbonate* of strontites, has been found but in small quantities in any other place.

It will be advisable for the preceptor to procure specimens of this and other minerals, that the pupils may learn how to distinguish them. It will also serve to give a variety to the lessons, and prevent satiety.

153. Strontites is more abundantly produced by Nature, when in union with sulphuric acid; particularly near Bristol, where it is in such quantity as to be employed in the repairs of the neighbouring roads.

154. Strontites, when separated from its acid, is considered to be a pure earth, and, like barytes, is then soluble in water; it is of a greyish white colour; its taste is acrid and alkaline, but less so than barytes or the alkalies.

In order to procure this earth in a state of purity, carbonate of strontites may be treated in the same way as carbonate of barytes is treated, to procure pure barytes.

155. The solution of this earth in water is capable of crystallization. It is distinguished from barytes chiefly in not being poisonous, and also in giving a purple colour to flame.

Strontites is not soluble in less than 200 parts of cold water; hot water dissolves it much easier; it then crystallizes on cooling, and is similar to barytes in many of its habitudes.

Exp.—Mix a spoonful of good alcohol with a little powdered strontian, and set fire to the mixture. The whole will burn with a flame the colour of carmine.

156. Though strontites combines readily with all the acids, and possesses alkaline properties, it has not hitherto been employed for any useful purpose. Hereafter it may be found to possess valuable properties; for it exists in abundance, and the Author of Nature has formed nothing in vain.

157. Lime is of a white colour, and of a hot caustic taste; it forms peculiar salts with acids, which is perhaps the most decisive proof that can ever be obtained to identify this or any other earth.

The specific gravity of pure lime is 2.3. It is soluble in 200 parts of water.

Lime forms with sulphuric acid a compound soluble in water to a certain degree; so that this earth is easily distinguished from barytes and strontian, whose sulphates are insoluble. Oxalic acid is the usual test for this earth, with which it forms an insoluble precipitate.

Exp. 1.—Pour a little lime-water into a wine-glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of oxalate of lime will immediately become visible.

Exp. 2.—Pour some lime-water into a glass, and a solution of Epsom salt into another glass. When these transparent fluids are poured together, a mixed precipitate of carbonate of magnesia, and sulphate of lime, will be produced; showing the affinity of lime for sulphuric acid.

Exp. 3.—For another experiment, take in the same manner, separately, lime-water, and a solution of alum. The union of these solutions will produce a mixed precipitate of alumina and sulphate of lime.

158. This earth changes vegetable blues to a green; it is incapable of fusion; it solidifies water, when sprinkled with that fluid, occasioning it to give out a great quantity of caloric; it absorbs moisture and carbonic acid when exposed to atmospheric air; but is itself very sparingly soluble in water, and possesses the peculiar property of dissolving more copiously in cold than in hot water.

Quick-lime has such an affinity to water that it will absorb one-third of its weight of that fluid, forming what is called hydrate of lime; and yet remain perfectly dry. The water becomes solidified and identified with the earth. The heat therefore that is evolved in the process of slacking lime, proceeds from the water as it passes to the solid state, and not from the earth as is generally supposed.

Exp. 1.—Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will seize the lime, and precipitate it in the state of carbonate of lime.

Exp. 2.—Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be re-dissolved, and the liquor rendered transparent.

Exp. 3.—Take the transparent liquid produced in the last experiment, and give it heat. The earth will now be precipitated in the state of carbonate of lime, as before.

Exp. 4.—Pour some lime-water into a wine-glass, and a little solution of carbonate of potash into another glass. When these two transparent fluids are thrown together, an abundant precipitate of carbonate of lime will be the consequence.

Exp. 5.—Fill a glass tumbler half full of lime-water; then breathe into it frequently; at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and, if suffered to remain at rest, real chalk will be deposited.

Exp. 6.—Mix in a wine-glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potash, both transparent *fluids:* stir the mixture, and a solid mass will be the product.

159. Lime is never found pure; it is always in a state of combination, generally with an acid, and more frequently with the carbonic acid, as in chalk, marble, limestone, &c.

The vast mountains of calcareous earth which occur in different parts of the world, owe their origin, in general, it is supposed, to the destruction of marine testaceous animals, which in long process of time formed these extensive and accumulated heaps.

To make quick-lime, the carbonate of lime, by whatever name it is called, whether chalk, marble, limestone, oyster-shell, &c. is broken into convenient pieces, and stratified in alternate layers with coal, furze, or any other fuel, in proper kilns, where it is kept for a considerable time in a *white* heat. By this means the carbonic acid and water are driven off, and tolerably pure lime is the product.

160. It is found also in vegetables, and it is the basis of animal bones. It occurs like-

wise in the waters of all springs and rivers, but always in combination with an acid.

This earth is dissolved in such quantities in the waters of Tuscany, that the artists there are said to form *basso-relievos* of very considerable hardness, merely by frequently filling their moulds with the waters.

161. Lime united with the acids is applied to various useful purposes, and, next to silica, forms a material portion of the solid fabric of the terrestrial globe.

The inhabitants of towns and houses built on a chalky or limestone foundation are observed to be less liable to infectious or epidemic disorders than those of any other situation.

162. In its pure state it is used in many of the arts, particularly in making mortar for buildings. It is employed by the farmers as a manure; also by bleachers, tanners, sugar-bakers, soap-boilers, iron-masters, and others, in their several manufactories, and in medicine.

Lime is used in the manufacture of glue. The design of it is to prevent its becoming flexible by the absorption of moisture, and to add to its strength. Some persons use alum for the same purposes.

163. Pure lime has, when united to a certain portion of water, a very strong affinity for silica, another most essential ingredient in all mortar and cements; for without this it never hardens.

The nature of the sand which is mixed with lime to form mortar or cement, is of the utmost consequence; the harder and sharper the sand the better, for if this matter be of a friable nature like chalk, the mortar must be weak.

164. If pure lime be slacked with water and then mixed with a proper proportion of silica, the gradual absorption of carbonic acid from the atmosphere occasions it in a series of years to become as hard as unburnt limestone.

When lime is made into mortar, it takes a long time in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than even limestone itself.

165. The use of lime in agriculture may be attributed to the property which it possesses of hastening the dissolution and putrefaction of all animal and vegetable matters, and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of the plants.

Hence lime and chalk are found to be particularly useful on sandy soils. Marle is a mixture of carbonate of lime and clay.

Every farmer should ascertain the *nature* of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime contains magnesia, which renders it injurious to the growth of vegetables. See Mr. Tennant's memoir on this subject in the *Philosophical Transactions* for 1799. The limestone of Breedon in Leicestershire contains half its weight of magnesia. That of Humbleton hill near Sunderland, 45 per cent. of carbonate of magnesia.—Thomson's *Annals of Philosophy*, vol. iv. page 417.

Magnesian limestone is generally of a fawn colour, but it may be known by its being much longer in dissolving in an acid than common limestone. This is the lime which the Yorkshire farmers call *hot* lime. Common lime soon becomes mild after it is spread upon the land; and hence it cannot injure the young plants, as explained in a former note: but where there is a large portion of magnesia in the lime it is otherwise, because the magnesia does not absorb carbonic acid with the same facility as lime, and therefore does not readily acquire that degree of mildness which is necessary for the safety of the young crop.

166. There is no good soil that does not contain a certain portion of lime, though always, without exception, combined with carbonic acid.

Marles are useful in agriculture only in proportion to the calcareous earth they contain. Unless they contain more than 30 per cent. of lime, they are of no value to the farmer.

Exp.—Take an ounce of marle and dissolve it in a certain weight of diluted muriatic acid. An effervescence will take place, and carbonic acid gas will escape from the mixture. When the effervescence has entirely ceased, weigh the whole again to ascertain what portion of its weight it has lost by the escape of this air. If the ounce has lost only 40 grains, it may be concluded that the ounce of marle contained only 100 grains of calcareous earth, and that it would be the interest of a farmer to pay seven times as much for a load of lime as he must pay for a load of such marle at the same distance.

167. Lime is used by the tanner in a state of solution; in this the hides are immersed in order to dissolve the gelatinous part of the skin, and to facilitate the removal of the hair.

The theory of tanning is shortly this: After the impurities of the skins are removed, they are steeped in an infusion of oak-bark, which consists of two distinct substances, viz. the gallic acid, and the tanning principle; the latter of these combines chemically with the gelatine and albumen of the skins, and forms leather.

168. Lime is used in refining sugar, because by boiling the sugar in lime-water the manufacturer deprives it of a certain uncombined acid which prevents its crystallization.

Lime is frequently used by chemists in processes where there is a superabundant and injurious quantity of acid. The lime seizes the acid, and frees the solution from it, by forming with it a neutral salt.

169. In the manufacture of soap, lime is mixed with the alkali in order to deprive it of carbonic acid. The alkali is thus rendered what is called *caustic*, and by this means is fitted to combine with the oil or tallow which is thereby converted into soap.

As different alkalies require different proportions of lime to render them perfectly caustic, every soap-maker should be acquainted with a test by which he may precisely ascertain the necessary quantity.

170. We have hitherto spoken only of lime and of carbonate of lime: but lime is found native in several other states of combination.

171. It occurs in combination with sulphuric acid forming gypsum; with the fluoric acid constituting fluor spar; with the phosphoric acid in a mineral called *apatite*, and in some precious stones.

Gypsum, or, as it is also called, selenite or sulphate of lime, when crystallized, is composed of about 33 lime, 46 parts of sulphuric acid, and 21 water.

Lime combined with the fluoric acid forms those beautiful fluor spars which are brought from the mines of Derbyshire. The most usual colour of this mineral is that of a deep purple; but by exposing it to the rays of a hot sun, or to different degrees of artificial temperature, the artist has found the means of forming a suit of colours of great variety and beauty.

The bones of all kinds of animals are formed of lime and phosphoric acid in the proportion of 48.5 parts of that earth and 51.5 of phosphoric acid.

172. Magnesia is a very soft, white, light earth, with little taste or smell; unalterable in the fire, and almost insoluble in water.

Magnesia converts vegetable blues to a green. In this respect it resembles the alkalies. It was formerly confounded with carbonate of lime. Hoffman was the first who distinguished it from all other earths.

Though this earth is infusible of itself, it assists the fusion of every other body. It requires 2000 times its weight of water to hold it in solution: notwithstanding this it has the property of rendering camphor, opium, and resins, soluble in water. Its specific gravity is about 2.33.

Magnesia dissolves in alkaline carbonates, but is not soluble in the caustic alkalies.

Exp.—Magnesia when combined with muriatic acid has the property of communicating a peculiar colour to flame. If some muriate of magnesia be mixed with a little alcohol and then set on fire, a very beautiful orange-coloured flame will be produced.

Sulphate of magnesia (the Epsom salt of commerce) is found in several mineral waters. The *bitter* saline waters generally owe their taste to this salt. That which is found in the shops is generally procured from the mothers which remain after the separation of common salt from sea-water, by subsequent evaporation and crystallization. All the salts formed with this earth are bitter, and generally very soluble.

173. Magnesia is never found in a state of purity, but always in combination with some acid. It is generally procured from sulphate of magnesia, which exists with the muriate of this earth in sea water, and in many springs.

Exp.—Make hot a saturated solution of sulphate of magnesia, and pour into it some solution of carbonate of potash. An immediate decomposition will take place, and carbonate of magnesia will precipitate in a white light powder. This is the process by which the common magnesia of the shops is prepared.

174. Magnesia is also a component part of several minerals.

Inverary-House is built with a stone called *lapis ollaris*, which contains 16 per cent. of magnesia. Magnesia is found also in talc, steatites, asbestus, fossil cork, and other minerals. The stones which contain a large portion of this earth have generally an unctuous feel, a fibrous texture, and a silky lustre.

175. Pure magnesia, as well as the sulphate and carbonate, has important uses in medicine.

When magnesia is taken as an aperient, it ought to be in the state of carbonate of magnesia, or what is called mild magnesia. When as an absorbent to correct acidities, calcined or caustic magnesia is most proper. On several accounts it is of consequence to attend to this distinction.

176. It is also required in some chemical processes, and is employed by the manufacturers of enamels and porcelain. Calcined magnesia is also the most effectual antidote in case of poison by the mineral acids.

It is probable that some of the most esteemed of the porcelain clays may owe their estimable properties to an admixture of magnesia. Magnesia is of use in porcelain, by lessening the degree of contraction to which it is liable in the process of burning.

177. Three other earths are at present known, besides those already enumerated, viz. zirconia, glucina, and yttria.

As these earths are so extremely rare that it is probable the student may never be able to procure even specimens of them, I have thought it useless to enumerate their properties, &c. here.

178. We have hitherto spoken only of the nine distinct earths; but minerals are found,

in every part of the world, in which the earths are combined in different proportions by processes unknown to us, which nature employs to produce that endless variety of what, in common language, we call rocks, stones, gems, &c.

Alumina and silica are the earths which have the greatest affinity; they are found in nature oftener united than any other. Some of the hardest stones are formed of these two earths.

179. The earths have several properties in common; yet as every earth possesses different and specific properties, it is evident that Nature designed them for different and distinct purposes of utility.

Many of the advantages that these earths might yield to man are probably still unknown; but those benefits which we now derive from lime, silica, clay, and magnesia, are very numerous and of the utmost importance.

A few short directions for analysing stones are given in Mr. Parkinson's *Chemical Pocket-book*, last edition, page 216.

180. Some of the more important uses of those earths with which we are best acquainted, are these:—Lime has an extensive and important use in agriculture; it is employed in buildings, and adds much both to the neatness and durability of our dwellings. Silica is the basis of all mortar and cements, and is a necessary ingredient in earthen-ware, porce-

lain, and glass. Barytes is employed as a reagent. Magnesia, besides being the basis of several salts, is of great use in medicine; and Alumina, by a due mixture with silica, is capable of forming vessels for chemists that will resist the action of the most concentrated acids; it is the material of which the bricks are formed which construct the walls of our habitations, and is also spread out by the great Author of nature in strata within our hills and mountains, to arrest the progress of subterraneous waters, and to produce those springs that fertilize the valleys, and which take such diversified courses upon the surface of the globe.

CHAPTER VI.

OF THE ALKALIES.

181. The alkalies are distinguished by an acrid and peculiar taste; they change the blue juices of vegetables to a green, and the yellow to a brown; and have the property of rendering oils miscible with water. They themselves are soluble in water; they form various salts by combination with acids, and act as powerful caustics when applied to the flesh of animals.

The word alkali is of Arabian origin, and signifies the "dregs of bitterness."

To a person who has not had an opportunity of examining an alkali, no written description that can be given will convey any correct idea of the taste or properties of this class of bodies: let the pupil therefore procure a specimen of each kind, before he enters upon this chapter. It will be necessary for him to *taste* and examine one of these bodies, in order to acquire any thing like a just idea of their nature. Let him form potash or soda into a neutral salt by saturating it with one of the acids, and he will perceive still more of the nature of these bodies.

Exp. 1.—Take an ounce of a solution of potash, pour upon it half an ounce of sulphuric acid; lay the mixture aside, and when cold, crystals of sulphate of potash will be formed in the liquor. Here a mild salt has been formed from a mixture of two *corrosive* substances.

Exp. 2.—Take caustic soda one ounce, pour over it one ounce of muriatic acid, both of these corrosive substances. The produce will be our common table salt.

Exp. 3.—Pour boiling water upon a little red cabbage sliced, and when cold decant the clear infusion. Divide the infusion into three wine-glasses. To one add a solution of alum, to the second a little solution of potash, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beautiful crimson.

Exp. 4.—Prepare a little tincture of litmus. Its colour will be a bright blue with a tinge of purple. Put a little of it in a phial, and add a few drops of diluted muriatic acid; its colour will change to a *vivid red.* Add a little solution of potash; the red will now disappear, and the *blue* will be restored. By these means the liquor may be changed alternately from a red to a blue, and from a blue to a red, at pleasure. An instance of the effects of acids and alkalies in changing vegetable colours.

Exp. 5.—Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{2200}$dth part of the water. The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, as these restore its original yellow.

Exp. 6.—Add a drop or two of solution of potash to tincture of turmeric. This will change its original bright *yellow* colour to a dark *brown:* a little colourless diluted acid will restore it. By this tincture we can detect the most minute portion of any alkali in solution.

Exp. 7.—Immerse a piece of animal flesh in a strong solution of potash or soda, it will immediately be so acted upon by the alkali, as to be soon entirely dissolved.

182. There are three alkalies; two of which have been called *fixed* alkalies, the other the *volatile* alkali.

A new alkali has been discovered by M. Arfvredson, a young Swedish chemist, in a mineral called *petalite*. This alkali, which is called *lithia*, is distinguished both from potash and soda by its power of neutralizing a much larger quantity of any acid. Sir Humphry Davy has shown that this new substance, like potash and soda, is a metallic oxide. Several salts have already been formed by the artificial combination of lithia with the acids. See *Chemical Catechism*, 10th edit. p. 267.

Three new vegetable alkalies have also been discovered, viz. morphia, picrotoxine and vauqueline. For some account of their properties consult the Introduction to the xiiith volume of Thomson's *Annals*, page lvi, &c.

183. The epithet *fixed* is applied to two of these alkalies, because they will endure a great heat without being volatilized; and yet in a very high temperature they are dissipated in vapour.

184. *Potash* and *soda* are the names now generally adopted for the two fixed alkalies.

Potash was formerly procured by burning vegetables in large iron pots; hence it acquired the name of *pot*ash. Soda acquired its name from the plant *salsola soda*, which grows on the Spanish coast, and is burnt for its preparation.

185. Formerly the fixed alkalies were considered to be *simple* substances, no one having been able to decompose them; but they are now found to be *compound* bodies.

It will be recollected, that, in the *first* edition of the *Chemical Catechism*, written seventeen years ago, I offered this opinion of the compound nature of the alkalies. The galvanic experiments of Sir Humphry Davy have confirmed the truth of this conjecture, and proved beyond all doubt that potash and soda are both metallic oxides; as will appear from the following experiments.

Exp. 1.—Take a small piece of pure potash, gently breathe on its surface, and place it on an insulated plate connected with the negative side of a powerful galvanic battery in a state of intense activity. Then bring a metallic wire from the positive side of the battery in contact with the upper surface of the alkali, and soon a very vivid action will be observed. Small globules, having a high metallic lustre, and of the appearance of quicksilver, will be seen, some of which will burn with explosion and a bright flame as soon as they are formed. Thus potash may be decomposed, and its metallic base rendered visible in a separate state.

Exp. 2.—Take the metallic substance formed in the last experiment, called *potasium*, make it very hot, and confine it in a small glass vessel of oxygen gas. Here a rapid combustion, with a brilliant white flame, will be produced, and the metallic globules will be converted into a white and solid mass, which will be found to be regenerated pure potash.

Exp. 3.—Place a small piece of potasium within a dry wine-glass, and in order to acquire an idea of its specific gravity pour a little alcohol, ether, or naphtha upon it; when, quitting the bottom of the glass, it will immediately rise to the surface of the liquid, it being, notwithstanding its metallic appearance, one of the lightest bodies known.

Exp. 4.—If a little potasium be dropped into a jar of chlorine gas, it burns spontaneously, and emits a bright red light. In this experiment a white salt is formed, being a true muriate of potash.

Exp. 5.—If a globule of potasium be thrown upon water, it decomposes it with great violence: an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result.

Exp. 6.—If a similar globule be placed upon ice, it will spontaneously burn with a bright flame and perforate a deep hole in the ice, which will contain a solution of potash.

Exp. 7.—Take a piece of moistened turmeric paper, and drop a globule of potasium upon it. At the moment that it comes in contact with the water, it burns and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace.

186. Potash is chiefly procured by lixiviation from the ashes of burnt wood, and other vegetable substances; but as it exists in minerals and earths, there is reason to believe that plants receive it from the earth during vegetation: hence it may be proper to discard the word *vegetable* entirely, when speaking of this substance.

It has been ascertained by experiment that potash is formed in what are termed nitre-beds, or collections of the materials from which nitre is procured, though it could have pre-existed in none of them. How this takes place we are quite ignorant.

Potash is prepared in large quantities in wine countries, by the incineration of wine-lees and must. This article is known in France by the name of *cendres gravelées*.

Potash was called the vegetable alkali, because it was supposed to exist only in vegetables. Soda was called mineral alkali, because it exists in rock salt. Soda, as distinguished from potash, has been known but of late years; and yet some of the properties of soda were known in times of remote antiquity. A Hebrew writer speaks of washing with natron. *Jeremiah* ii. 22.

187. Soda is generally procured from the ashes of *marine* plants; but its great depository is the ocean, soda being the base of sea-salt, or muriate of soda.

The *salsola soda*, which grows among the cliffs on the sea-coast, is said to be endowed with the property of decomposing sea-salt, and that by some process of vegetation it separates the muriatic acid and absorbs the soda. Hence it acquired the name of *saltwort.* This plant is collected by the Spaniards with great care, and burnt for the manufacture of barilla, which is a considerable article of commerce.

By means of a galvanic apparatus, soda also may be decomposed and its metallic base exhibited entire.

Exp. 1.—Take 10 or 15 grains of pure soda, treat it in the same way as directed for potash, *Exp.* 1. p. 83, and small globules of a metallic appearance will be produced.

Exp. 2.—When a globule of the *sodium*, produced by the last experiment, is thrown into *hot* water, the decomposition of the water is so violent that small particles of the metal are thrown out of the water, and actually burn with scintillations and flame in passing through the atmosphere.

188. Soda combined with carbonic acid is found in great plenty in the natron beds of Egypt, and in the East Indies: it occurs also in various other parts of the world, though never in a state of purity.

The natron lakes of Egypt annually produce a large quantity of mineral alkali. In summer the water of these lakes is evaporated by the sun, which leaves a bed of natron generally two feet thick; and this is broken up by wedges, and sent to the European markets.

189. The two fixed alkalies are very similar in their general properties; but are easily distinguished by the variety of salts which they

form with the acids; and by potash being more deliquescent than soda.

The sulphuric acid and soda form a salt very soluble in water, which crystallizes in long separate six-sided prisms, effloresces in the air, and undergoes watery fusion by the action of heat; whereas, the same acid and potash form a salt extremely difficult of solution, which crystallizes either in dodecahedrons with triangular faces, or in short hexahedral prisms terminated by hexahedral pyramids, is not affected by the action of the air, and decrepitates in the fire.

The oxalic acid has been used as a test to distinguish the mineral from the vegetable alkali. With the latter it forms a very soluble salt, but, with the former, one of difficult solubility.

The acetic acid is one that may be employed, as it forms a *crystallizable* salt with soda, and a *deliquescent* salt with potash. Potash may also be known from soda by supersaturating it with tartaric acid, with which it forms a salt very *insoluble* in water.

Sir H. Davy has shown that the affinity of the alkalies for acids is owing to their being in *opposite* states of electricity, the one being naturally in a positive, the other in a negative state; and that the formation of every chemical compound entirely depends on the electrical state of the materials of which it is composed. The affinity that the alkalies have naturally for acids, will appear from the following experiment.

Exp.—Let a clear saturated solution of sulphate of magnesia be poured into a strong solution of caustic potash. The potash has such an affinity to the sulphuric acid of the Epsom salt, that it will immediately decompose that salt; which will appear from the abundant precipitate that will result from the union of these two transparent fluids.

190. There are also several chemical tests, by which these alkalies can be distinguished; a solution of the ore of platinum in nitro-muriatic acid will answer this purpose most completely.

Exp. 1.—If a little of any alkaline solution be poured into a solution of the ore of platinum in nitro-muriatic acid, a yellow precipitate will be seen, if the alkaline solution contains potash; but if it contains only soda, no precipitate will occur.

Exp. 2.—Into a glass of Aix-la-Chapelle water, or water holding a small portion of potash, drop a little of the solution of nitro-muriate of platinum, and an immediate yellow precipitate will be produced. This affords an instance of the nature of the means usually employed to detect whatever substances may be dissolved in mineral waters.

191. The fixed alkalies have various uses in surgery and medicine: they are the bases of several salts; are employed much in the arts; and are of great importance to the analytical chemist.

192. In the arts they are employed in large quantities by the glass-maker, the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

Soda and potash are also both used in washing, and for other domestic purposes; as they powerfully unite with all greasy substances, which they render soluble in water.

Exp.—Boil equal parts of arnotto and common potash in water till the whole are dissolved. This will produce the pale reddish buff so much in use, and sold under the name of Nankeen dye.

193. In dyeing, they are employed to extract the colouring matter from a few of the foreign woods, and, in some processes, to precipitate the colours from metallic salts.

The fixed alkalies facilitate the solution of the colouring part of dye-goods, and generally render the colours darker.

194. An alkali is an essential ingredient in common soap, as it is the only article capable of converting tallow or oil into a saponaceous substance similar to the soap of commerce, and enabling it to combine with water.

Exp.—Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if some solution of caustic potash be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a perfect soap produced.

195. The nature of the action of the alkalies in making colours is not fully understood, though many colours are now manufactured in this country which cannot be made without an alkali.

196. Animal matters are always incinerated with an alkali to form Prussian blue; a

fixed alkali is also employed as a flux in the formation of the potter's blue from cobalt; and what are called French and mineral greens are made by precipitating copper from its solutions by means of these alkalies.

Exp. 1.—Mix 4 drachms of potash with an equal weight of dried bullock's blood; calcine the mixture in a covered crucible until it cease to emit any flame, and then wash the calcined mass till the whole of the saline matter be dissolved, and filter the lixivium. Now dissolve 4 drachms of alum in four ounces of water, and add to the solution half a drachm of strong nitrate of iron. If these solutions are mixed, the whole will acquire an intense blue colour, and a bulky precipitate will quickly be seen at the bottom of the vessel, which is a true *Prussian blue.*

Exp. 2.—Dissolve some sulphate of copper in a large portion of pure water, and, while hot, add to it gradually a warm solution of carbonate of potash, or carbonate of soda; this will precipitate a beautiful green colour, similar to that known in commerce by the name of *French green.*

Exp. 3.—Prepare some sulphate of copper as in the last experiment, and suffer the solution to become quite cold. Into this cold solution pour a very dilute solution of arseniate of potash. Here a very different colour will be produced, and which, when dried, will be similar to that used for painting in oil, called *mineral green.*

197. These alkalies are employed also in making alum; in bleaching linen; in scouring wool; and in many other processes too various to be enumerated.

Alum, which is a triple compound, cannot be perfect without the addition of a portion of potash or ammonia.

The design of using alkali in bleaching is to loosen and carry off that particular substance in the cloth which occasions its brown colour, and which Dr. Home says is a kind of heavy oil.

198. The alkalies are seldom sold in a state of purity, for both potash and soda always contain carbonic acid and water; and are often contaminated with earths, sulphur, and other impurities.

The potash and soda of commerce contain nearly one-fifth of their weight of carbonic acid, besides lime, silica, &c.

Exp.—Dissolve some soda or potash of commerce in water, and pour diluted sulphuric acid into the solution. This will occasion an immediate extrication of carbonic acid gas.

199. Both potash and soda, as well as ammonia, have a strong affinity for sulphur; they combine by trituration or heat, and form *sulphuret* of alkali, formerly called *hepar sulphuris*, or "liver of sulphur."

Such compounds are now generally named from the substance combined with the sulphur; thus we have sulphurets of potash, soda, lime, &c. Also, those of iron, lead, and the other metallic bodies.

Sulphuret of potash or soda is similar in colour to the liver of animals; it cannot exist but in a *dry* state, for it decomposes water when dissolved, and then sulphuretted hydrogen is produced.

If equal parts of sulphur and pure potash be triturated together in a mortar, the sulphur will soon acquire a green colour, the temperature of the mixture will be raised, and a *sulphuret of potash* formed. Carbonate of potash or soda will answer for this purpose as well as the pure alkalies, if heat be employed.

200. The alkalies of commerce are purified for the use of the chemist or manufacturer, by mixing them with a portion of quick-lime to divest them of carbonic acid; they are then lixiviated in proper vessels to obtain a solution of the caustic alkali, free from other impurities.

Exp.—If a little of the solution of carbonate of potash be poured into a glass of lime-water, an abundant precipitate of carbonate of lime will be occasioned by the mixture of these two transparent fluids. This is owing to the readiness with which the lime absorbs carbonic acid.

201. If potash or soda be required *perfectly* pure for nice purposes, the alkali must be dissolved in alcohol, and purified by a peculiar process.

202. The fixed alkalies are sometimes used in a state of combination with carbonic acid, for carbonic acid gives potash and soda the property of crystallizing readily: it also renders them mild, and fit for purposes in which caustic alkali would be improper.

Carbonate of soda and carbonate of potash are of use in chemical laboratories as *re-agents*, being employed for purposes which could not be effected by the *caustic* alkalies. Thus the two fixed alkaline carbonates will precipitate barytes, strontites, lime, magnesia, manganese, and iron, from their solutions, by means of double affinity.

Exp. 1.—Dissolve a little common American potash in water, and divide the clear solution into two portions. Then saturate one portion with carbonic acid gas, and place both solutions in a cool situation where they may remain until the next day undisturbed. If then examined, the one solution will appear unaltered, while that which was impregnated with carbonic acid will be found in a crystallized state.

Exp. 2.—Pour some barytic water, or a little of a solution of pure strontites, into a wine-glass, and add a small portion of the solution of carbonate of potash or soda. An immediate precipitate of the barytes or strontites will be perceived. Hence the use of carbonated alkali in precipitating these earths.

203. The other alkali, ammonia, when uncombined with water, or any other substance, exists in the state of gas, and is then so extremely volatile as to exhale at all known temperatures.

204. Its volatility is diminished in some degree by combination with water, still more so by combining with carbonic acid, and most when combined with the mineral acids.

205. In the gaseous state it has a remarkably pungent smell, it instantly extinguishes flame, and would be fatal to any animals that were obliged to breathe it. It is lighter than atmospheric air in the proportion of 6 to 10.

Exp.—By the following process ammonia may be formed so as to become evident to the senses in a short time. Take some filings of tin or zinc, pour on them some moderately diluted nitrous acid. After a short time stir into the mixture some quick lime, or caustic alkali, and a very strong pungent smell of ammonia will be produced.

206. There is a strong mutual attraction between ammonia and water; they form the *liquid* ammonia; in which state this alkali is generally used.

It is owing to the levity of ammonia, that water becomes specifically lighter in proportion to the quantity of gas it contains. Next to hydrogen, ammonia is the lightest of all the gaseous bodies.

Exp.—Mix two parts of fresh burnt lime in powder, with one part of powdered muriate of ammonia; put the mixture into a small glass retort, to which a receiver is connected, similar to the apparatus, fig. 23. Plate VI. If the heat of a lamp be now applied to the retort, the gas will be disengaged in abundance, and will combine with the pure water in the receiver. When the water is saturated, the strongest liquid ammonia will be formed by the process. If the liquid be now weighed, the specific gravity of the water will be found to be reduced by the addition of the ammonia from that of 1.000 to that of about 0.910.

207. Ammonia has another peculiar property, that of reducing the oxides of metals to a metallic state.

Ammonia being composed of hydrogen and nitrogen, the hydrogen seizes the oxygen from the metal and forms water, while the nitrogen escapes in a gaseous form. Some metals are oxidized and dissolved by liquid ammonia.

208. Ammonia is a compound of hydrogen and nitrogen, in the proportion of about one part of the former, and four parts of the latter, when calculated by weight; or if calculated by volume, of one measure of nitrogen and three of hydrogen, condensed into two measures by the combination.

One thousand parts of ammonia consist of 807 parts of nitrogen, and 193 parts of hydrogen. This is the result of experiment; but Sir H. Davy has lately, by means of galvanism, separated *oxygen* and a metallic substance from ammonia.

209. Ammonia may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat, and then nitrous acid and water will be the result.

Dr. Priestley was the first chemist who decomposed ammoniacal gas; indeed he was the first who procured it in a state of purity; but I believe Berthollet was the first person who proved its composition by synthesis as well as analysis.

Exp.—Fill four-fifths of a long glass tube with water saturated with chlorine gas, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the solution of chlorine, but by its passing a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

210. A very different result may be obtained if ammonia be decomposed in contact with mercury, by means of galvanism; for in this case a metallic substance of a very uncommon nature may be separated from this alkali.

This experiment was first made in the year 1808 by Dr. Zeobeck of Jena, and also about the same time by MM. Hissinger and Berzelius of Stockholm. Mercury, by combination with about one twelve-thousandth part of its weight of new matter, is thus rendered a solid, and at the same time so expanded in volume that its specific gravity is reduced from 13.5 to less than 3; while all its metallic characters of colour, lustre, opacity, and conducting powers, remain unimpaired.

As the quantity of ammonia obtained from different substances corresponds with the quantity of nitrogen which they contain, and knowing that ammonia is one of the products of putrefaction, it has occurred to me that a manufacture of volatile alkali might be established with advantage on any part of the coast where herrings, pilchards, &c. arrive in such shoals as to be employed in manure for land. Besides, as fish bones contain more phosphoric acid than those of quadrupeds, the bones might be advantageously employed afterwards in the manufacture of phosphorus, &c.

211. All animal and vegetable substances, when in a state of putrefaction, will furnish ammonia: this alkali is, however, generally procured in England by a dry distillation of bones, horns, and other animal substances.

Ammonia is also found in mineral waters. According to Dr. Austin, ammonia is formed whenever iron rusts in water which has a free communication with the air.

Large quantities of ammonia are now procured from the waste liquor in the manufactories of the gas-light companies at a very cheap rate.

Exp. 1.—Mix one part of powdered sal-ammoniac with two parts of powdered quick-lime in a retort, and apply the heat of a lamp. This will disengage the gas in abundance. On account of its affinity for water, this gas must be received over mercury, when it is intended to exhibit it in the state of gas.

Exp. 2.—Ammoniacal gas may be procured also by heating strong liquid ammonia, and collecting the gas as before.

Exp. 3.—If muriatic or acetic acid be held over any thing evolving ammonia, white fumes will appear, which are owing to the ammonia uniting with the acid, and forming a visible cloud, which is a true neutral salt in vapour. These acids are the tests usually employed to discover the presence of ammonia.

Exp. 4.—Whenever uncombined muriatic or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, and held over the mixture, will immediately render the vapour visible.

Exp. 5.—Let sulphuric acid be poured into a saucer upon some acetate of potash. Into another saucer put a mixture of about two parts quick-lime, and one of sal-ammoniac, both in powder, adding to these a *very small* quantity of boiling water. Both saucers while separate will yield *invisible* gases; but the moment they are brought close together, the operator will be enveloped in a cloud of very visible vapours.

212. Ammonia is applied to various purposes, as well in our manufactories as in medicine; but in its combination with water it

is preferred; it is also a valuable re-agent to the chemist.

Ammonia is of use in making archil, an article in great demand with dyers; it is constantly employed in chemical laboratories to distinguish zinc from other metals, and to detect the presence of copper, cobalt, &c.

Exp. 1.—Pour a little caustic ammonia into a clear solution of sulphate of zinc. This will precipitate the metal in a white powder. If the phial be now shaken, the zinc will be immediately redissolved, thus serving as a test to distinguish zinc from iron and various other metals.

Exp. 2.—Drop as much nitrate of copper into water as will form a colourless solution; then add a little ammonia, equally colourless, and an intense blue colour will arise from the mixture.

Exp. 3.—Take the blue solution formed by the last experiment, add a little sulphuric acid, and the colour will *disappear;* pour in a little solution of caustic ammonia, and the blue colour will be restored. Thus may the liquor be alternately changed at pleasure.

Exp. 4.—Dissolve some oxide of cobalt in caustic ammonia; this will produce a *red* solution different in colour from that of all other metallic solutions.

213. This alkali, when combined with carbonic acid, takes a concrete form and a beautiful white colour; being then the article known in commerce by the name of *volatile salts.*

Exp.—When ammoniacal gas is passed into carbonic acid gas, the two gases become condensed, and a crystallization of carbonate of ammonia, in silky fibres or fine powder, takes place upon the internal surface of the vessel. This is a beautiful experiment; but it must be made over mercury, and not upon water, as water would absorb the ammoniacal gas.

214. Ammonia is serviceable in dyeing, and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

215. The muriate is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac.*

Exp. 1.—Convey some muriatic acid gas into a glass jar containing a portion of ammoniacal gas. From the mixture of these two invisible gases a solid substance will be produced; viz. the common sal-ammoniac: this may be perceived to deposit itself upon the sides of the vessel in a neat crystallized form.

Exp. 2.—Take carbonate of ammonia (the common volatile *smelling* salt), and pour upon it muriatic acid so long as any effervescence continues. The produce will be a solid salt, perfectly *inodorous*, and of little taste.

216. Sal-ammoniac is also employed in many of our manufactories, particularly by dyers to give a brightness to certain colours; also by braziers, tin-plate workers, and others; and in medicine.

Sal-ammoniac is used also by some dyers in what they call composition, to prevent the tin from precipitating. In tinning metals it is of use to cleanse the surfaces, and to prevent them from oxidizing by the heat which is given to them in the operation. This salt is employed also in the assay of metals, to discover the presence of iron.

217. Formerly we were indebted to Egypt for the chief supply of this very useful salt, but now it is made in various parts of Great Britain.

CHAPTER VII.

OF THE ACIDS.

218. THE name ACID, in the language of chemists, has been given to all substances, whether liquids or solids, which produce that sensation on the tongue which we call *sour:* some however are comprehended in this class which do not possess this character.

219. Acids change the blue, green, and purple juices of vegetables to red; and combine with alkalies, earths, or metallic oxides, so as to form those compounds called *salts.*

It is desirable as soon as possible to give the chemical student correct ideas of the properties of the acids and alkalies. To this end, let him be early instructed in the use of chemical tests. If he be accustomed to carry a few test papers in his pocket-book, it will be a very rational amusement to try the succulent vegetables which he will meet with in his walks, many of which will be found to contain acids of different kinds. The hope of making an important discovery will furnish an additional zest to this employment.

Exp. 1.—Make an infusion of red roses, violets, or mallow flowers; treat it with solution of potash, and it will become *green;* the addition of diluted muriatic acid will convert it immediately to a *red.* This experiment may be frequently varied, and furnishes an excellent test for acids and alkalies.

Exp. 2.—Pour a little tincture of litmus into a wine glass, and into another some diluted sulphate of indigo; pour these two blue fluids together, and the mixture will become perfectly red.

Exp. 3.—Take a slip of blue litmus paper, dip it into acetous acid, and it will immediately become red. This is a test so delicate, that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its original blue colour.

Exp. 4.—Take some water impregnated with carbonic acid, and add to it a little blue tincture of litmus. The whole will be changed to a red.

Exp. 5.—Take some of the same carbonated water, and boil it. Then add a little tincture of litmus, and the blue colour will experience no change.

220. Most of the acids owe their origin to the combination of certain substances with oxygen, which was formerly called the acidifying principle. These axioms must, however, be now received with some limitation.

The substances which are combined with oxygen to form acids are (in all the decomposable acids) *combustible* substances. Indeed several of the acids are the *product* of combustion: witness the sulphuric, the phosphoric, &c. Five of the metals, and the other simple combustibles, hydrogen not excepted, are all convertible into acids.

The term OXYGEN is derived from the Greek words *oxys geinomai*, signifying *that which produces or generates acids:* but as Sir Humphry Davy has discovered that this substance is necessary also to the production of the alkalies, some other term, surely, should be found that would be more applicable to this wonderful invisible agent!

221. Some acids may be decomposed, and deprived of their oxygen, and others may be formed artificially by a direct combination of oxygen with certain radicals.

Any combustible body, that has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid. Charcoal, when made red-hot, will in this way decompose sulphuric acid.

Exp. 1.—Put a little common sulphur into an iron dish, place it under a jar of oxygen gas, and set fire to it, and sulphuric acid will be formed. This is an example of the formation of an acid by combustion.

Exp. 2.—Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the decomposition of an acid.

222. Some of these acidifiable radicals combine with different proportions of oxygen, and consequently produce different states of acidity.

The first portion of oxygen converts some bodies into oxides, as is the case with carbon, forming carbonic oxide; and sulphur, forming oxide of sulphur: the second, into that class of acids of which the specific names drawn from their particular bases terminate in *ous*, as the sulphurous acid: the third degree of oxygenizement changes some of these into that division of acids which are distinguished by the termination in *ic*, as the sulphuric acid, &c.

223. When two acids have the same radical, but contain different quantities of oxygen, they are distinguished by their termination. The name of that which contains most oxygen ends in IC, the other in OUS. Thus we say *sulphuric* acid, and *sulphurous* acid; *phosphoric* acid, and *phosphorous* acid.

224. A variety of substances are capable of being acidified by oxygen; for the mineral, the vegetable, and the animal kingdoms, all furnish bases or radicals, which become acid by their union with this important agent.

The mineral acids are generally formed with a peculiar base and oxygen; the vegetable acids, with carbon, hydrogen, and oxygen; while the animal acids are composed of the same substances united with nitrogen.

Some of the mineral acids are decomposable, as already mentioned, by charcoal heated to redness. Some of the vegetable acids are also decomposed, and reduced into water and carbonic acid, by leaving them in an exposed situation to the action of their own principles: others may be changed into different acids, by imparting or abstracting a portion of oxygen.

The animal acids are of all others the most liable to decomposition. In an elevated temperature the carbon and oxygen unite to form carbonic acid, and the hydrogen and nitrogen combine to produce volatile alkali.

225. There are substances however that possess acid properties which contain no oxygen. Until lately, there were also three acids whose composition was unknown.

Those acids were, the muriatic, the fluoric, and the boracic; these, however, have now yielded to the power of voltaic electricity, and their bases have been separated.

Sulphuretted hydrogen has all the properties of an acid without oxygen; but the following experiments show that it has a great affinity for that substance. And it has not yet been proved that prussic acid contains any oxygen. Iodine and chlorine also are capable of forming distinct and peculiar acids by combination with hydrogen.

Exp. 1.—If a bit of silk be immersed in diluted acetate of lead, and exposed while *wet* to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself, like a passing shadow, over the whole surface of the silk, accompanied with a bright coat of reduced lead resembling silver.

Exp. 2.—If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while *wet* to a stream of the same gas, reduced tin of great brightness will immediately cover the surface, and in a little time this will be accompanied by various colours, such as blue, orange, and purple.

Exp. 3.—A piece of silk, treated in the same way, but dipped in an aqueous solution of muriate of arsenic, will be covered with resplendent metallic arsenic, attended with a citron yellow colour.

226. The acids were formerly divided into three classes, viz. the mineral, the vegetable,

and the animal acids; but the more useful and scientific way of dividing the acids is into two classes only.

227. The undecomposable acids, and those which are formed with two principles, are comprised in the first class; while those acids which are formed with more than two principles compose the second class.

Fourcroy, in his work entitled *Philosophie Chimique*, divides the acids into four classes: 1st, those with known radicals; 2d, unknown ditto; 3d, single ditto; 4th, compound ditto: but I conceive that the above division is better calculated for an elementary treatise.

228. The acids of the first class are, the sulphuric, the sulphurous, and the muriatic acids; the nitric, the carbonic, the phosphoric and phosphorous; the fluoric, the boracic, the arsenic and arsenous; the tungstic, the molybdic and molybdous; the telluric and the chromic acids.

229. The acids of the second class are, the acetic, the oxalic, the tartaric, the citric, the malic, the lactic, the gallic, the mucous, the benzoic, the succinic, the camphoric, the suberic, the laccic, the prussic, the sebacic, the uric, the amniotic, and the fluoboric acids.

As several of these acids are rare, and are seldom used in the arts, it will not be necessary here to give any account of their origin or properties. Confining myself *therefore to the acids which more generally occur, I shall begin with those of the first class.*

230. Sulphuric acid is procured by burning sulphur, in contact with some substance containing oxygen; by which process the sulphur combines with the oxygen, and becomes acidified. In commerce it is commonly called oil of vitriol.

The pupil may be satisfied that sulphuric acid is really produced by the combustion of sulphur, by burning a little sulphur, mixed with an eighth of its weight of nitre, in a glass jar of oxygen gas inverted over water, as directed in the *Chemical Catechism*, 10th edition, page 143. He may see that sulphuric acid has actually been formed, by adding a few drops of a solution of muriate of barytes to the water; for as this is the proper reagent for discovering the presence of sulphuric acid, it will not fail in this case to precipitate the barytes.

231. The sulphuric is a very ponderous, corrosive acid, destitute of colour and smell, and has a very strong acid taste. It has a great attraction for water, and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called sulphates.

Sulphuric acid and water combine so intimately that the compound gives out a large portion of caloric.

Sulphuric acid is a test for barytes: a single drop poured into any solution of this earth instantly causes a white precipitate. It is also a good test for lead.

Exp.—Weigh one pound of water into a vessel capable of bearing a sudden heat. Pour gradually four pounds of sulphuric acid upon the water, and stir the mixture. So great will be the condensation of the water by this mixture, that the temperature of the whole will instantly rise to 300°.

232. The sulphurous acid, like the sulphuric, is a combination of sulphur and oxygen, but with less oxygen, or, we may say, with more sulphur, than the latter.

Sulphurous acid gas is produced by the *slow* combustion of sulphur. If this gas be received in water, the gas combines with it, and sulphurous acid will be the result. Water at 40° absorbs one third of its weight of sulphurous acid gas.

Exp.—Put into a glass retort two parts of sulphuric acid, and one of mercury, and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing in a mercurial trough. In this process the mercury in the retort combines with a part of the oxygen of the sulphuric acid; and the sulphuric acid, having lost a certain portion of its oxygen, is converted into *sulphurous* acid.

233. Sulphurous acid in the gaseous state is invisible like air, but of a strong suffocating smell. It is readily absorbed by water, and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms the salts called *sulphites*.

Sulphurous acid gas is very abundant in the environs of volcanos. It was the vapour of sulphurous acid which suffocated Pliny the naturalist in that eruption of Vesuvius by which Herculaneum was swallowed up in the year of Christ 79. Sulphurous acid gas is composed of 68 parts sulphur and 32 parts oxygen. Its weight is double that of atmospheric air.

Sulphurous acid possesses very slight acid properties. Instead of changing vegetable blues to a red, as acids generally do, it invariably renders them white.

Exp.—Suspend a red rose within a glass jar similar to that described at fig. 25, Plate VI. and in that situation expose it to the confined fumes of a brimstone match. This will soon produce a change in its colour, and at length the flower will become quite white.

234. That peculiar acid which we call MURIATIC is usually obtained from sea salt. Until lately, the radical or base of this acid was entirely unknown.

Muriatic acid is disengaged from muriate of soda in the state of gas, by a process similar to that for drawing the nitric acid. It preserves its gaseous state even in the coldest temperature, unless it come in contact with water; and if thrown upon ice it melts it in an instant. It is nearly double the specific gravity of atmospheric air. It may here be remarked that all acids contain water as an essential part of their composition, and that the whole of the water cannot be separated from any of them without occasioning the destruction of the acid.

Exp.—Prepare a jar of muriatic acid gas; suffer the gas to become quite cold, and then suspend a solid lump of ice within it, and notice the effect. The gas, in consequence of its great affinity for water, will give out so much of its latent caloric, that the ice will be melted in an instant.

235. This acid in the gaseous state is invisible like air; and has a pungent suffocating

smell. With water it forms the liquid muriatic acid, which preserves the smell of the gas, and gives out white fumes when exposed to the atmosphere. This acid is much employed in the arts and in chemical laboratories. With various bases it forms the salts called *muriates.*

Liquid muriatic acid, or water saturated with this gas, is about the spec. grav. 1.196. The muriatic acid of commerce varies from about 1.120 to about 1.164.

Sulphuric, phosphoric, nitric, and some other acids may be decomposed by charcoal; muriatic acid is unalterable by any of the combustibles with which we are acquainted.

Muriatic acid is the best test for silver, owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

Exp. 1.—Pour one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collect the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. This is muriatic acid gas.

Exp. 2.—Take some of the muriatic acid of commerce, heat it in a glass retort, and muriatic acid gas may be collected as in the last experiment.

Exp. 3.—Proceed as in the first experiment, but instead of collecting the gas over mercury, receive it in a vessel containing a small portion of water. By these means liquid muriatic acid will be formed.

Exp. 4.—Take a small quantity of silver, or a piece of an ore containing silver, and digest it in some *purified* nitric acid, which will dissolve the whole of the silver. A single drop of muriatic acid will separate a portion of the silver in white flakes, which will fall to the bottom of the glass in an insoluble precipitate.

Exp. 5.—Proceed as in the last experiment; but instead of using muriatic acid, drop in a portion of common salt, which will as effectually precipitate the silver. By these means any ore may be divested of the whole of the silver that it contains.

236. It is now a prevailing opinion that the oxymuriatic acid, or chlorine as it is called, is a simple substance. It is known in the gaseous state, and in combination with water: but in the latter form, or, when combined with the alkalies or alkaline earths, it is more commonly used in the arts.

The gaseous substance which was formerly called oxygenized muriatic acid and now *chlorine*, is not a compound of muriatic acid and oxygen as has already been remarked, but a simple body obtained from common salt by distillation with the black oxide of manganese and sulphuric acid. The modern theory is this: that common salt is a true muriate of soda only while it remains in an aqueous solution; and that when reduced to dryness, both the muriatic acid and the soda become decomposed; and the hydrogen of the muriatic acid uniting with the oxygen of the soda, they both pass off in the form of water; while the chlorine of the muriatic acid uniting with the metallic base of the soda forms *chloride of sodium*, which is the true character of our common salt when in a dry state.

Exp. 1.—Chlorine gas may be obtained for chemical experiments by the following method: Put into a retort a little black oxide of manganese in powder; and pour upon this double its weight of strong muriatic acid; connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance. Its specific gravity is to that of hydrogen, nearly as 34 to 1.

Exp. 2.—If a small quantity of liquid oxymuriatic acid be wanted for experiment, it may readily be formed, mixed with a little *euchlorine*, by dissolving a few grains of oxymuriate or chlorate of potash, and adding the solution to an ounce of common muriatic acid. It is of a yellowish green colour, which was the cause of its being called *chlorine*, a name given to it by Sir Humphry Davy.

237. Chlorine gas is so suffocating, that it cannot be breathed without great injury; yet it will support combustion. This gas discharges vegetable colours; it burns all the metals, and even when combined with water, will dissolve gold and platinum: with various alkaline and earthy bases it forms salts, called chlorides.

Acids in general change blue vegetable colours to red; but chlorine destroys colour. Instead of considering it as one of the acids, it would be more proper to call it an acidifying principle, for it possesses few properties which characterize that class of bodies. Its taste is not acid, but astringent; and, unlike the acids, it combines very sparingly with water. It has not been decomposed either by electricity or galvanism; which is a presumptive proof of its being a simple substance.

The great use of chlorine is in bleaching. A full account of the methods of applying it may be seen in my Essay on Bleaching in the 4th volume of the *Chemical Essays*.

Exp. 1.—If a few strips of dyed linen cloth, of different colours, be dipped into a phial of oxy-muriatic acid, the colours will be quickly discharged; for there are few colours that can resist its energetic effects.

This experiment may be considered as a complete example of the process of bleaching coloured goods.

Exp. 2.—Procure a glass jar, such as is generally used for deflagrating the gases, and fill it with oxy-muriatic acid gas. If nickel, arsenic, or bismuth in powder be thrown into this gas, and the temperature of the atmosphere be not lower than 70°, the metal will inflame, and continue to burn with the most brilliant combustion.

Exp. 3.—Prepare a jar of chlorine (oxymuriatic gas), and suspend in it a piece of Dutch metal, or copper-foil; it will immediately inflame, and the combustion will continue till the whole is consumed, affording a very striking spectacle. It will however soon subside in the jar, and form a substance exactly similar to the native muriate of copper brought from Peru.

238. Chlorine will combine with oxygen, with hydrogen, and with nitrogen; also with carburetted hydrogen, and with the carbonic oxide; some of which combinations possess very curious properties.

Exp. 1.—Chlorine and oxygen do not unite by simple mixture; but if chlorate of potash, formerly called hyperoxymuriate of potash, be distilled by a gentle heat in a glass retort with diluted muriatic acid, a gas will be set at liberty which consists of chlorine and oxygen. If this gaseous compound be received over mercury, it will be found to possess a brighter colour than chlorine, more inclining to yellow; and its smell will be different, being like that of burnt sugar.

Exp. 2.—Hydrogen and chlorine unite readily. If equal measures of each be mixed and exposed to the light of day, the two gases will gradually combine without condensation, and the result will be muriatic acid gas. In making this experiment the mixed gases must not be submitted to the action of the sun's rays, as this would occasion them to explode.

Nitrogen does not unite with chlorine by simple mixture, but this compound may be formed by passing chlorine gas into a solution of nitrate of ammonia. By this process the salt is decomposed, and part of its nitrogen unites with the chlorine to form the compound in question, called *chloride of azote*, a substance possessing some very singular and dangerous properties.

The mixture of carburetted hydrogen with chlorine has been treated on by Dr. John Davy in the *Philosophical Transactions* for 1814. This also possesses some very remarkable properties.

Carbonic oxide and chlorine when united by peculiar management form a singular compound, which the discoverer, Dr. John Davy, has named *phosgene gas*. This compound gas, which Dr. Thomson now calls *chloro-carbonic acid*, has a very peculiar and remarkably pungent odour; it is the heaviest of all the known gases, 100 cubical inches of it weighing nearly 112 grains, which is almost four times as much as an equal volume of atmospheric air.

239. By peculiar management chlorine may likewise be combined with sulphur, with phosphorus, and with the metals, including also the metals of the earths and alkalies.

When sulphur is heated in contact with chlorine, a red fuming fluid is obtained of the specific gravity of 1.60. It is called *chloride of sulphur*, but has not yet been found to be of any use in the arts.

The combination of chlorine with phosphorus has very peculiar properties. It is a solid snow-white substance; very volatile at a temperature much below that of boiling water; is fusible when submitted to pressure, and on cooling crystallizes in transparent prisms. It has been named *phosphorana*. These compounds are now called *protochloride* and *perchloride* of phosphorus.

Chlorine is capable of combining with all the metals, and in many cases the combination is accompanied with inflammation, those metals which are most readily oxidized burning with the most brilliancy.

By heating potassium or sodium in chlorine gas, compounds may be formed resembling those which result from heating those metals in common muriatic acid gas. Ten grains of potassium or sodium absorb about eleven cubic inch measures of chlorine: but the combination is accompanied with a more brilliant combustion than when these alkaline metals are burnt in oxygen gas.

240. Chlorine has no action whatever upon charcoal, even though the charcoal be intensely hot when plunged into it. This fact has been adduced as a decisive proof that chlorine contains no oxygen.

241. Nitric acid is one of the constituent parts of nitre or saltpetre. It is a compound of oxygen and nitrogen, in the proportion of about 26 parts by weight of nitrogen, to 74 of oxygen.

Exp. 1.—Take three measures of oxygen gas and one measure and a quarter of nitrogen gas, and pass a number of electric explosions through the mixture. This will occasion a union of these gases, and *nitric acid* will be the product.

Exp. 2.—Upon an ounce or two of nitrate of potash, in a retort to which a proper receiver is joined, pour some sulphuric acid, and by means of the heat of a lamp the nitrous acid may be readily obtained.

242. Pure nitric acid is clear and colour-

less, like water; its smell is pungent, its taste exceedingly acid, and its action on animal substances very corrosive. It has the property of permanently staining the skin yellow. It has a great affinity for water; is capable of oxidizing most of the metals, and with various bases forms the salts called *nitrates.*

243. The common nitrous acid, improperly so called, is merely nitric acid impregnated with variable portions of nitrous acid gas.

Exp. 1.—If nitric acid be poured on iron filings, the acid will in part be decomposed; its oxygen will render the metal soluble, and nitrous gas will be thrown out in copious red fumes.

Exp. 2.—Take a few shreds or filings of copper, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas evolved is nitrous gas.

Exp. 3.—Take a portion of dried sulphate of iron, and an equal quantity of nitrate of potash, grind them together in a mortar, and put the whole into a small glass retort. Adapt a receiver to the retort with one or two bottles, according to the plan of Woulfe's apparatus, Plate I. fig. 1. and apply the heat of an Argand's lamp. After some time a gas will be disengaged, which will be condensed by the cold receiver, forming the true *nitrous acid.* We have here a corrosive *fluid* produced from the mixture of two *mild and solid* substances.

244. Nitrous acid is similar to *nitric* acid in its properties; but its colour varies according to the proportions of nitrous acid gas,

which it has absorbed, and the water that it contains.

Dr. Priestley having separated nitrous gas from nitric acid, by means of iron, he received the gas under an inverted vessel filled with water, and found it a transparent *colourless gas*, resembling air; whence it appears that it is red or coloured, only when combined with atmospheric air.

Nitrous acid is generally used for purposes of manufacture and experiment. The *nitric* acid is principally employed in medicine. Two parts of either nitrous or nitric acid, and one of muriatic acid, form aqua regia, or nitro-muriatic acid, the true solvent of gold.

The changes which take place on the addition of water to strong nitrous acid exhibit very curious phenomena. Different portions change its colour to a blue, a green, a yellow, &c. while the vapours which rise from it preserve their original flame-coloured red.

Exp. 1.—If four parts of water, by measure, be added to twelve parts of strong fuming nitrous acid, the colour will be changed from a deep *yellow* to a *green.*

Exp. 2.—Mix four measures more of water with the diluted acid produced in the last experiment, and the colour will thereby be changed to a *paler green*, mixed with *yellow.*

Exp. 3.—Add four measures more of water to the above, and the green will *disappear*, and a *pale yellow* acid will be produced.

Exp. 4.—If 40 measures of water be now added to the yellow acid produced in the last experiment, you will have an acid as colourless as pure water.

245. Carbonic acid is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being so intimately combined in chalk, limestone, magnesia, &c.

Carbonic acid is composed of 27.5 parts carbon and 72.5 oxygen; which has been ascertained by analysis as well as synthesis.

Exp. 1.—Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red-hot, remove them from the fire; and when cold, the carbonic acid of the chalk will have been decomposed, and the *black charcoal*, the basis of the acid, may be easily perceived amongst the materials.

Exp. 2.—Put about an ounce of marble grossly pulverized into an eight-ounce phial, with about an equal quantity of water. Pour upon it a little sulphuric acid, and carbonic acid gas will be evolved.

246. Carbonic acid is invisible when in the state of gas, and unfit for combustion, or respiration. Water, by pressure, may be made to absorb three times its bulk of this gas; by which it acquires an acidulous and not unpleasant taste. Carbonic acid in the proportion in which it exists in atmospheric air is favourable to the growth of vegetables, but in a large proportion is highly injurious. This acid enters into combination with the alkalies, with earths, and metallic oxides, and forms with them those salts called *carbonates*.

The earthy carbonates are insoluble in water. Hence breathing into a phial of lime-water renders it turbid. Thus lime-water is a good test for the presence of carbonic acid.

Carbonic acid gas is found in abundance in many natural waters. Those of Pyrmont, Spa, and Seltzer, are instances; the last particularly is highly impregnated with this acid.

M. Saussure jun. found by experiment that an atmosphere containing even an eighth part of carbonic acid aids the growth of vegetables, but that when in a larger proportion it is injurious.

Exp. 1.—To a glass of water, suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a sparkling appearance on the sides of the glass and surface of the fluid.

Exp. 2.—Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas, and cautiously pour it into the jar containing the taper. This being an *invisible* gas, the operator will appear to invert merely an *empty* vessel, though the taper will be as effectually and instantaneously extinguished as if water itself had been used.

Exp. 3.—Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potash, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its inner surface will be seen covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

247. Phosphoric acid is a compound of oxygen and a peculiar substance called phosphorus. It was formerly procured only by burning phosphorus in oxygen gas; but since it is known that this acid is a component part of animal bones, we now procure it from that source.

When animal bones are divested of their oil and jelly, the earth which remains is chiefly lime, united with phosphoric acid, and this phosphate of lime is often employed for the preparation of the medicinal salt called phosphate of soda. But Mons. Chaptal jun. son of the Count Chaptal, employs bones in Paris, as I am informed, in a very different manner. Having a large establishment for the preparation of soda, in which process a larger quantity of muriatic acid is afforded than can be consumed in the ordinary way, he employs persons to collect bones from all parts of the city, and digests them in this spare muriatic acid. The acid dissolves the phosphate of lime, and leaves the gelatine. The latter is made into soup, and distributed throughout every district of Paris.

248. Phosphoric acid is very soluble in water; the solution is colourless; it has a strong acid taste; by evaporation the solution becomes very dense and of an oily consistence. It forms by its union with earthy, alkaline, and metallic bases, that variety of salts which we call *phosphates*, and occurs in nature combined with lime, oxide of lead, and other bases.

Pure phosphoric acid obtained, without the addition of water, by burning phosphorus in oxygen gas, has the form of white, snowy, light flocks, of a very strong acid taste. By exposure to the air it attracts humidity, and becomes a *fluid* acid.

Phosphoric acid may be concentrated until it be of greater specific gravity than sulphuric acid; but though the taste is very acrid, it does not possess a causticity sufficient to burn organic substances, like sulphuric acid.

249. Phosphorous acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus.

Exp.—Phosphorous acid is prepared by exposing sticks of phosphorus to the action of atmospheric air, in a glass funnel, and receiving the acid, as it forms, in a bottle placed underneath. Two or three pieces of broken glass placed in the neck of the funnel to support the phosphorus, and a small quantity of distilled water put into the receiving bottle, complete this simple apparatus. The pieces of phosphorus should be placed so as not to touch each other.

250. Phosphorous acid is a dense, viscid liquid, with an acid taste, and emits the smell of garlic when heated. This, like the phosphoric acid, may be decomposed by charcoal, but cannot be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites.*

251. The fluoric is an acid of a very peculiar nature, found in the fluor spar, which is a natural production, composed of fluoric acid and lime.

Fluoric acid is obtained by pouring sulphuric acid upon the powdered spar in a leaden retort, and applying a gentle heat. The sulphuric acid expels the fluoric, and unites with the lime in its stead. To preserve the liquid acid, it should be kept in vessels of lead or platinum.

252. In the state of gas it is invisible like

air. Water rapidly absorbs it, and forms liquid fluoric acid. It has an acid taste, and the peculiar property of corroding silica. With the alkalies and earths it forms salts called *fluates*. Though it has been decomposed, the nature of its radical is not yet known.

This acid acts so powerfully on silica that it is impossible to use glass vessels for its distillation. A glass retort would be destroyed before a pound of the gas could be obtained. It combines with the siliceous earth of the glass, and carries it over with it in distillation.

Exp. 1.—Its action on glass may be shown by strewing some powdered fluor spar on the surface of a pane of glass, and pouring a little sulphuric acid upon it. The sulphuric acid will disengage the fluoric acid from the spar, which will act upon the glass immediately as it becomes disengaged, and destroy the polish.

Exp. 2.—If a small animal or reptile be exposed to the vapour of this acid, drawn in glass, the animal moisture will absorb the acid, and the silica will be precipitated, so as to give it the appearance of a real petrifaction, or an animal covered with stone.

It has been a fashionable employment for young ladies to etch landscapes and other drawings on glass by means of this acid. They cover the surface of the glass with wax, and trace any kind of drawing upon it by cutting out the wax with proper instruments. The piece is then put into a leaden receiver, and the gas, disengaged from the fluor spar by means of an Argand's lamp, is thrown in upon it. In this way drawings of great beauty are made as imperishable as the glass itself.

253. Silicated fluoric gas is a compound gas

of great specific gravity, and is merely fluoric acid holding a large portion of silica in solution.

Pure fluoric acid has never been obtained in the state of gas, and yet when combined either with silica or boracic acid it is capable of assuming that form.

254. Fluoboric acid is a compound of the fluoric and boracic acids, neither interesting nor useful.

255. The boracic is a peculiar acid separated from a substance called borax. Until lately the nature of its radical was unknown.

See the note at N° 225.

Exp. 1.—Dissolve some refined borax in hot water, and add sulphuric acid till the solution has a slight acid taste. If the whole be then left to cool, crystals of boracic acid will be found at the bottom of the vessel.

Exp. 2.—Expose some crystals of boracic acid to a strong heat, until they become fused; a solid white glass will thus be formed, fit to be employed in the composition of artificial gems.

256. Boracic acid is in the form of thin scales, slightly acid, and unalterable in the air. It forms, when combined with the alkalies, some earths, and some of the metallic oxides, the variety of salts called *borates*. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies.

This acid is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all the stones into solution.

Exp. 1.—If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful green flame.

Exp. 2.—If a paper be dipped in alcohol and then sprinkled with this acid, that will burn with a green flame.

257. Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass; very soluble in hot water; of an acid taste, and extremely poisonous. With different bases it forms the salts called *arseniates.*

Arsenic acid is not affected by exposure to the air. It is composed of 66 parts of arsenic and 34 oxygen. It is made by giving more oxygen to the common white oxide of arsenic, known to chemists by the name of the *arsenous* acid; this being a compound of two atoms arsenic and three atoms oxygen, while the arsenic acid is composed of two atoms arsenic and five atoms of oxygen.

258. Acetic acid is principally obtained from saccharine liquors which have undergone the vinous fermentation.

In making vinegar, the casks should be only half filled; that a large surface of the liquor may be exposed to the atmosphere, from whence the oxygen is to be derived to acidify it.

259. Acetic acid, as it is usually prepared, is a pleasant yellow liquor, well known. When distilled it is as colourless as water, and of an

agreeable odour. In both states it is known in commerce by the name of vinegar.

260. Concentrated acetic acid, or radical vinegar as it is sometimes called, is obtained from acetate of copper, acetate of soda, or acetate of potash, by decomposing either of them by means of sulphuric acid, and then distilling the product.

261. Acetic acid thus prepared is very pungent, acrid and volatile, and corrodes animal substances. With various bases it forms the salts called *acetates.*

This acid evaporates entirely when exposed to the air; and when heated with free access of atmospheric air, it takes fire so readily that one is tempted to suspect the presence of *ether* in it. It dissolves camphor, and, with the addition of essential oils, forms the *aromatic vinegar.*

262. The oxalic is a peculiar acid found in the juice of sorrel, in combination with potash. Several substances also, and particularly sugar, contain the bases of this acid in a convenient form for conversion into oxalic acid by combining with oxygen; and hence this acid has been called the acid of sugar. It crystallizes in four-sided prisms, has a very acid taste, is soluble in water, and highly poisonous. It is composed of oxygen, hydrogen, and carbon.

Sal-acetosellæ, or the salt of sorrel of commerce, is the superoxalate of potash. It has usually been imported from Switzerland and the neighbouring countries, where it is prepared in large quantities from the juice of sorrel.

Oxalic acid when taken into the stomach in a quantity equal to two drachms or upwards, destroys the coats of that viscus, and produces almost instantaneous death.

263. Oxalic acid is of service in detecting the presence of lime in solution. It has also been an article of great consumption with the calico-printers, both in the state of crystallized oxalic acid, and in that of superoxalate of potash. In combination with earths, alkalies, and metallic oxides, it forms the salts called *oxalates*.

The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth.

The oxalic acidule attacks iron, zinc, tin, antimony, and lead. It dissolves also the oxides of all the other metals, and forms with them triple salts.

Exp. 1.—Pour a few drops of the solution of oxalic acid into a neutral solution of muriate of lime, and an abundant precipitate of insoluble oxalate of lime will immediately appear. If there be any excess of muriatic acid in the solution, the lime will be redissolved. Hence the superiority of oxalate of ammonia, to simple oxalic acid, as a test.

Exp. 2.—Spot a piece of linen with common ink, and, when the spots are dry, rub them over with a solution of oxalate of potash. This will dissolve the iron in the ink, and the stains will consequently disappear.

264. Tartaric acid is a peculiar acid found in the tartar of commerce. It is capable of crystallization, and easily soluble in water. It is used by calico-printers to discharge false prints. The salts formed with it are called *tartrates.*

Tartaric acid appears to be a necessary substance in all wine; for it seems from experiment that *must* will not ferment if all the tartaric acid be taken from it.

265. Citric acid is found in the juice of limes, lemons, and several other fruits. It crystallizes in beautiful rhomboidal prisms, is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, for medicine, and in the arts. The salts formed with it are called *citrates.*

This elegant acid is very useful to our manufacturers on account of its solubility. One ounce of cold water will dissolve 1½ oz. of it, and boiling water will dissolve double its weight.

Exp. 1.—This acid may be kept ready mixed with either of the dry carbonates of potash or soda; and, as no effervescence ensues till the mixed powder is put into water, we have a ready mode of making a pleasant saline draught.

Exp. 2.—Dip a piece of white calico in a cold solution of sulphate of iron, and suffer it to become entirely dry. Then imprint any figures upon it with a strong solution of colourless citric acid, and allow this to dry also. If the piece be then well washed in pure warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either of a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white. This experiment is designed to show the effect of acids in discharging vegetable colours.

Exp. 3.—If lemon juice be dropped upon any kind of buff colour, the dye will be instantly discharged. The application of this acid by means of the block, is another method by which calico-printers give the white spots or figures to piece goods. The crystallized acid in a state of solution is generally used for this purpose.

266. Malic acid is obtained from the juice of apples, in which it exists ready formed. It is a very acid, reddish-coloured liquid, composed, like the other vegetable-acids, of oxygen, hydrogen, and carbon. In its usual state it is incapable of crystallization, and has not yet been brought into any use except as a chemical test. Its salts are called *malates.*

The malic acid is found not only in apples, but in strawberries and other summer fruits. It was discovered by Scheele in the year 1785.

Malic acid is of use in the analysis of earths for separating alumina from magnesia.

267. Lactic acid is prepared by a peculiar process from milk after the curd has been separated. It is an acid of a yellow colour, incapable of crystallization, and has not hitherto come into use. The salts formed with it are called *lactates.* The earthy and alkaline lactates are all deliquescent salts.

Lactic acid is prepared by evaporating sour whey to one-eighth of its volume; filtrating the liquor to separate all the caseous matter, and adding lime-water to precipitate the phosphate of lime; it is then diluted with water, and the excess of lime is precipitated by oxalic acid; the liquor is evaporated to the consistence of honey; alcohol is then poured in, which separates all extraneous matter and dissolves the lactic acid; lastly, the liquor being drawn off clear is distilled till all the alcohol that has been added is collected; and what remains in the retort is pure *lactic acid.*

268. Gallic acid is found in the nut-galls of commerce, and in most astringent vegetable substances. It is obtained in thin transparent plates, and in minute needle-shaped crystals, of an acid austere taste. It has the property of precipitating iron, from its solution in acids, of a black colour. Its salts are called *gallates.*

Gallic acid exists in galls, in oak bark, and other vegetables, independently of the astringent principle. It has been found that the property of giving a black colour to the solutions of iron is owing to this acid, and not to the astringent principle as was formerly supposed.

Exp. 1.—Prepare a phial with pure water and a little tincture of galls; and another with a weak solution of sulphate of iron; then mix these transparent colourless fluids together, and they will instantly become black.

Exp. 2.—Write with a weak solution of sulphate of iron; let it dry, and it will be invisible. By dipping a feather in tincture of galls and drawing the wet feather over the letters, the writing will be restored and appear black.

Every substance, an infusion of which precipitates gelatine from its solution, possesses a tanning property.

Exp. 3.—Add a few drops of the solution of common glue to a wine-glass full of an infusion of the substance to be examined. If tannin be present the liquor will become turbid, and a whitish substance will precipitate, which is a true powder of leather.

The gallic acid may be entirely freed from the tanning principle by means of muriate of tin. The tan will unite with the muriate of tin, and form with it an insoluble precipitate. There is reason to believe that tan is the source of the astringent principle in all astringent vegetables.

269. Mucous, or saccholactic, acid, as it has been called, is obtained by nitric acid from gum arabic and other mucilaginous substances. It is in the form of a white gritty powder, with a slightly acid taste. Its salts are called *mucites.*

Exp.—Upon one ounce of pulverized gum arabic in a small glass retort, pour two ounces of nitric acid. Apply a gentle heat for a short time, till a little nitrous gas and carbonic acid gas come over; then allow the mixture to cool. A white powder gradually precipitates, which may be easily separated by filtration. This powder is saccholactic or mucous acid.

270. Benzoic acid is prepared from a vegetable resin called benzoin. It is a light whitish powder, with a peculiar and aromatic odour. Its taste is acrid and bitter. It is unalterable in the air, insoluble in cold but soluble in boiling water. It is used in medicine under the name of flowers of benjamin. Its salts are called *benzoates.*

Benzoin is a resin procured from a tree which grows in the island of Sumatra. The acid procured from this resin has been known for 200 years. It is obtained from benzoin, in the form of flowers, by sublimation.

Exp. 1.—Boil some benzoin with carbonate of soda, and add to the filtered decoction diluted sulphuric acid so long as it produces any precipitation. The precipitate which forms, is the benzoic acid.

Exp. 2.—Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of sublimation.

271. Succinic acid is prepared from amber. It takes the form of shining white crystals, of a slight acid taste. In a great heat it sublimes. It is soluble in hot, but dissolves in small quantities in cold water. It is useful as a re-agent, but of no use in the arts. Its salts are called *succinates.*

Amber is a transparent combustible substance, dug out of the earth, or found upon the sea-coast. It manifests electricity by friction, and was much admired by the ancients as an ornament of dress.

Exp. 1.—Fill a retort half way with equal parts of powdered amber and dry sand; lute on a receiver, and distil in a sand-bath with a gentle heat. The succinic acid will attach itself to the neck of the retort.

When combined with ammonia this acid becomes a valuable re-agent, by the property of separating iron from its solutions, and not operating upon other metals.

Exp. 2.—Pour a little of this succinate of ammonia to a solution of sulphate of iron, and a succinate of the metal will be precipitated. It may be calculated that every 100 grains of the precipitate contain 68 grains of iron.

272. Camphoric acid is prepared from camphor by means of nitric acid. It is in very white crystals, which have a slightly acid, bitter taste, and a smell like saffron. It is very slightly soluble, requiring 100 times its weight of cold water to dissolve it. In boiling water it is much more readily soluble, and will dissolve in any quantity in boiling alcohol. With salifiable bases it forms *camphorates.*

Camphor is a white crystalline substance of a very strong taste and smell, obtained in the East from a species of laurel. It is so inflammable that it burns even on water.

273. Suberic acid is not a native production, but is formed from cork by means of nitric acid. Its taste is acid; it is generally seen in the state of powder, and is not crystallizable. Boiling water dissolves half its weight, but it is very insoluble in cold water. Its salts are called *suberates.*

This acid was discovered by Brugnatelli in the year 1787. He gave it the name of suberic acid from *suber,* the Latin name of the cork-tree.

Neither this acid nor any of its compounds have ever been of any use in the arts.

274. Laccic acid is procured from a substance called *white lac.* It is a reddish fluid which has a bitter saltish taste, but not at all sour. It crystallizes in needle-like crystals, and when dissolved in lime-water assumes a green colour.

White lac is a peculiar substance distinct from the shell lac and stick lac of commerce, and is brought from the East Indies. This substance, which has a resemblance to bees'-wax, is secreted by an opaque and rough insect, of a gray colour.

Laccic acid was discovered by Dr. Pearson. It is generally in a fluid state. Its specific gravity at 60° is 1.025, and when heated it has the smell of newly baked bread.

275. The prussic or hydrocyanic acid is a peculiar acid, composed of hydrogen, nitrogen, and carbon. It is a colourless liquid like water, has a sweet acrid taste, and is extremely poisonous. It is of great use to chemists for detecting metals in solution. It is prepared from blood and other animal substances; and when united with iron forms that beautiful colouring substance called prussian blue.

A method of obtaining prussic acid in a state of absolute purity has been announced: it is merely by distilling a mixture of two parts of prussian blue, one of sulphuric acid, and one of water.

There is great reason for believing that hydrocyanic or prussic acid does not contain oxygen.

Prussian blue was discovered by accident in the year

1709; but it was not till the year 1775 that Bergman ascertained that this colouring matter was a peculiar acid.

Exp. 1.—Into a wine-glass of water put a few drops of prussiate of potash, and a little dilute solution of sulphate of iron into another glass: by pouring these two *colourless* fluids together, a bright deep blue colour will be immediately produced, which is the true prussian blue.

Exp. 2.—Put some prussiate of potash into one glass; into another a little nitrate of bismuth. On mixing these colourless fluids, a yellow will be the product.

Exp. 3.—Pour a little prussiate of potash into a glass containing a *colourless* solution of sulphate of copper, and a reddish brown will be produced, being a true prussiate of copper.

Exp. 4.—Take water holding carbonate of iron in solution, and add some diluted prussiate of potash: prussian blue will be formed by the mixture.

Exp. 5.—Take some of the same water as that used in the last experiment; boil it, and now add prussiate of potash. In this case no colour will be produced.

276. Sebacic acid is procured from animal fat or tallow. It is in the form of a liquid, has an acid, sharp, bitterish taste; and when mixed with nitric acid will dissolve gold. It combines with alkalies, earths, and metallic oxides, and forms the salts called *sebates.*

Sebacic acid crystallizes in needles, and when heated liquefies like tallow.

277. The Uric or lithic acid is found in human urine. Some calculi are composed en-

tirely of this acid. When pure it has neither taste nor smell, but it reddens vegetable blues, and combines with alkalies and earths.

If urine voided in the morning after sleep be preserved, the liquor will in a few hours present a light cloud, which occupies the upper part of the vessel; this cloud, gradually augmenting in quantity, subsides, and becomes a sediment of small red crystals, with brilliant facets; this is *uric acid.*

Nitric acid is a test for discovering uric acid. If a little uric acid be heated in a watch-glass over a lamp, the smallest quantity of nitric acid that can possibly be conveyed upon it will instantly convert it to a very brilliant crimson. Uric acid dissolved in nitric acid stains the skin of a pink colour.

Dr. Prout has discovered that a new acid may be formed by the action of nitric acid on uric acid. Dr. Wollaston has named the new substance *purpuric* acid.

Those concretions called chalk-stones, which form upon the joints of gouty persons, are for the most part composed of uric acid and soda.

278. Amniotic acid is obtained from the liquor of the amnios of the cow. It is slightly acid; it reddens the tincture of turnsole; and may be obtained in brilliant white crystals. It is scarcely soluble in cold water, though very readily in hot water. It is incapable of decomposing the alkaline carbonates, but unites with the pure alkalies, and with them forms neutral salts.

The amniotic acid was discovered by Vauquelin and his coadjutor Buniva. In order to obtain it, nothing more is necessary than to evaporate the liquor of the amnios of the cow to one-fourth, and leave the remainder to cool, which will be found to contain the acid in crystals.

The MELLITIC and the COLUMBIC acids I have omitted to describe, because the minerals from which they are procured are so rare, that few chemists will ever be likely to obtain even a specimen of them.

279. The NUMBER of the acids that are well known amounts to more than forty; besides which, a variety of substances have been announced as new acids, that require to be further examined before they be finally admitted into this class of bodies.

For these speculations we are indebted to some of the foreign chemists. The following however do seem, on good authority, to be really new and distinct acids, viz. the hydrosulphurous, uranic, manganesic, purpuric, ellagic, lampic and pyromucic. For an account of their several properties, see the Introduction to the xiiith volume of Thomson's *Annals*, page 44 to 56.

280. The USES of the acids are so many and important, that it is impossible to enumerate them. They are indispensable to various arts and manufactures; they are employed for culinary purposes, and for medicine; they act an important part in the great elaboratory of nature,—they produce that numerous class of bodies called salts, and form a great proportion of many of the mountainous districts of the globe.

CHAPTER VIII.

OF THE SALTS.

281. When an acid is combined with an alkali, an earth, or a metallic oxide, it forms what is called A SALT. Such compounds were formerly called *neutral* salts; but that term is now applied only to those salts in which there is no excess either of acid or of base.

To give the pupil a clear idea of this class of bodies, it may be advisable to set him to form some of the salts from their component parts.

Exp. 1.—Pour a little sulphuric acid into a solution of soda in water, evaporate the superfluous water, and then notice the crystallization of the newly-formed salt. If the liquor be allowed to stand for a few hours undisturbed in a cool place, the salt will be seen to shoot into beautiful crystals of sulphate of soda.

Exp. 2.—Dissolve some magnesia in diluted sulphuric acid, so as to saturate the acid. Pour off the clear liquid, and evaporate a portion of the superfluous water. If the remainder be suffered to cool, a crystallized salt will be formed, similar in every respect to Epsom salt.

Exp. 3.—Put about half an ounce of quicksilver into an oil flask, and pour about an ounce of diluted nitric acid upon it. The nitric acid will be decomposed by the metal with astonishing rapidity; the bulk of the acid will be quickly changed to a beautiful green, while its surface exhibits a dark crimson: and an effervescence indescribably vivid and pleasing will go on during the whole time the acid operates upon the quicksilver. When a part only of the metal is dissolved, a change of colour will again take place, and the acid by degrees will become paler, till it is as pellucid as pure water. This is one instance of a metallic solution by means of an acid; in which the opacity of a metallic body is completely overcome, and the whole rendered perfectly transparent.

Exp. 4.—Take the metallic solution formed in the last experiment, add a little more quicksilver to saturate the acid; then place it at some distance, over the flame of a lamp, so as gently to evaporate a part of the water. The new formed salt will soon be seen to begin to shoot into needle-like prismatic crystals, crossing each other in every possible direction; affording an instance of the formation of a metallic salt.

282. As the acids are capable of forming various combinations with the different earthy, alkaline, and metallic bases, the precise number of the salts is not known. Probably they amount to more than two thousand.

283. There is such a great variety of salts, that it has been thought necessary to adopt a new nomenclature for the purpose of distinguishing one species from another; and this nomenclature is as simple and ingenious as it is useful.

284. In this nomenclature every salt has a double name, one part of which indicates its acid, and the other its base; so that, in a collection of many hundred different salts, the

composition of each is immediately known by its appellation.

Forty years ago not more than 20 or 30 species were known; since then more than 100 new species, comprising many more than a thousand distinct salts, have been added to the list.

285. All substances which are compounds of metallic oxides, earths, or alkalies with the sulphuric acid, are called *sulphates;* with the muriatic acid, *muriates;* with the nitric acid, *nitrates;* with the carbonic acid, *carbonates*, &c. &c.

These are the terms generally made use of in chemical language; but sometimes, in order to prevent monotony, we give an adjective termination to the word which expresses the base of the acid. Thus we say calcareous salts, instead of salt of lime; ammoniacal salts, instead of salts of ammonia; aluminous salt, instead of salt of alumina; and with the same design, the terms barytic, magnesian, and the like, are used.

286. In conformity with this plan, the saline compound, formerly called *Glauber's* salt, is now called sulphate of soda, because it is a combination of sulphuric acid and soda; what was called *gypsum*, or plaster of Paris, a compound of lime and sulphuric acid, is now called sulphate of lime; in like manner, what was called *green copperas* is now sulphate of iron, that substance being a compound, not of copper, as the old name seemed to import, but of *iron* and sulphuric acid.

It would be easy to make out a long list of substances with names equally improper with those noted above, and which have characteristic and appropriate names now assigned them in the new nomenclature.

It is necessary to remark, that when an acid is combined with *two* bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumina and potash, and tartrate of potash and soda.

287. I have said that these bodies were formerly called neutral salts, but no salt can strictly be called *neutral*, except such in which the acid is completely neutralized by the base, and the base by the acid, so as for the acid and the base to be mutually saturated by each other.

The propriety of restricting the use of the term *neutral* will appear, if we consider that we have some bases that combine with more than one dose of acid, and thereby form salts which differ in their appearance and properties. Thus we have *sulphate* of potash, and *super*-sulphate of potash. The former is a neutral salt, the latter a salt with excess of acid. These salts are however now called sulphate of potash, and bi-sulphate of potash; which are terms more appropriate, because 100 parts of potash combine with 82 parts of sulphuric acid to form the sulphate; and with twice that quantity or 164 of acid to compose the bi-sulphate.

288. This is not the case with all saline compounds; for some have an excess of acid, as cream of tartar and most of the metallic salts; others have an excess of base, as common borax.

Many of these super-salts may be discovered by carbonate of magnesia: for, if an acid be present in the solution, an effervescence will take place on the addition of the magnesian carbonate.

289. When a salt is found to contain an excess of acid, the preposition SUPER is generally prefixed to its name; but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added: thus we say super-tartrate of potash, and sub-borate of soda.

We are indebted to Dr. Pearson for this mode of distinguishing these salts. Before his method was adopted, the former of these salts was called tartrate of potash with excess of acid, or acidulous tartrate of potash, and the latter, borate of soda with excess of base.

290. Some salts are formed with acids not fully oxygenized, as the sulphurous and phosphorous acids: all salts therefore that are composed with such acids, or with acids ending in *ous*, take an ending in *ite*, instead of *ate*; as *sulphite* of lime, or *phosphite* of potash.

When sulphur is fully saturated with oxygen, it forms what is called sulphuric acid, and the salts composed with this acid are called sulphates. But when sulphur is partially oxygenized, an acid is produced called sulphurous acid, and the salts formed with it are called sulphites.

The new nomenclature thus enables us to distinguish between acids which are partially oxygenized, and those which contain a maximum of oxygen. This is of great importance, because the properties of the salts formed with these acids vary as much as the acids themselves.

* * * * * *

Having shown the nature of the present chemical nomenclature as far as respects the salts, it will now be necessary to enter on the consideration of each genus separately :—We begin with the SULPHATES.

291. The sulphates have generally a bitter taste; are always decomposed by the agency of a solution of barytes; and most of them afford sulphurets when heated red-hot with charcoal.

When a sulphate has been converted to a sulphuret by being submitted to a red heat in conjunction with charcoal, the sulphuret may be decomposed, and the sulphur precipitated by the addition of pyroligneous acid.

If any of the solutions of barytes be added to a solution containing sulphuric acid, a sulphate of barytes will instantly be formed and precipitated, and every 100 grains of the precipitate, when dried, indicate 24 grains of sulphuric acid.

Exp.—Into some Epsom mineral water, or any water containing a sulphuric salt, pour a transparent solution of muriate or acetate of barytes, and an immediate precipitate of sulphate of barytes will be occasioned.

292. Among the first of these sulphates are sulphate of barytes, sulphate of strontites, sulphate of potash, sulphate of soda, sulphate of lime, sulphate of magnesia, sulphate of am-

monia, and sulphate of alumina and potash, commonly called alum.

Sulphate of barytes, or *ponderous spar* as it has been called, is abundant in different parts of the earth. Sulphate of strontites is found near Bristol and elsewhere in abundance. Sulphate of potash, sulphate of soda, and sulphate of ammonia are prepared by chemical manufacturers in many of their processes. Sulphate of lime, sulphate of magnesia, and sulphate of alumina are native productions.

Besides these, sulphates of the earths glucina, zirconia, and yttria have been formed, and their properties ascertained, but neither of them has been found useful.

293. The SULPHITES have always a disagreeable sulphurous taste and smell; they are decomposed or changed by the nitric, muriatic, and some other acids which do not affect *sulphates:* if exposed to fire they yield sulphur, and become sulphates: and even by mere exposure to the action of the atmosphere, if moistened with water, they absorb oxygen, and are converted into sulphates.

It is observable that these salts when pure are not decomposable by a solution of barytes, as is the case with the sulphates.

The *sulphites* were first pointed out by Stahl. Sulphite of potash was the first of these salts that he examined. From this circumstance it acquired the name of sulphurous salt of Stahl.

Exp. 1.—If sulphate of soda be heated in a crucible, it will melt without undergoing any decomposition; but if *sulphite* of soda be submitted to the same process, sulphurous acid will be given out and sulphur will be regenerated, which will take fire and burn with a violent flame.

Exp. 2.—Into some concentrated nitric acid drop a few crystals of sulphite of potash; these salts will decompose the nitric acid, red vapours will be disengaged in abundance, and the salt will be converted to a sulphate.

Exp. 3.—The effect of nitric acid on the sulphites may, perhaps, be better understood after performing the following experiment. To some pure sulphurous acid add a little solution of muriate of barytes, and no change will be perceptible; but if some nitric acid be added to sulphurous acid, and it be then treated with the muriate of barytes, an abundant precipitate of sulphate of barytes will be produced. This may be attributed to the change which the sulphurous acid undergoes by absorbing oxygen from the nitric acid, and which converts it to the sulphuric acid.

294. The principal sulphites are those of barytes, of lime, of potash, of soda, of ammonia, of magnesia, and of alumina.

These salts are mostly formed artificially, by saturating the alkaline and earthy bases with sulphurous acid. For the easiest method of conducting the process, consult Thomson's *Chemistry,* vol. ii. 449.

295. The MURIATES, when acted upon by concentrated sulphuric acid, yield muriatic acid in the form of vapour. They are among the most volatile, and yet are the least decomposable by fire, of all the salts; not being perceptibly altered by combustibles, even when assisted by an intense heat. They are soluble

in water, and are often dissolved in it for the purpose of raising the boiling point of that fluid. They evolve chlorine gas when treated with nitric acid.

The unchangeable nature of the muriates in the fire is a most remarkable character of this species of salt. Muriate of soda may be volatilized by heat, but if the vapour be collected it will be found still to be muriate of soda.

Exp. 1.—Charge a small retort with two ounces of muriate of soda, and adapt 2 or 3 receivers to it, similar to the apparatus, Fig. 23, Plate VI. Then pour one ounce of sulphuric acid, previously diluted with an equal portion of water, upon the salt, and apply the heat of a lamp. The distillation will soon commence, and muriatic acid will be collected in the receivers.

Exp. 2.—Take some of the acid procured in the above process, and add a few drops of the solution of nitrate of silver to it. This will occasion an abundant precipitate, and show that the liquid which has been distilled is real muriatic acid.

Though the muriates are not easily decomposed by heat, other means have been discovered to effect their decomposition. Take one example.

Exp. 3.—Weigh one ounce of muriate of soda, and having mixed it with four ounces of litharge of lead, form the whole into a paste with water. Stir the mass frequently, and add more water as the whole thickens. In a few days the salt will be decomposed; the oxide of lead will have been converted to a muriate of lead, and pure soda will be found in the supernatant liquor.

296. The principal salts in the muriatic class are: the muriates of barytes, of potash, of soda, of strontites, of lime, of magnesia, of ammonia, and the muriate of alumina.

Muriate of soda is the salt which has been longest known. It is our common culinary salt. Muriate of potash has been found native in the bogs of Picardy: this salt was formerly, and is still, much used by some alum-makers, to procure the crystallization of alum. Muriate of ammonia is the common sal-ammoniac of commerce. Muriate of barytes and strontites are both factitious salts. Muriate of lime is found native in various states; it is also furnished in abundance by the makers of carbonate of ammonia: it is used for the production of artificial cold.

Exp. 1.—Immerse a thermometer in a bason of snow, and it will presently become stationary at 32°. If the snow be now well mixed with a portion of fresh crystallized muriate of lime reduced to a fine powder, the thermometer will sink rapidly; for, of all the salts, muriate of lime is capable of producing the greatest degree of cold.

Muriate of lime, though itself colourless, imparts a brilliant colour to the flame of burning bodies.

Exp. 2.—Pulverize some of this salt, and throw a little of it into a spoonful of burning alcohol. This will produce a beautiful *red* flame, the colour of which may be rendered still more intense by agitating the mixture during the inflammation.

297. The HYPEROXYMURIATES, or *chlorates* as they are now called, yield very pure oxygen gas by the action of fire, and are thus converted into common muriates: and the stronger acids expell the chloric acid from these salts, without the assistance of heat. When mixed with combustibles, they detonate with great violence, by mere friction or percussion, and sometimes spontaneously.

They are all soluble in water, and some of them dissolve readily in alcohol. We have the chlorates of potash, of soda, of lime, of magnesia, of barytes, and of strontites.

Those salts which have been called oxymuriates, Mr. Chenevix named hyperoxymuriates. He was desirous of exhibiting the acid in a separate state: but when he attempted to obtain it from only 500 grains of hyperoxymuriate of potash, the retort burst with a loud report, and was reduced almost to a powder, so that scarcely any fragment of it could be found in the laboratory.

Hyperoxymuriate or chlorate of potash is used not only for experiment, but also in medicine. From its explosive effects, Berthollet was induced to propose it as a substitute for nitre in the manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it.

Exp. 1.—By *gently* triturating three grains of this salt and one of sulphur in a mortar with a metallic pestle, a series of detonations takes place resembling the cracks of a whip. If struck on an anvil, the report is as loud as that of a gun.

Exp. 2.—Take about six grains of chlorate of potash and three grains of flour sulphur; rub them together in a mortar, and a smart detonating noise will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by the firing of a pistol.

Exp. 3.—Take ten grains of chlorate of potash and one grain of phosphorus. Treat this mixture as in the last experiment, and very violent detonations will be produced. It is advisable *never to exceed* the quantity of phosphorus that is prescribed here, and in other similar experiments.

Exp. 4.—Take a similar quantity of chlorate of potash with three or four grains of flour sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful column of flame will be perceived, the moment the powder comes in contact with the acid.

Exp. 5.—Put a little chlorate of potash and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass, so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phænomenon, combustion under water.

Exp. 6.—Proceed in all respects as in the last experiment, and add a morsel of phosphuret of lime. Here, besides the former appearance, we shall have combustion also on the surface of the water.

Exp. 7.—Prepare a mixture of equal parts of lump sugar and chlorate of potash; put a small quantity of this mixture upon a plate or a tile; then dip a piece of sewing thread into a phial of sulphuric acid, so as to convey the smallest quantity of the acid:—with this touch the powder, and an immediate burst of flame will be the consequence.

Exp. 8.—Mix, without much friction, ten grains of chlorate of potash with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of detonation and flame being produced, by the mixture of a powder with a cold liquid.

Exp. 9.—If strong nitric acid be poured upon a small quantity of a mixture of chlorate of potash and phosphorus, flashes of fire will be emitted at intervals for a considerable time.

Exp. 10.—Add a few grains of chlorate of potash to a tea-spoonful or two of alcohol, drop one or two drops of sulphuric acid upon the mixture, and the whole will burst into flame, forming a very beautiful appearance.

Exp. 11.—A mixture of chlorate of potash and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once; the arsenical mixture burns with the rapidity of lightning, while the other burns with comparatively extreme slowness.

298. The NITRATES yield oxygen gas mingled with nitrogen gas by the action of fire; they give out a white vapour of nitric acid when acted on by concentrated sulphuric acid; and, when mixed with combustible substances, produce, at a red heat, inflammation and detonation. They are soluble in water, and capable of crystallization; and when heated with muriatic acid, chlorine is exhaled from that acid in the form of gas.

Exp. 1.—Take three parts of nitre, two of potash, and one of sulphur; all of these should be thoroughly dry; then mix by rubbing them together in a warm mortar: the resulting compound is called *fulminating powder.* If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it explodes with a violent report. *Note, This mixture is not dangerous, like the metallic fulminating powders; none of which should be intrusted in the hands of young people.*

Exp. 2.—Mix eight grains of nitrate of potash with four grains of phosphorus, place the mixture on a warm anvil, and strike it smartly with a hot hammer.

This will produce a violent detonation.

Exp. 3.—If ten grains of nitrate of potash be mixed well with three grains of pulverized charcoal, and the mixture thrown on a red-hot fire-shovel, a very brilliant combustion, accompanied with a loud detonation, will be the consequence.

Exp. 4.—Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it by small quantities at a time. The carbonaceous matter will decompose the nitre, and the bituminous part will burn away without acting upon it. This experiment will exhibit a mode of analysing coal; for every 100 grains of nitre that are decomposed in this way, denote ten grains of carbon.

Exp. 5.—If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed together in a metallic mortar, a loud detonation will be produced.

299. Among the most noted of the nitrates are those of potash, of barytes, of soda, of strontites, of lime, of magnesia, and of ammonia.

Nitrate of potash, or salt-petre, is generated by nature in abundance, particularly in the East; in some districts it appears in an efflorescence on the surface of the soil, from whence, at a certain season of the year, it is regularly swept off two or three times a week, and as repeatedly renewed; it appears that nothing is necessary for its production but the presence of lime, animal and vegetable matters, heat, and dry atmospheric air.

Nitrate of lime is generally found native with saltpetre, and in the greatest proportion. This salt, if properly heated, becomes luminous in the dark, and forms what is called Baldwin's phosphorus.

Nitrate of strontites mixed with burning bodies produces a striking and remarkable effect.

Exp. 1.—If pulverized nitrate of strontites be mixed with burning alcohol, the colour of the flame will instantly be changed to a lively purple.

Exp. 2.—If a little of the same kind of salt be mixed with a much larger quantity of dry pulverized charcoal, and the mixture thrown on a red-hot fire-shovel, a brilliant crimson flame will be produced.

300. The generic characteristics of the CARBONATES are, that all the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble, unless the acid be in excess; and they all effervesce, and give out the carbonic acid, when treated with the sulphuric and some other acids. Some of the earthy carbonates are also decomposed by mere heat without the intervention of any other substance, as is exemplified in burning lime; in which process the carbonic acid is expelled, and the base remains pure.

There are eleven species of carbonic salts at present known; only four, however, of the native earths are found combined with this acid, viz. lime, barytes, strontites, and magnesia.

Exp.—Pour some diluted sulphuric acid upon a little pulverized marble (carbonate of lime) in a retort, and collect the gas which arises by means of a pneumatic trough and apparatus, as described fig. 19, Plate V. This will be found to be carbonic acid gas.

301. The carbonates of barytes, of strontites, of lime, of magnesia, of potash, of soda, and of ammonia, are the principal salts of this class; and that of lime is probably the most abundant in nature.

Crystallized carbonate of lime may be known by its lightness, and by being found in rhomboids. Its specific gravity is less than 3.00, being the lightest of all the earthy salts.

Carbonate of barytes was discovered by Dr. Withering in 1783. It is not so scarce and dear as it was formerly; and from the superior affinity of barytes for sulphuric acid, this mineral substance may become a most useful article in the arts. It is a compound of 78 barytes and 22 carbonic acid. The carbonate of strontites was found at Strontian by Dr. Hope. It consists of strontites 70 and carbonic acid 30. Carbonate of lime exists in great abundance in all countries and under an extensive variety of forms. The other carbonates are in general formed artificially.

There are two carbonates of potash, the one consisting of 68 potash and 32 carbonic acid, possessing alkaline properties; and the *bi-carbonate,* which is formed with a double portion of carbonic acid, and is incapable of changing the colour of turmeric paper.

Crystallized carbonate of soda consists of soda 21½, carbonic acid 15½, and water 63. The dry carbonate of soda consists of 58½ of soda, and 41½ of carbonic acid. Whereas the bi-carbonate is a compound of 37 per cent. of soda, 52¼ of carbonic acid, and 10¾ water.

302. The PHOSPHATES are fusible either into opaque or transparent glass; are phosphorescent at a high temperature; are soluble in nitric acid without effervescence; and are precipitable from their solutions in that acid by lime water. They are partially decomposed by sulphuric acid, but neither the earthy nor alkaline phosphates are decomposable by being heated with combustible matter.

303. The chief of the phosphoric salts are: the phosphates of lime, of soda, and of ammonia, and the phosphate of soda and ammonia, formerly called microcosmic salt.

Phosphate of lime is found in bones, milk, and some other animal matters. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed of 48.5 lime and 51.5 of phosphoric acid.

Phosphate of lime and phosphate of barytes are both insoluble salts, but they become soluble in an excess of acid.

Exp. 1.—Into a clear solution of phosphate of soda, pour a transparent solution of muriate of barytes. This will produce a phosphate of barytes, which will immediately precipitate in the state of an insoluble salt.

Exp. 2.—Having separated the insoluble precipitate produced in the last experiment, add to it phosphoric acid. This will take up the salt and convert it to an acidulous phosphate of barytes, which is permanently soluble, and may be preserved to be used as a chemical re-agent.

Phosphate of soda is prepared for medicine. Phosphate of ammonia is found in urine, and is also prepared by art to be used as an ingredient in making pastes, to imitate precious stones. It is one of the best fluxes for experiments with the blow-pipe.

304. The PHOSPHITES yield a phosphorescent flame when heated; and in a strong fire give out a portion of phosphorus, by which they become converted into phosphates. By a very strong heat they are fusible into glass; but if heated with nitre, they detonate, and become converted into phosphates. A similar change is also effected in them, if they are treated with chlorine or nitric acid.

None of the phosphites have been found in nature; they are all formed artificially, by saturating the different bases with phosphorous acid, either directly or by means of double decomposition. None of them have yet been brought into use. Fourcroy distinguishes eleven species of the earthy and alkaline phosphites.

305. The chief of the phosphites are those of lime, of barytes, of potash, of soda, and of ammonia.

Phosphite of ammonia exhibits several curious appearances when treated with caloric.

Exp.—If phosphite of ammonia be heated on charcoal by means of a blow-pipe, it boils, and loses its water of crystallization; it then becomes surrounded with a phosphorescent light, and bubbles of phosphuretted hydrogen gas are emitted, which burn in the air with a lively flame, and form a fine coronet of phosphoric acid vapour.

306. The FLUATES are decomposed by sul-

phuric acid, yielding a vapour which corrodes glass, and which, when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustibles. Some of them are insoluble in water, and others very sparingly soluble in that fluid.

The fluates were first made known by Scheele in 1771. Some of them phosphoresce when heated.

307. The chief fluoric salts are: fluate of lime, fluate of soda, fluate of ammonia, fluate of alumina, and fluate of silica.

Many varieties, both in form and colour, of fluate of lime have been found.

Exp. 1.—If any of these coloured fluates be pulverized, and then heated on a shovel, they will emit a very curious violet-coloured phosphoric light, the cause of which is not known.

Fluate of ammonia is a very delicate test of lime. This earthy salt was first recommended by Scheele for this purpose.

Exp. 2.—Into a glass of transparent lime-water let fall a single drop of fluate of ammonia, and an immediate precipitate will be occasioned.

308. The BORATES are all fusible into glass, and, with several of the metallic oxides, form glass of different colours. Concentrated solutions of some of the borates, especially that of soda, afford, when decomposed by the stronger acids, scaly crystals of boracic acid.

The borates are not decomposable by charcoal like the sulphates; for, whatever may be the temperature to which they are exposed, none of the combustible substances have the power of decomposing them. The borates are advantageously employed in fusing mineral substances and in soldering metals.

It is from the property which the borates possess of fusing mineral substances and metallic oxides, that they are used by braziers, tin-men, &c. We employ sub-borate of soda to fuse such stones as cannot be brought into fusion by the alkalies.

309. The principal salts in this class are: the borates of lime, of magnesia, and of potash; and the sub-borate of soda, which is known in commerce by the name of borax.

What is called *boracite*, or cubic quartz, is a borate of lime and magnesia, consisting of lime 11, magnesia 13.5, and boracic acid 68, with a little silica, alumina, and oxide of iron.

Borate of magnesia has been found near Lunenberg. The other borates are factitious salts.

The common borax of commerce is called sub-borate, because it contains an excess of soda. According to Bergman, it requires half its weight of boracic acid to bring it to the state of a neutral salt.

310. The distinguishing characteristic of the ARSENIATES is, that when heated with charcoal they are decomposed, and arsenic sublimes. This is known by its alliaceous or garlic-like smell.

311. The arseniates of lime, of barytes, of magnesia, of potash, of soda, and of ammonia; also the super-arseniate of potash, long known under the name of 'the arsenical neutral salt of Macquer,' are the principal arseniates that are known.

Most of the arseniates are formed artificially; and a few of them are used in the arts.

Arseniate of potash may be formed by detonating in a crucible a mixture of nitrate of potash and arsenous acid. This salt when heated melts into a white glass.

312. The ARSENITES are combinations of the alkalies or earths, with the white oxide of arsenic, sometimes called arsenous acid; while the arseniates are formed by the union of certain bases with the *arsenic* acid. The alkaline arsenites are soluble in water, but the earthy arsenites are insoluble.

313. The only salt of this kind with which I am acquainted is the arsenite of potash, which is made for the preparation of a beautiful pigment, known by the name of 'Scheele's green.' The salt is formed by boiling white arsenic in a solution of caustic potash; and then by mixing this with a solution of the sulphate of copper, the pigment in question precipitates in the state of an impalpable powder.

314. The salts called TUNGSTATES are combinations of the yellow acid of tungsten with the alkalies and earths. Most of them have a metallic and caustic taste.

315. The tungstates of lime, of magnesia, of potash, of soda, and of ammonia, are the principal salts of tungsten.

Tungstate of lime, and tungstate of iron, which are found native, are both well known to mineralogists: the other tungstates are formed by art.

316. The ACETATES are all very soluble in water; are decomposed by the action of heat, and afford acetic acid when distilled with sulphuric acid.

Exp.—Put a few ounces of dried acetate of lead into a glass retort, and having poured upon it two-thirds of its weight of concentrated sulphuric acid, a pungent acetic acid may be procured by distillation.

317. These salts, if exposed to the air when in a state of solution, are soon destroyed, owing to the gradual decomposition which the acid undergoes; an inconvenience which is experienced by the printers of calicoes whenever their red mordant (the acetate of alumina) has been long kept, without being properly preserved from the action of the atmosphere.

318. We have the acetates of barytes, of potash, of soda, of lime, of ammonia, and of magnesia, besides the acetate of alumina of the calico-printer, just mentioned.

Acetate of barytes has been employed as a chemical test. It is the most delicate test that can possibly be for sulphuric acid, and is often used for the discovery of this acid in vinegar that has been sophisticated with it. This salt is, however, decomposable by the alkaline carbonates.

The acetates of potash and of ammonia have long been known and prepared for medicinal use; the other earthy and alkaline acetates have not yet come into much use, except the acetate of alumina, which is employed by calico-printers as a mordant.

319. The OXALATES are decomposable by a red heat; and those which are soluble in water are decomposed also by lime- or barytes-water; and the precipitated oxalate is soluble in an excess of oxalic or of most other acids.

Oxalic acid when taken into the stomach produces excruciating pain, which soon terminates in death.

320. Oxalate of lime, of barytes, of strontites, of alumina, of magnesia, of potash, of soda, and of ammonia, are the principal oxalic salts.

Oxalate of potash and oxalate of ammonia are both very useful tests of lime. These never fail to discover the presence of this earth, except it be supersaturated with some acid—in which case it is necessary to take up the excess of acid by the addition of caustic ammonia before using the test.

Superoxalate of potash is sometimes prepared in England, but it is found ready formed in the juice of *wood-sorrel*. The other oxalates are not yet in use.

321. The generic characteristics of the TARTRATES are, that when they are exposed to a red heat, the acid is decomposed, and the base remains. The earthy tartrates are less soluble than the alkaline, but all are capable of combining with another base, and forming triple salts. The tartrates are also capable of combining with an excess of acid, of which com-

mon tartar or super-tartrate of potash is a well-known instance.

322. The principal tartaric salts are the tartrates of lime, of strontites, and of potash; and the tartrates of potash and ammonia, and of potash and soda, commonly called Rochelle salt.

Tartrate of lime is found in the tartar of commerce; and it is also formed by art, by adding lime or its carbonate to a boiling solution of cream of tartar. This latter salt is merely the common tartar, or argol, purified, which adheres to the inside of wine casks, and is brought in large quantities from the wine countries. There is a considerable demand for it by the dyers and other manufacturers; and both in the crude and refined state there is an excess of acid, therefore they are properly called *super*-tartrates of potash. It is composed of 77 per cent. of tartaric acid and 23 of potash. Tartrate of potash and soda, usually called Rochelle salt, or sel de Seignette, is formed artificially by adding soda in crystals to a solution of cream of tartar, till the excess of acid is saturated. This medicinal salt is composed of 54 tartrate of potash and 46 tartrate of soda. A neutral tartrate of potash is also formed in our laboratories, called soluble tartar. The other tartrates are made without any view to their use in the arts.

323. The CITRATES are decomposed by the strong mineral acids; they yield traces of acetic acid when distilled; and the oxalic and tartaric acids decompose them, producing an insoluble precipitate in their solutions. The aqueous solutions of these salts are not per-

manent, but are liable to be decomposed by age.

324. The principal citrates are: the citrates of lime, of barytes, of potash, of soda, and of ammonia.

The citrates are all formed artificially. Citrate of potash is used much in medicine, and is usually called the *saline draught*. It is composed of 56 acid and 44 potash. The other citrates are not yet found to be of any use.

325. The camphorates have generally a bitterish taste; they are decomposable by heat, and burn with a blue flame. The camphorate of potash and some other of these salts crystallize very readily.

326. The principal of this class of salts are the camphorates of lime, of potash, of soda, of barytes, of ammonia, of alumina, and of magnesia.

Camphoric acid saturated with potash forms crystals in regular hexagons; with soda, irregular crystals; with ammonia it forms needle-formed crystals; and with magnesia, a white pulverulent salt.

These salts, which have not been applied to any useful purpose, are also all formed artificially.

327. The several SUBERATES differ so much in their properties, that it would be difficult to characterize the genus otherwise than by saying that they generally possess a bitter taste, and are decomposable by heat. The mineral

acids also decompose them, and precipitate from their solutions the suberic acid in distinct acicular crystals.

328. The principal suberates are: suberate of barytes, of potash, of lime, of magnesia, and of ammonia.

The suberates, which are all factitious, are more or less soluble: some readily crystallize, others with difficulty; there are some which remain pulverulent, whilst others are deliquescent. None of these salts are yet come into any use.

329. PRUSSIATES are easily formed by boiling the alkalies or earths with prussian blue; in which process the prussian blue is decomposed, the prussic acid uniting with the alkali or earth in preference to the oxide of iron. The salts which are thus formed retain however some iron, and are called triple prussiates. Those of potash and soda crystallize readily, and the former is much used as a test to detect the presence of iron and some other metals.

330. The principal prussiates are: the prussiates, or triple prussiates of potash, soda, lime, or ammonia, with iron: that of potash was formerly called prussian alkali.

The prussiates are all made by art, but the class is very interesting. There are two prussiates of iron, the white and the blue prussiate. Prussiate of lime and iron, or the prussiate of potash and iron, is used as a test to ascertain the presence of metals held in solution.

The latter, known by the name of *prussian alkali*, is the best combination of the prussic acid for detecting the existence of iron.

331. These different salts are known from each other by the peculiar figure of their crystals, by their taste, by their fusibility, and other distinctive or *specific* characters.

332. There is a great variety in the form of crystallized salts: and each salt preserves its own peculiar form: thus common culinary salt generally crystallizes in small cubes, and sulphate of soda in six-sided prisms.

Exp. 1.—If common Glauber's salt be dried and reduced to powder, and then dissolved in three times its weight of boiling water, it will not only be found to crystallize again on cooling, but the crystals will assume the identical forms which they exhibited before they were pulverized. This experiment is designed to show that a determinate figure has been instamped upon every individual salt.

Exp. 2.—Dissolve ¾ of an ounce of Glauber's salt in two ounces of boiling water; pour it while hot into a phial, and cork it close. In this state it will not crystallize, even when perfectly cold; but if the cork be now removed, the crystallization will be seen to commence and proceed with rapidity; affording an instance of the effect of atmospheric air on crystallization.

Exp. 3.—Repeat the experiment with a small thermometer immersed in the solution, and closed so as to exclude the atmospheric air. If the solution be suffered to cool completely under these circumstances, the thermometer will be seen to rise on the removal of the cork. This experiment is designed to show that saline solutions give out caloric in the act of crystallization.

333. The separation of salts from the water in which they may be dissolved, is generally effected by evaporation and cooling.

334. When a certain portion of the water of solution is evaporated, and the remainder left in a proper temperature at rest, the salts will shoot into crystals, and will be found dispersed through the mother water at the bottom and at the sides of the vessel, and sometimes also on the surface of the solution.

Solution is effected by means of water or caloric, one of which is necessary to keep the parts of the substance in a state of minute division. In order that regular crystallization may take place, it is necessary that the cause of fluidity, whether water or caloric, or both, should be subtracted *gradually*, and without movement. This gives an opportunity for the parts of the substance to unite regularly, according to their several attractions, and to produce crystals as perfect as those exhibited by Nature; whereas, a sudden subtraction of the fluid causes the particles often to unite in a shapeless mass.

335. The solution which remains after the separation of a part of the salt that it originally contained, is called *mother water*. By repeating the evaporation, and cooling, the mother waters generally afford fresh portions of salt.

336. The crystallization of salts is owing to the abstraction of the heat or water by which they were dissolved; and, in those crystals

which contain water, their peculiar form and crystalline appearance are in a great measure owing to that portion of water having parted with its caloric of fluidity and taken a solid form.

It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly grain tin. Nothing can exemplify this kind of crystallization better than muriate of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. If glass be kept in a red heat for a long time and cooled gradually—instead of being the transparent body we generally see it, it will crystallize like the metals. Starch is another instance of what may be called *dry* crystallization; and probably, in every instance, the phenomenon may be attributed to the loss of caloric, and consequent shrinking of the whole substance.

337. The water which combines with salts, during their crystallization is called the water of crystallization, for it is generally this that gives them the crystalline appearance.

This water gives out caloric, and *solidifies* as the salt crystallizes, and thus becomes itself a part of the salt. When abstracted from salts, it is found to be as pure as distilled water.

It is probable that salts generally combine with *two* definite proportions of water, viz. that with which they unite in *crystallizing*, and which is well known to exist only in fixed proportions; and secondly, that quantity which they combine with in *dissolving*: the first is called water of crystallization; the second, water of solution.

338. The quantity of this water varies very much in different salts; for though some salts take up very little or no water, others combine with more than their own weight; which is the case with alum, sub-carbonate of soda, and some others.

Exp.—Mix a little acetate of lead with an equal portion of sulphate of zinc,—both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible: but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a fluid will be produced. If alum or Glauber's salt be used instead of sulphate of zinc, the experiment will be equally successful.

339. Crystallized salts are liable to changes in their appearance by exposure to atmospheric air. Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

340. Some salts have so great an affinity for water, that they absorb it with avidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, by exposure to atmospheric air.

Some deliquescent salts have so little force of cohesion, that the action of water, however small the quantity, is sufficient to prevent their crystallization; but even such salts may be crystallized by the addition of alcohol, for which the water has generally a greater affinity than it has for the salts. Therefore, whenever alcohol is added to such saline solutions, part of the water combines with the alcohol, and crystallization takes place. This shows that those salts do possess in themselves an active cohesion of parts.

341. Some salts, on the contrary, having less affinity for water than atmospheric air has, they lose their water of crystallization by exposure, and readily fall into powder: such salts are said to effloresce. The crystals of sub-carbonate of soda and of sulphate of soda are good examples of this property.

Muriate of barytes, *pure* muriate of soda, and some other salts, seem to have exactly the same affinity for water that atmospheric air has. Such salts neither effloresce nor deliquesce by any exposure to the atmosphere.

342. Salts are capable of other changes besides efflorescence and deliquescence; they have also the properties of solubility and fusibility.

We generally denominate all salts as insoluble, which require for solution more than 1000 times their weight of water. An opinion may in some measure be formed of the *solubility* of a salt by its taste. Those salts which have the most taste are generally the most soluble in water. Thus Epsom salt dissolves in its own weight of water at the common temperature of the atmosphere, and the solution continues perfectly fluid and transparent; while sulphate of lime requires 500 times its own weight of water to hold it in solution.

343. By the solubility of a salt is meant its capacity to unite with and remain dissolved in

water; but the different salts possess different degrees of solubility, requiring more or less of this fluid for their solution.

The difference which there is in the solubility of salts is of great use in separating them from each other. The refiners of salt-petre operate entirely on this principle. The rough petre, as it is called, is always contaminated with a portion of muriate of soda and other salts. In order therefore to separate them they dissolve the whole in water, and then, by boiling the solution to evaporate a part of the water, the muriate of soda, &c. falls down, while the salt-petre is held in solution.

We have several instances of salts that are in themselves very soluble, producing by double decomposition, when mixed, other salts that are nearly insoluble in water. Take the following as an example.

Exp. 1.—Dissolve some muriate of lime and carbonate of potash in water, so as to form a saturated solution of each of these very soluble salts; then, on pouring these two transparent fluids together, muriate of potash and carbonate of lime will be formed; and if the mixture be well stirred, a solid mass will be the product.

Exp. 2.—The following is an experiment of a different kind. Mix a little acetate of lead with an equal portion of sulphate of zinc, both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible; but if they be rubbed together in a mortar, the two solids will operate upon each other; an intimate union will take place, and a fluid will be produced. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful.

Exp. 3.—To Bouillon La Grange we are indebted for the account of a very singular anomaly in the solution of salts. If pure lime be added to a solution of borate of potash, the salt will be decomposed, and borate of lime, an insoluble salt, will be precipitated. But if more lime be gradually added, the precipitate will be dissolved, and of course a soluble salt produced.

344. Salts have not only the property of dissolving in water, but will melt by exposure to great heat; and yet the different salts require different degrees of heat to put them in a state of fusion.

Tables of the fusibility of different salts have not yet been formed; but with the aid of Wedgwood's pyrometer it would be no very difficult task to ascertain the degree of fusibility of each. The relative fusibility of several of them is already known: for instance, it has been ascertained that sulphate of potash requires a much more intense heat to put it in a state of fusion than sulphate of soda; whereas nitrate and muriate of soda melt as soon as they become red.

345. Besides the properties already enumerated, many of the salts have a reciprocal action, and are capable of mutually decomposing each other.

346. When such salts are mixed in solution, the acid of the *first* and the base of the *second* having more affinity for each other than for the base and acid with which they are respectively combined, double decomposition, as it is termed, ensues. The acid of the first unites with the base of the second, and consequently the base of the first combines with the acid of the second: so that two new salts are

produced, differing in appearance, and possessing properties different from those of the original salts.

Exp. 1.—Take a saturated solution of sulphate of magnesia, (Epsom salt,) and pour into it a like solution of caustic potash, or soda. The mixture will immediately become almost solid. This instance of the sudden conversion of two fluids to a solid, and that related Exp. 1, N° 343, have been called *chemical miracles.*

Exp. 2.—Take any solution of iron, a chalybeate water for instance, and add a little succinate of ammonia; a precipitate will be immediately visible, being succinate of iron. By this test the quantity of iron in any solution may be accurately ascertained.

Exp. 3.—Make a solution of arseniate of potash and another solution of sulphate of copper, both very soluble salts. Mix these solutions, and an insoluble arseniate of copper will immediately be formed and precipitated.

Exp. 4.—Mix some solution of borate of soda with a solution of muriate of lime, and then if both these solutions be poured together, a mutual decomposition will take place, and an insoluble borate of lime will be found in the liquid.

Exp. 5.—If a little nitric acid be poured upon the substance produced in Exp. 1, N° 343, a very different effect will be produced. The consequence will be, the solid matter will again be taken up, and the whole exhibit the appearance of one homogeneous fluid. An instance of a solid *opake* mass being converted by a chemical agent to a transparent liquid.

347. This is occasioned by the mutual chemical attraction which subsists between the several substances of which the respective salts

are composed; and the operation itself is called double decomposition.

Exp.—If you add a transparent solution of sulphate of soda, or Glauber's salt, to one of muriate of lime, the solution is immediately rendered turbid, and two new salts are formed.—The sulphuric acid of the sulphate of soda combines with the lime of the muriate of lime and forms sulphate of lime or gypsum, and the soda which was combined with the sulphuric acid seizes the muriatic acid previously united to the lime and forms muriate of soda, or common salt, which continues in the solution, but may be obtained in a dry form by evaporation and crystallization. The white powder which precipitates, is the newly formed sulphate of lime.

348. By similar means many valuable salts are procured for the use of the chemist and the manufacturer, which can be formed in no other way.

The following are some of those useful salts which are not found native, but are formed entirely by art:—nitrate of ammonia, nitrate and muriate of barytes, chlorate of potash, phosphate of soda, phosphate of ammonia, &c.

As many of the salts are found native, and as great attention has been paid to these natural productions since the science of mineralogy has been so much cultivated, it would be improper, even in this small work, to leave these NATIVE SALTS *entirely unnoticed.*

349. The carbonates, sulphates, and muriates are the more frequent *native salts;* there

are also nitrates, fluates, borates, and some others less copiously distributed.

350. To enumerate a few of these native salts, it may be observed that of carbonate of lime there are immense mountains in most parts of the world: carbonate of barytes has been found in Lancashire and elsewhere; carbonate of strontites, at Strontian in Scotland; carbonate of soda, in the natron beds of Egypt, and in the East Indies; and carbonate of potash, as well as the carbonate of soda, has been discovered in some spring waters.

Chalk, limestone, and marble, are all included in the term carbonate of lime.

Carbonate of lime is found also in a crystallized state in a mineral called *calcareous spar*. It has never yet been crystallized by art. This process of Nature may require many ages to effect, for aught we know.

351. Sulphate of soda is found in some salt springs; sulphate of magnesia, in spring water; the sulphate of alumina is abundant at Whitby and Glasgow; sulphate of barytes, in Derbyshire and other parts of the world; the sulphate of strontites abounds in some parts of Gloucestershire; and few salts are more copiously disseminated than the sulphate of lime, particularly in the vicinity of Paris, and hence its name *Plaster of Paris.*

Sulphate of magnesia and sulphate of lime are both very common in our spring waters; the last salt and supercarbonate of lime are the chief causes of what we call *hard* waters, which are very unwholesome, and unfit for washing.

Exp.—Into distilled water drop a little spiritous solution of soap, and no chemical effect will be perceived: but if some of the same solution be added to hard water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ascertaining the comparative purity of spring water.

352. Of the native MURIATES, muriate of lime occurs with rock-salt, and muriate of magnesia is found in abundance in sea-water; muriate of ammonia appears in the neighbourhood of volcanos; and muriate of soda not only exists in immense quantities in the ocean; but vast mountains in different parts of the world are entirely formed of this salt.

The magnesia of commerce is generally procured from this source. It is prepared in great quantities in the island of Guernsey, also from the waters of Cheltenham, and elsewhere.

The ocean contains from 1-25th to about 1-35th of its weight of muriate of soda. On account of the cheapness of fuel at Newcastle, salt is procured there by the evaporation of sea-water. They evaporate 30 or 40 tons of water to procure one ton of salt.

353. Of the NITRIC salts, nitrate of potash, known by the more familiar name of nitre, or salt-petre, is collected in various parts of the globe; nitrate of magnesia sometimes occurs in combination with that salt; and nitrate of

lime is found also in the same combination, and likewise in mineral springs:—these are the only nitric salts that have been seen native in any considerable quantities.

Some of the salt-petre grounds are now much more productive than formerly, owing to a knowledge of the circumstance that carbonate of potash will decompose nitrate of lime. The salt-petre makers, in lixiviating the earths, now add a portion of *wood-ashes*, and hence their produce of nitre is rendered more abundant.

354. Besides the four species of native salts now enumerated, there are vast rocks in Derbyshire and elsewhere formed of fluate of lime; borate of soda is found in a crystallized state in the kingdom of Thibet; borate of magnesia at Luneburgh in the kingdom of Hanover; and phosphate of lime, which is the basis of all animal bones, exists native in Hungary, and composes several entire mountains in Spain.

355. The huge mountains of salts we have been speaking of, and which occur in various parts of the earth, were probably formed in very remote ages, and by processes of which we can form no idea. It may indeed be supposed that these changes have been slow and gradual, for several of the native salts exhibit marks of regularity and beauty in their crystallization, which cannot be imitated by art.

In order to account for these productions of Nature, various *theories* of the world have been formed by philosophers in different periods. Some of these have had many supporters. Thus we have had the theories of Burnet, Woodward, Whiston, Buffon, Whitehurst, Laplace, and other noted geologists who have written on the subject since their time.

The theories which divide the opinions of the philosophers of the present day, are those of Hutton and Werner. The former supposes the agency of heat, and is called the Plutonian system; the latter, which attributes all the present appearances of the globe to the effect of water, is called the Neptunian system.

CHAPTER IX.

OF SIMPLE COMBUSTIBLES.

356. Those bodies which have never yet been decomposed, or formed by art, are called *simple* substances.

The most minute particles into which any compound substance can be divided *similar* to each other, and to the substance of which they are parts, are termed the *integrant* particles: thus the smallest atom of powdered marble is still marble; but if by chemical means the calcium, the carbon, and the oxygen of this marble be separated, we shall then have the *elementary* or constituent particles.

Suppose a little common salt were reduced to powder, even though it be ground as fine as could be effected by art, still every single particle, however minute, would consist of a particle of sodium and a particle of chlorine; common salt being a *compound* body incapable of decomposition by mechanical means. But if we take a piece of sulphur, and pulverize that in the same way, every particle will be a homogeneous body, sulphur being one of the *simple* substances.

357. Very lately the simple substances were said to amount to more than 50 in number; but since the truly interesting and very important discoveries of Sir Humphry Davy, and other eminent chemists both at home and abroad, it is scarcely possible to say what substances are not compound bodies.

358. All the simple substances that we are at present acquainted with are fifty-two; viz. electricity, magnetism, light, caloric, chlorine, oxygen, nitrogen, iodine; the metals, (reckoning as such the bases of potash, soda, and some of the earths,) and the simple combustibles, carbon, phosphorus, sulphur, hydrogen, boron, and fluorine.

Most of the simple substances are combustible, or bear some relation to combustion. Light and caloric are evolved during combustion; oxygen is the principal agent of combustion; and hydrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments of this process.

359. It is extremely probable however that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it will be more con-

ducive to science, to consider them, for the present, as simple undecomposable bodies.

The fixed alkalies, which were formerly imagined to be simple substances, are proved by Sir H. Davy to be metallic oxides, while the volatile alkali has been found to be a triple compound of nitrogen, hydrogen and oxygen; so that oxygen appears to be not only the principle of acidity, but of alkalescence. He has succeeded also in decomposing the four alkaline earths, barytes, strontites, lime, and magnesia, the base of which he finds to be metallic substances of the colour of silver. He has likewise announced that he has reason to believe that sulphur and phosphorus are compound bodies, consisting of oxygen, hydrogen, and their peculiar bases; and by means of potassium and sodium he has been enabled to separate the bases of the boracic and fluoric acids; and he even imagines that he has succeeded in decomposing nitrogen, and that he shall be able to prove it to be an oxide of hydrogen, containing a still larger proportion of oxygen than is even necessary to form water.

It is curious that most of those substances which were thought by the old chemists to be the elements of all other bodies, are found by our improved methods of experiment to be more or less compounded; while, of those which were formerly ranked among the class of compounds, there are a great number that are really not decomposable, and can only be placed among the simple bodies. *Air*, *fire*, *water*, and *earth* were by the ancients called the elements of the globe: modern chemistry has demonstrated, that the three first of these are really compound bodies; and there is reason to believe that the earths are also all compound. On the other hand, *sulphur*, *phosphorus*, *carbon*, and the *metals*, which we call simple substances, were supposed formerly to be compounds.

Oxymuriatic acid, or chlorine, the basis of boracic and fluoric acids, and a substance of recent discovery, called *iodine,* have lately been added to the list of simple substances.

Having already examined the nature of all these substances, except the combustibles, we shall now enter upon the consideration of that class of bodies.

360. Besides the metals there are six simple combustibles, viz. hydrogen, sulphur, phosphorus, carbon, boron, and fluorine.

The metals ought to have been included in this chapter, with the other simple combustibles; but as several of their properties are so very different from the six substances now described, it was thought advisable to treat of them separately.

361. They are called *simple,* because we have no proof that they are compounded: whereas oil, spirit of wine, wax, tallow, and other combustible bodies, are well known to consist of two ingredients at the least.

For the nature of the compound combustibles, consult the chapter on Combustion.

It will be necessary to examine each of these substances separately: we shall begin with HYDROGEN.

362. Hydrogen is the basis of what has been generally called inflammable air, and is one of the component parts of water; but it

cannot be exhibited in a separate state. We therefore know it only in combination with other substances, or in the gaseous form, that is, with caloric.

Mr. Cavendish was the first person who examined hydrogen gas and pointed out its nature. This was in the year 1766. Dr. Black then suggested the propriety of applying it to the inflation of air-balloons; and Mr. Cavallo was the first to put it in practice. This gas is about fourteen times lighter than atmospheric air.

Like all other combustibles, hydrogen will not burn unless in contact with atmospheric air, or some substance that contains oxygen. If a portion of atmospheric air be mixed with this gas, and fire be applied, it will explode with violence.

Exp. 1.—Put about an ounce of iron filings into a phial, with about three or four ounces of water: pour a little sulphuric acid upon the contents, and hydrogen gas will be evolved.

Exp. 2.—Pour water into a small glass retort so as to occupy about one-third of its capacity, lute its beak into the end of a gun-barrel, the middle of which must be kept red-hot in a furnace, or by a chafing-dish; then if a lamp be applied to the retort so as to cause the water to boil, the steam will pass through the red-hot iron tube, and in this case also will be decomposed; for, as the oxygen combines with the iron, the hydrogen gas will be liberated, and may be collected in the usual way.

Exp. 3.—Procure a bladder furnished with a stop-cock, fill it with hydrogen gas, and then adapt a tobacco-pipe to it. By dipping the bowl of the pipe into a lather of soap, and pressing the bladder, soap-bubbles will be formed, filled with hydrogen gas. These bubbles will rise into the atmosphere, as they are formed, and convey a good idea of the principle upon which air-balloons are inflated.

Exp. 4.—Procure a bladder similar to that described in the last experiment, and charge it with a mixture of oxygen and hydrogen gases. With this apparatus blow up soap-bubbles as before, and touch them with a lighted match. The bubbles as they rise will explode with a smart noise.

Exp. 5.—Fill a moistened bladder with hydrogen gas; apply a lighted match to the end of a tobacco-pipe firmly tied into its neck, and press the bladder gently. A pencil of flame, extremely beautiful, will be seen issuing from the pipe, till the whole of the hydrogen gas is consumed.

Exp. 6.—Place some small phials on the shelf of the pneumatic tub, filled with water, and inverted as usual for receiving gases. Now fill these with mixed *oxygen and hydrogen gases* from the bladder, as described in Experiment 3. A lighted match will cause any one of them to explode with violence. When the phials are used, it will be prudent to fold them round with a handkerchief, to prevent any injury being received from the glass, in case of bursting; but if small bladders be employed in place of the phials, this precaution will be unnecessary.

Exp. 7.—A mixture of oxygen and hydrogen gases produces the most powerful heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each into a common tube connected with both, and throwing a stream of the mixed gases on burning charcoal, or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe and stopcock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown upon the burning substance.—*In performing this experiment all solid vessels* *should be discarded, as before recommended, for fear of an accident by explosion.*

363. Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon.

364. Water may be made, by pressure, to absorb a considerable portion of hydrogen gas. It is called hydrogenated water, and is said to be useful in medicine.

365. Sulphur dissolved in this gas forms sulphuretted hydrogen gas, which is a very fetid elastic fluid, somewhat heavier than atmospheric air and soluble in water.

Exp. 1.—Melt together in a crucible three parts by weight of iron-filings and one of sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: lute one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar being inverted and full of water. Then pour diluted muriatic acid through the other mouth of the vessel, which must immediately be closed up. Sulphuretted hydrogen gas will now be disengaged in abundance and flow into the glass jar, displacing the water.

Exp. 2.—Sulphuretted hydrogen gas may be discovered by means of lead. Write on paper with a solution of acetate of lead, and when the writing is dry dip it into any water that is suspected to contain sulphuretted hydrogen gas. If this gas be present in the water, the letters will immediately become black.

Water impregnated with sulphuretted hydrogen gas is of use to separate some metallic oxides when in solution. Thus, if it be added to a solution of acetate of lead, the lead will be precipitated of a deep brown colour.

366. SULPHURETTED HYDROGEN gas is transparent and colourless; it has the property of inflammability, is nauseous to the taste as well as fetid to the smell; it possesses all the characters of an acid: it combines with earths, alkalies, and with several of the metallic oxides; and forms with them those substances called *hydrosulphurets*.

This gas was long known by the name of *hepatic* gas, because the substances from which it was first obtained were called *hepars* or livers of sulphur. When set on fire in contact with oxygen gas, it burns with a pale blue flame, without exploding. It will however of itself extinguish burning bodies, and destroy animals which are made to inhale it.

Sulphuretted hydrogen gas is decomposed by atmospheric air. The oxygen of the atmosphere combines with the hydrogen and forms water, while the sulphur is precipitated. The sulphur which is found in the neighbourhood of mineral springs originates from this cause. The fetid smell which arises from house-drains is owing in a great measure to a mixture of this gas with other putrid effluvia.

367. The HYDROSULPHURETS are generally soluble in water, and their solutions precipitate the metallic oxides from metallic solutions. Exposure to the air, however, decomposes these hydrosulphurets when dissolved in water, and partially converts them into hydroguretted sulphurets.

The waters of Harrowgate, Aix la Chapelle, and others of a similar nature, owe their medicinal properties to sulphuretted hydrogen gas and muriate of soda. Hydrogen gas has the property of reviving metallic oxides; hence some ladies who have used metallic cosmetics, have instantly become dark tawnies by bathing in such waters.

Exp. 1.—If flowers, or any other figures, be drawn upon a ribband or silk with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures, firmly fixed upon the silk, will become visible, and shine with metallic brilliancy.

Exp. 2.—By proceeding in the same manner, and using a solution of gold in nitro-muriatic acid, silks may be permanently gilt at a most insignificant expense, and will exhibit an appearance the most beautiful that can be conceived.

Exp. 3.—Immerse a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas; but if another piece of silk be dipped in the solution and exposed while *wet* to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour will change from yellow to green, and a brilliant film of reduced gold will soon glitter on its surface.

Exp. 4.—If a piece of silk be immersed in a solution of nitrate of silver and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while *wet* to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the threads of the silk will look like silver wire. *During these experiments the silk should be constantly kept wet with distilled water.*

Exp. 5.—Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be observed; but if it be exposed while *wet* to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as red, yellow, orange, green and blue, variously intermixed.

368. There are three distinct combinations of sulphur and hydrogen with the earths and alkalies, which differ in their properties in consequence of the difference there is in the proportions in which their constituent parts are combined.

369. The first, which are called *sulphurets*, are merely compounds of sulphur united to some earthy or alkaline base; the second, called *hydrosulphurets*, are formed by the union of some base with sulphuretted hydrogen; and the third, called *hydroguretted sulphurets*, consist of a base united with supersulphuretted hydrogen.

The hydroguretted sulphurets have the property of absorbing oxygen with great rapidity from the atmosphere, and on this account are very proper for purposes of eudiometry.

370. SUPERSULPHURETTED HYDROGEN is merely sulphuretted hydrogen combined with an additional proportion of sulphur; that is to say, one part of hydrogen combines with 15 parts of sulphur to form sulphuretted hydro-

gen, and with 30 parts of sulphur to constitute supersulphuretted hydrogen.

371. Hydrogen gas when combined with phosphorus forms *phosphuretted hydrogen gas.* This gas has a fetid putrid smell, and takes fire whenever it comes in contact with atmospheric air.

Phosphuretted hydrogen gas may be formed by boiling a little phosphorus in a solution of pure potash. The water is decomposed thereby, and furnishes the hydrogen. The retort should be nearly filled with the solution, otherwise the gas will inflame.

Exp. 1.—By introducing phosphorus into a glass jar full of hydrogen gas standing over mercury, and melting the phosphorus by means of a burning glass, this compound gas will be formed in abundance.

Exp. 2.—Into an eight-ounce retort, pour four ounces of pure water, add a little solution of pure potash, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of phosphuretted hydrogen gas will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air.

Exp. 3.—Into an ale-glass of water put a few filings of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described *Exp.* 5, page 147, and phosphuretted hydrogen will presently be disengaged, which will inflame on rising to the surface of the water.

Exp. 4.—Take a small piece of phosphuret of lime, a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by small balls of fire darting from the mixture, and the most intolerable fetid smell that can be conceived.

Exp. 5.—If 20 grains of phosphorus, cut very small, and mixed with 40 grains of finely granulated zinc, be put into 4 drachms of water, and 2 drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real aqueous fountain of fire.

372. The elastic substance, which is called CARBURETTED HYDROGEN GAS, is carbon dissolved in hydrogen ; it has likewise been called heavy inflammable air. It is this gaseous compound which has occasioned so many dreadful accidents in coal-pits. The miners call it the *fire damp*.

In hot weather this gas is formed at the bottom of stagnant waters, and may readily be collected at their surface, by suspending a bottle of water over the pool, similar to the decanting of gases over a pneumatic trough, and stirring up the mud to disengage the carburetted hydrogen.

Exp. 1.—By exposing charcoal in glass vessels filled with hydrogen gas to the rays of the sun, carburetted hydrogen may be formed artificially. It is invisible, elastic, and inflammable.

This gas is procured from pit-coal by dry distillation for the purpose of lighting the public streets, lighthouses on the sea-coasts, mines, manufactories, &c. What renders this gas so extremely dangerous in mines, is the circumstance that, whenever the atmosphere of a mine becomes charged with more than one-thirteenth of its volume of carburetted hydrogen gas, the whole becomes explosive. It is, however, now expected that the safety-lamp of Sir H. Davy, which is a most important discovery, will be a means of lessening the number of these accidents.

Exp. 2.—Put a little small-coal into the bowl of a tobacco-pipe, cover it over closely with a piece of lute, and heat it in a common fire. When the coal becomes hot, carburetted hydrogen gas will be disengaged and pass off through the small end of the pipe. If the gas be inflamed, it will afford an exact imitation of the thermo-lamp.

All oils, resins, gums, wax, sugar, and numberless other inflammable substances, are composed of hydrogen and carbon in various proportions, and, in many cases, with the addition of oxygen.

Exp. 3.—Place a glass tube on the shelf of a pneumatic trough, send up into it three parts of fresh prepared carburetted hydrogen gas, and add to it *gradually* four parts of fresh prepared chlorine gas. After each addition of the latter gas, shake the mixture; an absorption will take place, caloric will be liberated, and the tube will become filled with white vapours. When the gases have totally disappeared, a peculiar fluid of an agreeable odour will be deposited, like a heavy oil, which will become yellow by exposure to the air. This is a process of the Dutch chemists for preparing what is called *olefiant* gas.

373. **Super-carburetted hydrogen** is a gaseous compound of carbon and hydrogen, in which the hydrogen combines with exactly twice as much carbon as it does in the carburetted hydrogen gas. It is extremely inflammable, and emits more light during combustion than is given out by the inflammation of that gas. It has been called *olefiant gas.*

In the year 1818, Dr. Thomson discovered a new gas, which he calls *hydrocarbonic gas.* It is obtained by heating in a retort a mixture of prussiate of potash and sulphuric acid. It is colourless, not sensibly absorbed by water, has a peculiar smell, a somewhat aromatic taste, and leaves a hot impression in the mouth. Its specific gravity is 0.993. It is combustible, and burns readily with a deep blue flame. Three volumes of it require for complete combustion two volumes of oxygen gas.

Hydrocarbonic gas is a compound of three volumes carbonic oxide and one volume hydrogen gas condensed into three volumes.

For further particulars, see Thomson's *Annals*, vol. xii. page 104. In that paper he denominates this new gas *hydroguretted carbonic oxide*, but he has since named it *hydrocarbonic gas.*

374. SULPHUR is found in most parts of the world combined with metals, from which it is procured by roasting; it also flows from volcanos; it is sublimed from the sulphureous grounds in Italy, and is found in many mineral waters, combined with hydrogen.

Sulphur is procured in large quantities from martial pyrites and other metallic ores. It is also found in abundance in the state of native sulphur, near several volcanos, in different parts of the world.

375. Sulphur, or brimstone as it is sometimes called, is a solid, opaque, combustible substance, of a pale yellow colour, insoluble in water, very brittle, and possessing a peculiar taste and smell. Its specific gravity is 1.990, or nearly twice as heavy as water, and

it is a non-conductor of electricity. It has various uses in medicine and the arts.

Sulphur during its combustion combines with oxygen, and becomes an incombustible substance. Like phosphorus, it is eminently combustible, owing to its great affinity for oxygen.

If sulphur be kept melted in an open vessel, it at length becomes thick, as has often been observed; but I believe it has not been noticed by any writer on chemistry, that it has the peculiar property of becoming *thinner* as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

376. Sulphur is the base of several compounds; it unites with oxygen, hydrogen, carbon, phosphorus, the alkalies, the metals, and with some of the earths.

Nature employs sulphur in a great number of her operations: she presents it under many forms among fossils; charges with it the waters denominated sulphurous; mineralizes with it the metals; causes it to pass into the vegetable and animal fibres; and exhibits it to chemists in an infinite number of combinations.

377. If sulphur be kept in fusion in atmospheric air, it absorbs a small quantity of oxygen, and forms oxide of sulphur; if it be heated sufficiently to take fire, it burns with a pale blue flame, and becomes converted to *sulphurous* acid; but if sulphur mixed with nitre be burned in pure oxygen, or in atmospheric air, it absorbs the full dose of oxygen, and *sulphuric* acid is the product.

Exp.—Melt sulphur in an iron ladle till it thickens, then pour it into water, and when cold it will be found to be that soft reddish substance which is frequently used to take off the impressions from medallions, &c. This is an oxide of sulphur. For the other combinations of sulphur with oxygen, see the chapter on Acids.

378. Sulphur will combine with potash, with soda, and with ammonia; which compounds possess several curious and interesting properties.

379. The alkaline and earthy SULPHURETS are hard substances of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and then emit a fetid odour, similar to that of putrid eggs. They have the property of decomposing water, and by that process they become partially converted to alkaline or earthy sulphates.

The sulphurets can only exist in a state of desiccation, or at least can contain but a very small portion of water without the water being decomposed, which occasions the sulphurets to be changed into hydroguretted sulphurets.

380. The alkaline sulphurets have also the property of decomposing the metallic oxides.

Exp. 1.—Dip a piece of white calico in an aqueous solution of acetate of lead, and then drop a little solution of sulphuret of potash upon it. If this be now placed in the palm of the hand, the lead will be observed gradually to revive, and will soon be reduced to its metallic state.

Exp. 2.—Dissolve some sulphuret of potash in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of manganese be now applied, films of metallic manganese, bright as silver, will instantly appear.

381. Sulphur may be combined artificially with most of the metals, and with some earths: but many of the metallic sulphurets are found native in great abundance.

Some of the metallic sulphurets have much colour, and are employed as pigments.

Sulphuret of lime is recommended by Mr. Higgins as a cheap substitute for potash in bleaching.

Exp.—If a few pounds of a mixture of iron filings and sulphur be made into a paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that combustion and flame will be the consequence.

382. PHOSPHORUS is both of animal and mineral origin. It was formerly obtained by a very tedious and disgusting process; but is now generally procured by the decomposition of the phosphoric acid which is found in animal bones.

Phosphorus was accidentally discovered at Hamburg, in 1669, by an alchemist of the name of Brandt, in his search after gold; and two years afterwards one Kraft brought a small piece of this substance to London, on purpose to show it to the king and queen of England. Mr. Boyle subsequently discovered the process, which he described in the *Philosophical Transactions* for 1680, and in a little book which he published in the same year, entitled *The Aërial Noctiluca.* Mr. Boyle instructed Mr. Godfrey Hankwitz of London how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years.

383. Phosphorus is a solid inflammable substance, which burns at a very low temperature, when in contact with oxygen gas or atmospheric air, and, when thus saturated with oxygen, it forms a peculiar acid. It may be easily cut by the knife, and melts at 90° of Fahrenheit. Its specific gravity is nearly twice that of water.

Exp. 1.—If any light substance capable of conducting heat be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the phosphorus on fire. This sudden inflammation is one characteristic of phosphorus.

Exp. 2.—Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, light will be evolved sufficient to show the hour upon a watch.

Exp. 3.—Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be beautifully luminous.

Exp. 4.—Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a liquid combustion.

Exp. 5.—If any part of the body be rubbed with liquid phosphorus, or phosphuretted ether, that part, in a dark room, will appear as though it were on fire, without producing any dangerous effect, or sensation of heat.

Exp. 6.—Phosphorus is so very combustible, that if a small piece be folded in paper and rubbed with a stick, a slight friction will evolve caloric sufficient to occasion it to burst into flame.

Exp. 7.—If strong nitrous acid be poured upon a small quantity of a mixture of oxygenized muriate of potash and phosphorus, flashes of fire will be emitted at intervals for a considerable time.

Exp. 8.—Pour a little pure water into a small glass tumbler, and put one or two small pieces of phosphuret of lime into it. In a short time flashes of fire will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession.

Exp. 9.—Put thirty grains of phosphorus into a Florence flask with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial fire-work, attended with the most beautiful coruscations.

Exp. 10.—Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop cock, force a stream of oxygen gas directly upon it. This will afford the most brilliant combustion under water that can be imagined.

Exp. 11.—Phosphorus has such an affinity for oxygen, that it is capable of decomposing some of the metallic oxides, even without the assistance of heat. With a needle pass a thread through a small bit of phosphorus, previously freed from moisture by immersing it in alcohol. If this be suspended in an aqueous solution of nitromuriate of gold, in a few minutes the phosphorus will become covered with pure gold.

Exp. 12.—Phosphorus, surrounded by cotton rubbed in powdered rosin, and placed under the receiver of an air-pump, takes fire after exhaustion, and displays very beautiful phænomena on the gradual admission of the air.

These experiments require extreme caution: phosphorus should indeed always be handled with great care, lest any part of it get under the finger nails, a small portion of which might for a long time occasion great inconvenience.

384. Phosphorus may be combined with oxygen, hydrogen, chlorine, carbon, iodine, sulphur, or with most of the metals, and also with some earths.

Sir Humphry Davy has formed two compounds with phosphorus and chlorine; the one is a white powder, composed of about 1 of phosphorus, and 6.8 of chlorine by weight; and which he calls *phosphorana;* the other is a fluid as clear as water, and its specific gravity is 1.450; he calls it *phosphorane.*

385. Phosphorus forms with oxygen, according to the proportion of the latter, either oxide of phosphorus, or phosphorous acid, except it be saturated with oxygen, and then phosphoric acid; with hydrogen, phosphuretted hydrogen; with sulphur, phosphuret of sulphur, and sulphuret of phosphorus; with the metals, metallic phosphurets; and with some of the earths, earthy phosphurets.

Phosphorus will combine with all the metals except gold and zinc. It unites with iron, and forms that kind of iron called *cold-short.* Iron of such property acquired this name on account of its being very brittle when cold, though malleable when heated. Such iron may however be made good and fit for most purposes, by heating it with carbonate of lime. For an account of the other combinations of phosphorus, see pages 118—120.

386. CARBON is the next simple combustible we have to treat of. Pure carbon is known only in the diamond: but carbon in the state of charcoal may be procured by heating to redness a piece of wood closely covered with sand in a crucible, so as to preserve it while in the fire, and afterwards while cooling, from the action of the atmosphere.

387. Carbon is capable of forming various combinations: it unites with oxygen, hydrogen, nitrogen, sulphur, or phosphorus, and with iron.

The compound formed by the union of carbon and nitrogen is known by the name of prussic gas. It was discovered by Gay Lussac, and by him called *cyanogen.* It is obtained from prussiate of mercury by distillation. It is a permanent gas, very inflammable, and nearly twice as heavy as atmospheric air. It affects the nostrils violently when inhaled by them.

388. Carbon with various doses of oxygen forms carbonic oxide or carbonic acid; with hydrogen and caloric, carburetted hydrogen gas; with nitrogen and caloric, carburetted nitrogen gas; with sulphur, sulphuret of carbon; with phosphorus, phosphuretted carbon; and with iron, plumbago, or carburet of iron.

Some of these compounds having been already *examined, it will now be expedient to consider the other states and combinations of carbon.*

389. CHARCOAL, which is the combination with which we are the most familiar, is the coaly residuum of any vegetable or animal substance that has been burnt in close vessels.

Charcoal for common purposes is made by a less expensive process. The wood is disposed in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up until all the water and oil are driven off; after which the fire is extinguished by shutting up all the air-holes.

390. Charcoal is generally black, sonorous, and brittle; very light, and destitute of smell.

Charcoal is so porous that it may be seen through with a microscope; and, however large the piece, it may be readily blown through.

391. Charcoal is a powerful antiseptic; is unalterable and indestructible by age; is a non-conductor of electricity, and a bad conductor of heat; but when ignited it has great affinity for oxygen; though if air and moisture be excluded, it is not affected by the most intense fire.

392. In the preparation of gunpowder charcoal is a most important ingredient; it is also employed in purifying rancid oils, and in abstracting the colour from sirups and many other valuable preparations; for decomposing

the sulphuric salts, which it effects by absorbing the oxygen of their sulphuric acid and liberating the sulphur: and for so many other purposes, by the chemist and the manufacturer, that it would be tedious, in such a compendium as this, to attempt to enumerate them.

Charcoal, from its affinity with oxygen, will decompose the sulphuric and nitric acids. It decomposes the latter with great rapidity.

Exp.—Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured in, so as to trickle down the inner side of the vessel and mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire-work.

Charcoal is used by mathematical instrument-makers and engravers, to polish their brass and copper-plates. Plates of horn and lantern leaves are polished with it. It is also much used by artists in tracing the outlines of drawings.

393. Common charcoal is generally a compound substance; an *oxide* of carbon, or the woody fibre partially oxidized; it also contains hydrogen, and a portion of fixed alkaline salt and some earth, but these are adventitious and not essential ingredients.

Messrs. Allen and Pepys have determined by experiment that charcoal properly prepared contains no sensible quantity of hydrogen, but that it absorbs moisture if exposed to the air only a few hours, which renders the result of analysis uncertain.

394. The base of common charcoal, divested of all impurities, is known to chemists by the name of CARBON.

395. Carbon is capable of crystallization, though not by art; and in that state it is called *diamond.*

The diamond is the purest carbon we know of. It is chiefly found in the kingdom of Golconda in Asia, and in Brazil. It always occurs crystallized; indeed, if not, it would be carbon and not diamond.

396. Carbon has the property of de-oxidizing the oxides of metals and other combustible substances, and with this view it is often used in the arts. These purposes are effected by means of fire, the carbon uniting to the oxygen to form carbonic oxide, or carbonic acid; and the metal thus deprived of oxygen, is left in its pure state.

For a further account of the uses of charcoal in reducing metallic oxides, see chap. xi. of this volume.

397. Carbon is found in large proportions in bitumen, petroleum, and pit-coal; it seems to be ready formed also in all vegetables, and in most animal substances; and combined with oxygen, enters into the composition of a great variety of the products of the mineral kingdom.

Common coal is composed of bitumen and charcoal in different proportions, according to its quality and the places whence it is procured.

398. Carbon is not only a component part, but it forms nearly the whole of the solid basis of all vegetables, from the most delicate flower in the garden to the huge oak of the forest.

399. Carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins; and of these again how indefinite is the variety!

Fourcroy has remarked that "vegetables may be considered as beings intended by nature to *begin* the organization of crude matter, and to dispose the primitive materials of the earth and atmosphere to become the source of life, and consequently to establish a communication between minerals and animals; from whence it follows, that plants are truly chemical apparatus employed by nature to produce combinations which would not take place without them."

400. All living vegetables have the power of decomposing water, and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic acid of the atmosphere, to form the numberless productions of vegetable nature.

When we decompose water, we can do it only by abstracting its oxygen and liberating the hydrogen, which is easily effected by some combustible bodies. But vegetables perform this process in a different way: they preserve the hydrogen and set the oxygen free.

This process of Nature, in the latter instance, has been noticed in a former chapter.

Organized beings cannot live upon the matter in which they vegetate: Nature, therefore, by making the air their food, has afforded them nourishment without offering violence to their tender organs.

401. It should be remembered that all orders of vegetables are produced from four or five natural substances, viz. caloric, light, water, air, and carbon. Nature has required only these in order to form even the most exquisite of her productions.

It has been shown that water and atmospheric air are the natural food of plants. Caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon.

When we consider the small number of simple substances which enter into the composition of plants, how astonishing is the variety that has been granted to us by the profuse hand of Nature! The species of vegetables already known are more than 40,000, and large additions are daily making to this number by new discoveries.

402. As carbon is a necessary part of sugar, of oils, &c., it consequently enters into the composition of animal milk, and of animal oils and fat; it is also found in albumen, gela-

tine, fibrina, and in many of the animal secretions.

403. It is imagined that most of the metals may be combined with carbon : but at present we know only of its combination with iron.

404. In one proportion it forms cast iron : in another, steel; and in a third proportion, plumbago, generally, though improperly, called black lead.

Cast iron acquires carbon from the charcoal used in the smelting furnaces for its fusion. See the article Iron, chap. x.

The name which plumbago has so long borne shows how necessary it was to give a new nomenclature to the science. It is now known that its metallic appearance is owing to *iron;* and that there is no *lead* in its composition. Many other instances might be adduced, in which the names of substances have given false ideas of their nature and properties :—thus, white and green copperas contain no *copper*, but are formed the one with zinc, the other with iron.

405. Upon an average cast iron contains, according to the analysis of Bergman, about one forty-fifth of its weight of carbon.

Cast iron does not owe its brittle qualities to the carbon which is combined with it; for that iron which contains most carbon is found to be the best metal.

406. Steel is iron combined with about one part of carbon in two hundred of iron.

To procure steel, nothing more is necessary than to heat good pure iron for several hours in a proper furnace, with charcoal, or any substances capable of furnishing a sufficient quantity of carbon, which is absorbed by the iron in the process.

407. Carburet of iron, or plumbago, has been found to consist of nearly nine parts carbon to one of iron.

Plumbago of the best kind is found in great plenty at Borrowdale in Cumberland. Besides making pencils, it is likewise useful to rub over wooden machinery to prevent friction. It protects iron from rust, and on that account is rubbed on various ornamental cast-iron works, such as the fronts of grates, &c.

408. Carbon has so great an affinity to oxygen, that when assisted by heat it will take it from most substances with which it may be combined; in certain proportions they form carbonic acid gas.

There can be no doubt that carbonic acid is formed by the union of carbon with oxygen; for steel may be made as effectually by the decomposition of carbonic acid, as it can by the direct union of iron with carbonaceous matter.

Exp.—Take one of those glass receivers generally used for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having a piece of ignited cortical part of charcoal ready, suspend it by a wire to the stopper of the receiver, and immerse it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful coruscations. When the inflammation is over, the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid; and if some transparent lime-water be poured in, the whole will become opaque from the carbonate of lime now formed.

409. Twenty-eight parts by weight of carbon require about 72 parts of oxygen to saturate them; so that 100 parts of carbonic acid are composed of nearly 28 parts of carbon and 72 of oxygen.

Oxygen has a greater affinity for carbon than for most other substances. Lavoisier was the first person who burned small quantities of charcoal in pure oxygen gas in close vessels, and found that a part of this gas was converted into fixed air, or carbonic acid. The composition of carbonic acid has been further proved by analysis, as it has actually been decomposed, and the charcoal exhibited entire.

410. Carbonic acid can only be exhibited in the form of gas; each cubical inch weighs about half a grain.

Exp.—Carbonic acid gas may be readily procured for experiment by pouring a little diluted sulphuric acid into a phial, or a retort, upon a little pulverized chalk. An action will immediately commence; and if one end of a bent tube be made fast in the neck of the phial, and the other brought under the mouth of a jar filled with water, and inverted in a vessel of water, the gas will pass from the mixture into the inverted jar.

411. Carbonic acid gas is invisible and elastic; is much heavier than atmospheric air; will mix with vital air; may be combined with water, to which it gives a brisk and acidulous taste; is destructive of flame, and will occasion

the death of animals that are obliged to breathe it.

In order to saturate water with this gas, it is necessary to subject it to a considerable degree of pressure. The persons who are engaged in making the acidulous soda water have peculiar conveniences for this purpose. Cider, perry, bottled beer, and other fermented liquors, owe their briskness and sparkling to the presence of this gas.

Plants of all kinds give out carbonic acid gas while growing in the shade: but when assisted by the rays of the sun, there is reason to think that the plants have the power of decomposing this acid; for then the leaves give out only oxygen gas.

Monsieur Saussure says that the leaves absorb oxygen gas in darknesss, and emit an equal quantity when exposed to the light. If this account of vegetation be correct, growing vegetables deteriorate the atmosphere in the night, and purify it in the day.

412. Carbonic acid is found in the proportion of about one part by measure, in every thousand parts of atmospheric air; also in caverns and mines, where it is called the choke-damp.

The floor of the grotto del Cane, in Italy, is lower than the door, and this hollow is always filled with fixed air, which can rise no higher than the threshold, but there flows out like water. It has been a common practice to drive dogs into this cavern, where they suffer a temporary death, for the entertainment of the passengers; but a man enters with safety, because his mouth is far above the surface of this deleterious air; its specific gravity being so much greater than common atmospheric air. Fatal accidents have happened to persons who have incautiously descended into brewers' vats, and wells, before they have been purified from this gas.

Carbonic acid gas so often occupies the bottoms of wells, that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter it with safety; if not, a quantity of *quick-lime* should be let down in buckets, and gradually sprinkled with water. As the lime slacks, it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

Fatal accidents often happen from the burning of charcoal in chambers; because wherever charcoal is burned this gas is always formed.—Workmen have also lost their lives by sleeping too near lime-kilns, where this gas is extricated in abundance.

413. It is abundant in Spa-water, and in some other acidulous waters.

These waters have a pleasant light acidity and briskness, and sparkle in the glass like fermented liquors; which is well known to be the case with water when artificially impregnated with fixed air.

414. Carbonic acid is found in all parts of the world in great plenty, in combination with the alkalies, with some metallic oxides, in earths, and in stones; particularly in chalk, limestone, and marble.

Carbonic acid is found combined with alkalies and with several metallic oxides. These combinations are called carbonates.

415. Carbonic acid renders mild and salutary some of the most acrid and destructive of all known substances.

We all know the causticity of pure quick-lime, and the corrosive qualities of the fixed alkalies; but whenever these substances are *fully* saturated with carbonic acid, the first forms mild calcareous earth (or chalk), and the others mild neutral salts, applicable to many purposes of medicine and domestic economy.

416. Carbonic acid may be disengaged by most of the other acids; but it is usually separated from alkalies by the addition of quick-lime, which absorbs this acid, and thus becomes converted into carbonate of lime.

Though the alkalies readily part with their carbonic acid to caustic lime, yet they have a great affinity to this acid.

Exp.—This may be shown by the following interesting experiment :—Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potash, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its surface will be seen covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

417. Carbonic acid may be collected in abundance from the surface of fermenting liquors; but it is more commonly obtained by pouring sulphuric acid upon a mixture of chalk, or marble and water.

418. In all vinous fermentations a decomposition of the saccharine matter takes place;

and a part of the disengaged oxygen, uniting with a part of the carbon of the sugar, forms carbonic acid. A decomposition also of part of the water of solution perhaps promotes the process.

419. The cause of vinous fermentation is not well understood; though it is a process which nature employs, and which art can imitate, for the decomposition of certain vegetable substances, (when in favourable circumstances of temperature and solution,) and also for their recomposition to form new products.

Fourcroy admits five distinct species of vegetable fermentations, viz. the saccharine (or that which forms sugar), the vinous, the acetous, the colouring (or that which is developed by the maceration of the indigo-plant), and the putrid. Some writers have spoken of another kind of vegetable fermentation, viz. the panary, or that which manifests itself in making bread; but surely this is a species of the acetous, for its tendency to acidity is very evident.

420. The presence of vegetable matters, of water, of sugar, a certain degree of heat, and free escape for the carbonic acid as it is generated, are circumstances necessary to produce vinous fermentation.

It appears from several late experiments carefully made, that sugar is composed entirely of hydrogen, oxygen, and carbon. Mr. Cruickshank made many experiments on fermentation, and invariably found, that whenever he added a fourth substance to the three which compose saccharine matter, no fermentation took place. He tried lime, and at another time a small quantity of potash: and the addition of either prevented fermentation.

To produce vinous fermentation, it is necessary that the matters subjected to that process should be placed in a temperature not lower than about 55 degrees of Fahrenheit. No kind of fermentation is ever known below the freezing point.

421. By the process of fermentation the sugar, which is a vegetable oxide, parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol by being thus partially deoxidized.

Lavoisier, having analysed sugar, found that it was composed of hydrogen, oxygen, and carbon, in the following proportions: Hydrogen 8lbs., oxygen 64lbs., carbon 28lbs., in every 100 pounds weight of sugar. Having subjected 100lbs. of sugar to fermentation, he found the products (alcohol, carbonic acid, and acetous acid,) when analysed, contained the precise quantities of hydrogen, oxygen, and carbon, which were contained in the original sugar. In consequence of the results which were obtained, he remarks, "The effect of the vinous fermentation upon sugar is thus reduced to the mere separation of its elements into two portions: one part is oxygenized at the expense of the other, so as to form carbonic acid; while the other part, being deoxygenized in favour of the former, is converted into the combustible substance called alcohol."

422. Sugar, however, does not become converted into alcohol merely by losing a part of its oxygen; it parts with a portion of its car-

bon at the same time, in the form of carbonic acid gas, and a new arrangement of the principles, both of the sugar, and of the water in which it is dissolved, taking place, furnishes an increased proportion of hydrogen, in order to form vinous liquor.

The spirituous or intoxicating quality of all fermented liquors is owing to the alcohol they contain, whether it be malt liquor, wine, or spirits.

423. To recapitulate the different properties of charcoal, which have been enumerated in this chapter, it may be said that it appears to be indestructible by age; that it is not in the least altered by the most intense heat, if heated in *closed* vessels; that when burnt in atmospheric air it becomes converted into carbonic acid gas; that it is a valuable antiseptic; is the basis of all vegetables; is one of the component parts of wax, oils, gums, and resins; and from its affinity to oxygen that it has the property of decomposing many substances in which oxygen constitutes a material part.

CHAPTER X.

OF THE METALS.

424. The general characters of the metals are, hardness, tenacity, lustre, opacity, fusibility, malleability, and ductility: but a metal may notwithstanding want one or more of these characters.

425. The metals are generally procured from beneath the surface of the earth, in a state of combination either with other metals, with sulphur, oxygen, or with acids; though a few of them have occasionally been found in a state of purity.

Metals are generally found in mountainous countries, in such as form a continued chain; but the metallic part of a mountain usually bears but a small proportion to its whole contents. Granite rocks seldom contain any metallic ores.

It is deserving of notice, that if minerals had been placed on the *surface* of the globe, they would have occupied the greatest part of the earth, and would have prevented its cultivation. Their being deposited *below*, is a proof of management and design worthy of that Being who could furnish so great a variety of this class of bodies.

426. Besides the metalloids discovered by Sir Humphry Davy, there are forty-two di-

stinct metals, which possess properties very different and distinct from each other.

For a knowledge of most of the metals, we are indebted to the more perfect modes of analysing minerals which modern chemistry has afforded. The ancients were acquainted with only seven of these metals.

427. There has been considerable difference of opinion as to the best mode of classing the metals; but as they all combine with oxygen, though in different proportions and under different circumstances, the mode in which this combination takes place, and the properties of the compound, furnish the best data for any division of the metals; and it is upon these principles that the whole have now been divided into the seven following classes.

1st. The metals which combine with oxygen and form alkalies. These are potassium, sodium, and lithium.

2d. Those metals which by combining with oxygen form the alkaline earths; viz. calcium, magnesium, barium, and strontium.

3d. Those metals which by combining with oxygen constitute the remainder of the earths. These are silicum, alumium, zirconium, glucinum, ittrium, and thorinum.

4th. The metals which absorb oxygen and decompose water at a high temperature. These are iron, tin, zinc, cadmium, and manganese.

5th. Those metals which absorb oxygen at different temperatures, but do not decompose water at any temperature. This class is composed of twelve distinct metals: viz. osmium, cerium, tellurium, titanium, uranium, nickel, cobalt, copper, lead, antimony, bismuth, and mercury.

6th. Those metals which do not decompose water, but absorb oxygen and are thereby converted into acids. This class includes arsenic, molybdenum, tungsten, chromium, columbium, and selenium.

7th. The metals which do not decompose water, nor absorb oxygen from the atmosphere at any temperature. These are platinum, gold, silver, palladium, rhodium, and iridium.

428. To begin with the first class:—Two of these metals were discovered by Sir Humphry Davy, and by him named potassium and sodium; the other, which is of later discovery, is called lithium.

429. Pure POTASSIUM is solid at the usual temperature of the atmosphere, but quickly becomes soft and malleable by the warmth of the hand; it is perfectly white, and has the lustre of polished silver. It has a stronger affinity for oxygen than any other known substance, and is a conductor of electricity.

The strong affinity of potassium for oxygen is very strikingly exemplified in its action upon water. If a morsel of it be laid upon the surface of water, it immediately becomes ignited, and burns, as it swims upon the water, with a beautiful flame; even when placed upon ice it instantly inflames, and the hole which it forms in the ice by the violence of the action is found to hold a solution of potash.

430. Potassium occurs in the animal, vegetable, and mineral kingdoms, but on account of its great affinity for oxygen it is impossible ever to find it in an uncombined state. All that has hitherto been obtained has been procured by chemical means from the potash of commerce, or what has usually been called the vegetable alkali.

Potassium was discovered by Sir H. Davy in the year 1807, by the agency of voltaic electricity upon pure potash. By this means he was enabled to detach the oxygen, and then the alkaline base made its appearance in the form of small bubbles, having the lustre and outward characters of quicksilver.

431. It is susceptible of three distinct degrees of oxidizement, forming the gray, the white, and the orange-coloured oxides of potassium.

432. Potassium in a state of purity has hitherto only been employed for purposes of philosophical chemistry.

Potassium is a most important agent in the hands of the philosophical chemist, as it is capable of detecting and separating oxygen wherever it may exist, and however intimate and energetic may be the nature of its combinations. By its means water may be detached from the most highly rectified alcohol and ether; and by its decomposition hydrogen gas will be evolved.

433. Sodium has properties very similar to

those of potassium. It has the whiteness and lustre of silver, is exceedingly malleable, and is a conductor of electricity. Unlike potassium, it does not inflame when laid upon water, although in decomposing the water in order to absorb its oxygen the action is evidently very energetic. If it be much heated and then plunged into oxygen or chlorine gas, it will burn with great splendour.

When sodium is laid upon water, the appearance of effervescence and the loud hissing noise which accompanies it, bespeak strong chemical action, and show that the affinity of the metallic substance for the oxygen of the water is great and energetic, though it does not inflame like potassium.

Sodium has a much stronger attraction for chlorine than for oxygen; for, if soda be decomposed by chlorine, the oxygen will be expelled from the sodium; and if the hydrate of soda be employed, oxygen and water will be expelled by the same means.

434. Sodium is the metallic base of soda, and was discovered by Sir H. Davy about the time when he discovered potassium: it is obtained by means of voltaic electricity, from purified soda, in the same manner as potassium is obtained from potash.

435. Sodium like potassium is susceptible of three degrees of oxidizement, forming the gray, the white, and the orange-coloured oxide of sodium.

The first oxide of sodium may be procured by heating together, to the point of fusion, some sodium with some pure dry soda. At first a dark *brown* fluid is obtained, but on cooling this becomes a solid of a dark *gray* colour.

The white, or deutoxide of sodium, is the basis of many saline compositions; and in fact it is soda, or the mineral alkali. It may be prepared by burning sodium in such a portion of atmospheric air as does not contain oxygen enough to convert it to the peroxide. It is however usually procured from kelp or barilla by a process already described. It consists of 77.5 of sodium and 22.5 of oxygen.

The orange, or peroxide of sodium, is obtained by burning sodium in an excess of oxygen. It possesses a deep orange colour, and unlike the deutoxide it melts very readily. It is a non-conductor of electricity.

436. Pure sodium has hitherto been employed only for the purpose of philosophical experiments. In the state of an oxide it is however eminently useful in the arts, independently of that important class of salts which is formed by its means.

For an account of the uses of soda, or the deutoxide of sodium, see the chapter on the Alkalies, pages 88—93.

437. LITHIUM is a metal of a white colour resembling sodium. As its oxide is strongly alkaline, it was at first supposed to be soda: it is however distinguished both from potash and soda, by its power of neutralizing a much larger quantity of any acid. The alkali which is called *lithia*, was discovered, by M. Arfvredson a young Swedish chemist, in a mine-

ral called petalite; and was afterwards shown by Sir H. Davy to be a metallic oxide, like potash and soda. This new alkali has since been found in two other mineral substances, viz. in *spodumene*, and in crystallized *lepidolite*.

The petalite is a mineral which is brought from the mine of Utoen in Sweden. The method of separating the new alkali from it, may be seen in the *Journal of the Royal Institution*, vol. v. page 337.

According to Vauquelin, lithia attracts carbonic acid very rapidly from the atmosphere, and in neutralizing the acids is more powerful even than magnesia.

438. Sir H. Davy having decomposed carbonate of lithium by a powerful voltaic battery, the metallic base of this alkali was obtained; but when this was exposed to the action of the atmosphere, it burned rapidly and was re-converted to *lithia*, or the oxide of lithium.

439. Several salts have already been formed by the artificial combination of this alkali with the acids. The sulphate of lithia crystallizes in small prisms of a shining white colour. It is more fusible and soluble than sulphate of potash, and its taste is not bitter, but saline. The muriate and nitrate of lithia are both deliquescent salts; while the carbonate is efflorescent, and sparingly soluble in water. Like other alkalies, lithia has the property of turning vegetable yellows brown.

440. Having thus dismissed the first class of metals, I shall proceed to those which form the second class, and which when combined with oxygen constitute the alkaline earths.

441. They are called *calcium*, the base of lime; *magnesium*, the base of magnesia; *barium*, the base of barytes; and *strontium*, the base of the earth called strontia, or strontites.

Calcium is a bright metal, white as silver, which burns when heated a little, and lime is re-formed.

Magnesium burns with a red light when strongly heated, and becomes magnesia.

Barium is unlike the two former metals, being of a dark colour and possessing but little splendour, even less than that of fresh cast iron. It is so heavy as to sink rapidly in sulphuric acid. When exposed to the air it quickly tarnishes and falls into a white powder, which is barytes.

Strontium has a resemblance to barium in some of its qualities; it has but little lustre; is difficultly fusible, and not volatile. They are all of them procured by the aid of voltaic electricity.

Owing to the minute quantities which have been procured, it is impossible to ascertain whether these metals are susceptible of more than one degree of oxidizement; though Gay Lussac and Thenard conceive that barium is capable of combining with more than one dose of oxygen; for, when they heated pure barytes in dry oxygen gas, the gas was rapidly absorbed, and the earth changed colour and acquired a glazed surface.

442. The third class of metals, or presumed metals, are *silicum*, which by oxidizement is converted into silica, or flint-earth; *alumium*,

the base of alumina, or common clay; and four others, viz. *zirconium*, *glucinum*, *ittrium*, and *thorinum*.

So early as the year 1805, Mr. Hume suggested the probability of silica being a metallic oxide, and several years afterwards Sir Humphry Davy pronounced it to be a compound of 31 base and 30 oxygen.

In his attempts to decompose alumina, Sir H. Davy submitted the earth to the same kind of experiments as those which had been made upon silica; but he did not succeed in exhibiting the base of this earth in a separate state. There can however be no doubt of the constitution of alumina being similar to that of the alkaline earths, as it has the power, when fused with potassium, of converting that metal into potash; and when fused with iron a globule of metal was obtained which was whiter than pure iron, which effervesced in water, became covered with a white powder, and which by a different examination yielded real alumina and oxide of iron.

The evidence which we have for believing that zircon is a metallic oxide, rests upon a similar foundation to that afforded by the action of potassium upon the earths last enumerated.

When zirconia is ignited to whiteness and a morsel of potassium brought in contact with it, a great part of the zirconia is converted into dark coloured particles, which, when examined by a magnifying glass, evidently appear in some parts to be metallic. The potassium is at the same time converted into potash.

When glucina is treated in the way just described for zirconia, the potassium is in this instance also converted into potash by the oxygen afforded by the earth: hence the natural conclusion is, that the base of glucina is likewise metallic. Its name will be *glucinum*.

Considerable doubt exists as to the nature of the base of yttria. All that is known in favour of its being a metallic oxide is, that when ignited with potassium it imparts its oxygen and converts the alkaline metal into potash; and when it has been intensely heated and then dissolved in muriatic acid, it gives out chlorine.

Thorina is a rare earthy substance lately discovered by Berzelius in a species of gadolinite. Its properties are little known, but it is presumed to be a metallic oxide, and the metal will of course be denominated *Thorinum.*

443. Little is known of these substances, as the earths from which they are obtained have hitherto resisted the means which were employed with success upon the alkaline earths. Methods were however afterwards devised by which they were partially decomposed; and though the quantity of the base was in every instance very small, the phenomena which accompanied the experiments were such as to leave no doubt that silica, alumina, zirconia, and glucina, are real metallic oxides. The earth called yttria may very probably have also a similar base.

444. The fourth class of metals are those which absorb oxygen, and decompose water at a high temperature. Of these there are only four, viz. iron, tin, zinc, and manganese.

445. IRON is plentifully and universally diffused throughout nature, pervading almost every thing, and is the chief cause of colour in earths and stones. It may be detected in

plants and in animal fluids. It is found in great masses, and in various states, in the bowels of the earth in most parts of the world.

There is a great variety of iron ores (chiefly composed of the oxides of iron and clay), which have different names given them by the workmen, and are of very different qualities :—for particulars consult Bergman, Kirwan, or other mineralogists.

Iron is found in greater abundance than any other metal. In the northern parts of the world whole mountains are formed of iron ore, and many of these ores are magnetic. Of the English ores, the common Lancashire hematite produces the best iron.

446. Pure iron is of a blueish-gray colour; it is one of the hardest metals, though extremely ductile; when dissolved in an acid it has a nauseous styptic taste, and emits a peculiar smell when rubbed strongly; it is attracted by the magnet, and has the property of becoming itself magnetic. It is fused with great difficulty, but gives fire by collision with flint, and is the most elastic of all the metals. Its specific gravity is about 7.7.

An iron wire only one-tenth of an inch in diameter will carry 450 pounds without breaking. A wire of tempered steel of the same size will carry nearly 900 pounds. Dr. Black's *Lectures.*

Iron becomes softer by heat, and has the capability of being welded to another piece of iron, so as to form one entire mass; and this may be done without melting either of the pieces. No other metal possesses this singular property, except platinum. Notwithstanding this, pure iron is nearly infusible.

If a bar of iron be suspended for some time in a perpendicular position, it becomes magnetic. If friction be employed in a peculiar way, it quickly acquires strong magnetic powers.

Prussiate of potash is the usual test for iron. When added to a liquid which contains iron, it will cause a blue precipitate, if the iron be in the state of a peroxide; but if the iron is partially oxidized, the precipitate will be gray.

Exp.—Write on paper with a weak solution of sulphate of iron, let it dry and the writing will be invisible. By dipping a feather in a solution of prussiate of potash, and drawing the wet feather over the letters, the writing will be restored and the letters will be of a bright blue, the true prussian blue having been formed by the process.

447. Iron is employed in three states; viz. that of *cast* iron, *wrought* iron, and *steel;* each of which is of a different nature, and used for different purposes.

448. The difference in these three kinds of iron consists in this:—*Cast* iron is the metal in its first state, rendered fusible by the combination of carbon and oxygen. *Wrought* iron differs from the former, in being deprived of this carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable. *Steel* is made of wrought iron, by various processes, whereby the metal resumes a small portion of the carbon, and acquires a capacity of receiving different degrees of hardness.

Though iron is deprived of part of its carbon and rendered malleable by hammering, a long continued hammering will entirely deprive it of its malleability.

Steel, like cast iron, contains carbon; but it is divested of oxygen, which is always combined with the latter.

If a slender rod of wrought iron be plunged into cast iron in fusion, it will absorb part of the carbon, and become steel. What is called *case-hardening* is a conversion of the *surface* of iron into steel.

Exp.—A steel instrument may be known from one of iron by the following experiment:—If a drop of nitric acid be let fall upon it, it will occasion a black spot if it be steel, but will not have this effect if it be wrought iron. The blackness is probably owing to the iron being dissolved and the carbon thereby exposed to view.

449. Respecting the oxides of this metal, iron has such an affinity for oxygen, that it will become oxidized merely by exposure to the air. The oxides of iron are found in great plenty ready formed in the bowels of the earth. This metal is susceptible of two degrees of oxidizement; the one producing the black and the other the red oxide of iron.

The chemical distinction between *black* and *red* oxide of iron is, that the latter contains one half as much more oxygen in a given portion as the former; 69 parts of the metal combining with 20 of oxygen to form the black oxide, and with 30 parts of oxygen to produce the red oxide. The scales which are detached from forged iron by a high degree of heat, and which Dr. Priestley employed in several of his last experiments in America under the name of *finery cinder*, are in the state of black oxide, whereas the common rust of iron is the red oxide.

450. The most useful salts of iron are those composed with the sulphuric, the nitric, the muriatic, and acetic acids; and these, with some others, are very essential to our manufactures.

Green vitriol, which is of so much use in dyeing, in colouring hats, and in other manufactures, is a sulphate of iron formed by the decomposition of martial pyrites. The iron in the pyrites is in a metallic state, and in the salt it is in the state of the black oxide. The nitrates, muriates, and acetates of iron are prepared by art for the use of the calico-printers, who consume great quantities of these salts in a state of solution.

451. The arsenite, sulphate, phosphate, chromate, and tungstate of iron, as well as the sulphuret of this metal, are all found native.

The native arsenite of iron is found in Cornwall; native sulphate of iron occurs frequently with pyrites; phosphate of iron ready formed is seen frequently in bogs,—it is called native prussian blue; chromate of iron is found in America, in France, and in Siberia; and tungstate of iron exists native in a mineral found in Britain, and elsewhere, called wolfram. The sparry iron ore is a carbonate of iron.

Besides the above, *carburet* of iron (usually called *black lead*) is found in several parts of the world. A combination of alumina, iron, and silica, also occurs native, and forms what is called *emery;* a substance very useful in the arts, and of which large quantities are found in the island of Jersey.

Carbonate of iron is also commonly found in solution in chalybeate waters: such waters may be known by the dark orange-coloured film which generally appears upon their surface: the oxide of iron is rendered soluble by an excess of carbonic acid.

Exp.—To a portion of such chalybeate water add a grain or two of powdered quick-lime. This earth, in its pure state, has such an affinity for carbonic acid, that it will immediately take it from the metallic oxide, which now becomes insoluble, and will be precipitated in the form of common ochre.

452. The uses of iron are innumerable; every thing we possess is manufactured by its means; it is assuredly the most useful substance in the world. When converted into steel it is employed in various ways, especially for edge-tools: all which are formed in part with this metal, from the ponderous pit-saw to the finest lancet. Its oxides are used in painting, enamelling, dyeing, and in medicine.

Iron was in use in the time of Moses. *Deuteronomy* iv. 20, viii. 9, and xviii. 5. The Greeks understood the method of tempering it. Homer describes the firebrand driven into the eye of Polyphemus, as hissing like hot iron immersed in water.

The property of *welding*, which, except sodium and platinum, no other metal possesses, renders iron the most suitable of all others for every common purpose. It becomes softer by heat, and thus may be moulded by the hammer into any form, and united in as many parts as the workman pleases, without rivets or without solder.

Good steel is much more ductile than iron, and hence the most minute instruments are generally made with it. A finer wire may be drawn from it than from any other metal.

The oxide of iron imparts its colour to a great variety of natural substances. It is the cause of the redness of common bricks; it gives colour to the carnelian, the garnet, and other precious stones. With different proportions of oxygen it imparts other and different colours. Thus it gives the blue to the lapis lazuli, the yellow to the topaz, &c.

Exp. 1.—If a piece of calico be immersed in a colourless solution of sulphate of iron, and, when dry, washed in a weak solution of carbonate of potash, a permanent colour will be produced, viz. the buff of the calico-printers.

Exp. 2.—Take some of the black liquid described in experiment 1, page 128, add by degrees muriatic acid to it, and the colour will be discharged. Now drop in a little solution of potash and the black colour will be restored. Some nicety is requisite in adding the acid and alkali; for if they be given in excess the effects will not be so apparent.

453. TIN is found in Germany, in Saxony, in South America, and in the East Indies; but in England it is chiefly procured from Cornwall and Devonshire.

Tin must have been known very early, as it is mentioned by Homer, and also in the books of Moses. The edge-tools of the ancients, and their coins, were made with mixtures of tin and copper.

Tin is found only in the primitive mountains. Its ores occur most frequently in granite, but never in limestone.

454. Tin is a white metal, of little elasticity, and small specific gravity. It is not very

ductile, but is so exceedingly malleable that it may be beaten out into leaves thinner than paper. It emits an uncommon smell when rubbed; and if suddenly bent, affords a crackling noise, which is almost peculiar to this metal.

The specific gravity of tin is 7.291. The purity of this metal may be known by its specific gravity, its purity being in exact ratio with its levity; while gold on the contrary, provided it be not alloyed with platinum, is fine in proportion to its density.

Tin is soluble in all the mineral acids. It may be precipitated from its solutions by potash, but an excess of potash will re-dissolve the metal.

455. Tin absorbs different proportions of oxygen; but only two well defined oxides of this metal are known, viz. the gray, and the yellow; the first being composed of 100 parts of tin and 13.5 of oxygen, the latter of 100 of tin and 27 of oxygen.

A *yellow* oxide of tin may be procured by dissolving granulated tin in very dilute nitric acid, and precipitating it from the solution by an alkali: by pouring very strong nitric acid on granulated tin, a *white* oxide may be prepared, which precipitates in a pulverulent form, and is to be washed and dried for use.

A *white* oxide of tin is used to form the opake kind of glass called enamel. To this enamel every kind of colour may be given by metallic oxides.

456. The muriate, the nitro-muriate, and the sulphate of tin are most known, though many others may be formed with this metal

which might possibly become useful to the arts. There are also two distinct combinations of tin with chlorine, and two with sulphur. None of the salts of tin have been discovered native, notwithstanding the ores of this metal are found in great abundance.

Tin by means of the muriatic acid decomposes water, and having been thus oxidized, it then dissolves readily in the acid to form muriate of tin. A recent solution of this metallic salt has a great affinity for oxygen.

Exp. 1.—If a little colourless and recently prepared muriate of tin be poured into a rich green solution of muriate of copper, the copper will be deprived of a portion of its oxygen, and a white muriate precipitated.

Exp. 2.—Into the phial containing the white muriate of the last experiment, pour a little muriatic acid. The precipitate will quickly be dissolved, and the solution will be colourless.

457. Tin is consumed in large quantities by the dyers; it is used also for covering sheet iron to prevent its rusting, and in forming plumbers' solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthenware, and for various other purposes.

Tin is used to form boilers for dyers, worms for rectifiers' stills, and many other utensils employed in the arts.

The consumption of tin for covering thin rolled iron, and forming what are improperly called sheets of tin, is very considerable: besides this, tin is used for coating the inside of iron and copper utensils, brass and iron pins, &c.

Tin is employed to form bell-metal, bronze, brass for cannon, and a variety of other compounds. The addition of tin renders copper more fluid, and disposes it to assume all the impressions of the mould. It was probably with this view that it was used by the ancient Romans in their coinage.

See my Essay on the "Manufacture of Tin Plate" in the *Memoirs of the Literary and Philosophical Society of Manchester*, vol. iii. N. S. page 347.

458. Tin is employed by the dyers to give a brightness to cochineal, archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes. For these purposes it is previously dissolved in a peculiar kind of aquafortis, called *dyer's spirit.*

Several of the colouring substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable by the use of this metallic solution.

Exp. 1.—Boil a little cochineal in water with a grain or two of cream of tartar (supertartrate of potash), and a dull kind of crimson solution will be formed. By the addition of a few drops of nitro-muriate of tin, the colouring matter will be precipitated of a beautiful scarlet. This, and some of the former instances, will give the student a tolerably correct idea of the general processes of dyeing woollen cloths.

Exp. 2.—Having found a piece of blue linen cloth, that will bleach in oxygenized muriatic acid, dip the tip of the finger in a solution of *muriate of tin*, and press it, while wet with the solution, upon a strip of this cloth. After an interval of a few minutes immerse the cloth in the phial of liquid oxygenized muriatic acid, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin has preserved its original colour, while the rest of the cloth has become white.

Exp. 3.—Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black, by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin will appear of a beautiful scarlet, although the ground will remain a permanent black.

Exp. 4.—Take a piece of very dark olive-coloured linen that has been dyed with iron and quercitron bark, or weld, and spot it in several places with a *colourless* solution of muriate of tin. Wherever the cloth has been touched with this solution, the original colour will be discharged, and spots of a bright yellow will appear in its stead.

459. ZINC is a very combustible metal possessing but a small degree of malleability and ductility, except under certain circumstances. When broken, it appears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle, which, in consequence of its affinity for oxygen and carbonic acid, reflects various colours. It is readily acted upon by acids and alkalies, either in its metallic state or when oxidized. It melts at 680° of Fahrenheit, and its specific gravity is 6.861; when hammered 7.190.

Zinc, if beaten out into thin leaves, will take fire from the flame of a common taper. It is the most combustible metal we have. Next to manganese, it has the strongest affinity for oxygen of all the metals. When intensely ignited it burns freely, and is thereby converted into an oxide. By the usual processes of sublimation this oxide is frequently formed, and collected for medicinal purposes, and sold under the name of flowers of zinc, or that of *zinci-oxydum*. It is extremely light, and has the appearance of fine wool.

460. Zinc, generally called by our artists *spelter*, is not found native; but, in England and elsewhere, is extracted from calamine and blende, two of its ores, by distillation.

Zinc is one of the most abundant metals in nature, excepting iron. Calamine, which is one of its ores, is found both in masses and in a crystallized state. The sparry calamine of Derbyshire consists of oxide of zinc 65 and carbonic acid 35, whereas the earthy calamine consists of about 71½ per cent. of oxide of zinc, 13½ of carbonic acid, and 15 water. The electric calamine contains from 25 to 50 per cent. of silica. Zinc occurs also in an ore called *blende*, which is an impure sulphuret, containing from 16 to 30 per cent. of sulphur. By the miners this mineral is called black-jack, and until lately was employed in Wales for mending the roads.

In China there is a great abundance of zinc: it is used in that country for current coin, and for that purpose is employed in the utmost purity.

Zinc may be known by dissolving it in a mineral acid, and then adding ammonia, which precipitates it of a white colour, and redissolves it instantly. Sulphuretted hydrogen, added to a solution of this metal, produces a white and lasting precipitate.

Exp.—Take a phial with a solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids. By mixing them, a curious phænomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and, if then shaken, almost as instantly re-dissolved.

461. When zinc is heated it readily attracts oxygen; and at a white heat the absorption of oxygen, even in the common atmosphere, is so rapid and violent that the oxide actually sublimes: hence its oxide acquired the name of *flowers* of zinc. It may also be oxidized by acids. We are acquainted with only one oxide of this metal, which is white, and consists of zinc 80.39 and oxygen 19.61.

Zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the metals except manganese will precipitate it from its solutions in a metallic form.

462. A great number of salts have been formed with this metal; but the carbonate, the sulphate, and the acetate of zinc are most known; the two first are found in a native state; a compound may also be formed of chlorine and zinc, and another with zinc and phosphorus.

Sulphate of zinc, formerly called *white vitriol*, is usually formed in Germany from the ore called *blende*, which is a sulphuret of zinc. By the agency of fire and the access of atmospheric air, the sulphur is converted into sulphuric acid, and by means of proper evaporation and cooling, the salt is obtained in a crystallized state. It has been discovered by Mr. Holt, the secretary of the Cork Society, that spiders will feed upon sulphate of zinc. One of these insects kept in a box for six months, was found to have eaten nearly four ounces of the salt. See Thomson's *Annals*, vol. xii. page 454.

463. Zinc is frequently combined with copper or tin, in various proportions, and these mixtures constitute some of the most useful compound metals or alloys; it is also largely employed in its metallic state unmixed with any other metal; it is used in medicine; it is the base of white vitriol; and its carbonate or oxide may be advantageously substituted for white lead in house-painting.

Three parts of copper and two of calamine, or native carbonate of zinc, constitute *brass;* five or six of copper and one of zinc, form *pinchbeck*. *Tombac* has still more copper, and is of a deeper red than pinchbeck. *Prince's metal* is a similar compound, excepting that it contains more zinc than either of the former. A mixture of tin and copper with zinc forms *bronze*.

464. **Cadmium** was discovered by Mr. Stromeyer, in 1817, in an ore of zinc. It resembles tin in its colour, lustre, softness and ductility; and also in the sound which it gives when doubled. Its specific gravity is 8.750.

Cadmium melts and volatilizes at a few degrees of heat below that which is required by tin. It does not tarnish by exposure to the air.

465. When cadmium is heated in atmospheric air, it combines with oxygen, and is converted into an orange-coloured oxide,

which is not volatile, and is readily reducible to the metallic state.

466. The oxide of Cadmium readily dissolves in acids, and forms with them soluble salts, which like arsenic give a white precipitate with the alkalies, and yellow with sulphuretted hydrogen.

On account of these properties Cadmium was at first supposed to be arsenic.

467. MANGANESE is a brilliant metal, of a darkish white colour inclining to gray, very brittle, of considerable hardness, and of difficult fusibility. Its specific gravity is somewhat greater than that of tin or zinc; it is not attracted by the magnet except when a portion of iron is combined with it; and if exposed to the air, it absorbs oxygen with rapidity and falls into powder. On account of its great affinity for oxygen, it is not likely ever to be found in a metallic state.

Manganese was first procured in its pure metallic form by Kaim and Gahn between 1770 and 1775. An account of the process which they adopted, may be seen in Sir Humphry Davy's *Elements of Chemical Philosophy*, part i. page 366.

M. Fischer of Schaffhausen reduced the oxide of manganese by means of a peculiar furnace, and procured metallic manganese with the following characters. Its colour is whitish, it is harder than tempered steel, it cuts glass nearly as well as the diamond, it scratches rock crystal, and takes a very good polish. See Thomson's *Annals*, vol. xiii. page 36 of the introduction.

468. The manganese which we use in this country is obtained in the state of black oxide from Somersetshire and Devon. It also abounds in America, and in various parts of the continent. It is usually found in large amorphous masses, but it occurs sometimes in well defined prismatic crystals of the colour of steel.

The oxide of manganese is abundant, and easily procured; but the *pure* metal can only be obtained by art, and requires to be carefully defended from oxygen, which it readily absorbs. In order to preserve specimens in a metallic state it is necessary to varnish them, or to keep them immersed in oil, or ardent spirits.

469. This metal, as I have already observed, becomes oxidized by mere exposure to the air: and is susceptible of at least two different degrees of oxidizement, forming the olive and the dark brown, or, as it is more commonly called, the black oxide of manganese, the first being a compound of 100 of manganese and $28\frac{3}{4}$ of oxygen, and the latter of 100 of manganese and $57\frac{1}{2}$ of oxygen.

Dr. John says there are three oxides of manganese, and Berzelius enumerates no less than five oxides of this metal; but the probability is, that there are only two well defined oxides.

If one part of the black oxide of manganese and three parts of nitrate of potash, both reduced to powder, be mixed and thrown into a red-hot crucible and continued there until no more oxygen gas be disengaged, a greenish friable powder is obtained, called *mineral cameleon*, from its property of changing colour during its solution in water.

Exp. 1.—Put into a wine-glass about a scruple of the oxidized manganese and potash, prepared as above, and an equal quantity of the same compound into another glass. On one pour hot, and on the other cold water. The hot solution will exhibit a beautiful *green* colour; the cold one, a deep *purple*.

Exp. 2.—If a small portion of the same compound be put into several glasses, and water at different temperatures be poured upon each, the contents of each glass will exhibit a different shade of colour. This experiment affords another instance of metals producing various colours according to their different states of oxidizement.

470. A variety of salts have been made with the oxides of this metal; but this class of salts has not yet been rendered useful.

There is this peculiarity in the salts of manganese, that, when dissolved in water, the manganese cannot be precipitated from its solution, in a metallic state, by any of the other metals, because, compared with all others, this metal has a superior attraction for oxygen.

A carbonate of manganese is found native in Norway and Sweden. A sulphuret of this metal also occurs in Cornwall and in Transylvania; and at Limoges in France a phosphate of manganese has been found which contains 27 per cent. of phosphoric acid. An artificial compound of manganese and chlorine, and another of manganese and phosphorus, may also be obtained.

471. The oxides of manganese are used in

preparing the bleaching liquor; in purifying glass; and in glazing black earthen-ware. It is also employed in some cases to give colours to enamels in the manufacture of porcelain. The black oxide is much used by chemists for producing oxygen gas, which, by the application of a red heat, it yields in great abundance.

Its use in discharging colour from white flint glass has been long known. According to Pliny, it was employed for this purpose more than two thousand years ago. The rationale of its operation has been admirably explained by Bergman.

Black oxide of manganese contains about 36 per cent. of oxygen. It quickly gives out 11 or 12 per cent. of this oxygen merely by the application of a red heat; but the remaining portions cannot be separated by the most intense heat.

Exp.—Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. Oxygen gas will be disengaged very copiously. If the same oxide be put into an iron retort, the sulphuric acid may be omitted, and a naked fire substituted for the lamp.

472. The fifth class of metals are those which absorb oxygen at different temperatures, but have not the power of decomposing water at any temperature. Of these there are twelve in number; viz. osmium, cerium, tellurium, titanium, uranium, nickel, cobalt, copper, lead, antimony, bismuth, and mercury.

The first five of these have been found only in very small quantities, and have hitherto been considered as mere matters of curiosity, and applied to no use.

473. OSMIUM was discovered in the year 1804, by Mr. Tennant, in the black powder which remains when crude platinum has been digested in nitro-muriatic acid; and from the singular property which it possesses of forming an oxide having a strong smell, he was induced to name it *osmium.*

Dr. Wollaston has discovered a distinct ore of osmium and iridium intermixed with the grains of crude platinum.

474. Osmium is a dark blue metal, which is insoluble in any of the acids. It is difficultly fusible, and even unchangeable in the most intense heat unless in contact with air, when it combines with oxygen, and is converted into a volatile oxide possessing that kind of pungent smell which has not been recognised in any other body. Its oxide, which is soluble in water, is a solid colourless semi-transparent substance, having a sweet taste, and giving when combined with potash an orange-coloured solution in water.

Osmium imparts to the skin an indelible stain of a dark colour, and produces a purple with an infusion of galls.

475. CERIUM was discovered in the year 1804 by Messrs. Hissinger and Berzelius, in

a peculiar mineral found at Ridderhytta in Westmannland in Sweden, which is of a reddish colour, and in appearance very like tungsten.

Hissinger and Berzelius called the new metal *cerium*, from the circumstance of the planet Ceres having been discovered by Piazzi about the same time.

476. The quantities of cerium which have hitherto been procured are so small that nothing respecting its nature or properties has been discovered, except that it is capable of being volatilized at a great heat. Hissinger, one of the original discoverers of this metal, has lately announced that it is susceptible of two degrees of oxidizement, producing the white and the red oxide of cerium.

Cerium had not been seen in a metallic form till Sir Humphry Davy procured it from some of the oxide discovered by Hissinger and Berzelius in 1804.

477. TELLURIUM was discovered by Klaproth, in the year 1798, in an ore of gold found near Zalethna in Transylvania. It occurs in its metallic state, and 100 parts of the ore yield more than 90 parts of tellurium.

Klaproth named this metal tellurium, from *Tellus* the Latin name of our own planet the Earth; Kirwan had called it *sylvan* from the circumstance of its having been found in Transylvania.

478. Tellurium is a metal of considerable lustre; its colour is nearly white, or rather si-

milar to that of antimony. It easily fuses, and rises in vapour at an intense red heat. It is soluble in nitric and nitro-muriatic acids, but its solutions are decomposed by the addition of water. It is capable of combining with sulphur, with some of the other metals, with hydrogen, and with chlorine. Its specific gravity is 6.115. It has not been employed in the arts.

This metal by fusion combines readily with potassium and sodium, emitting heat and light. These alloys are fused with difficulty, but when thrown into water they produce purple solutions consisting of the respective alkali united to tellurètted hydrogen.

Tellurium, as a metal, possesses the peculiar property of forming an acid with hydrogen gas. By union with hydrogen it forms two distinct compounds; one of which is gaseous, and called *telluretted hydrogen gas;* the other solid, and called *hydruret of tellurium.*

479. If tellurium be heated in atmospheric air, it burns with a pale blue flame edged with green, and becomes converted to an oxide. The oxide of tellurium is white, tinted with yellow; it is soluble in the various acids, and is composed of 83 tellurium and 17 oxygen.

No other oxide is known of this metal.

480. TITANIUM is obtained from a mineral known by the several names of *rutile*, *red schorl*, and *titanite*. The oxide of this metal was first discovered in the year 1781, by Mr. Gregor of Cornwall, in an ore of iron found

in the valley of Menachan in that county, and hence called *menachanite;* but metallic titanium was not produced until 1796 by Vauquelin and Hecht. We are now acquainted with several minerals which contain the oxide of titanium. This metal, or rather its oxide, was first named by its original discoverer *menachine;* but Mr. Klaproth afterwards gave this new metallic substance the name of titanium.

This ore, which is attractible by the magnet, occurs in the form of a black sand, having a great resemblance to grains of gunpowder. They are flattish angular grains, which have a rough shining surface. Their specific gravity, as stated by Mr. Gregor, is 4.427.

481. Titanium resembles copper in its colour, and has much lustre, but it tarnishes by exposure to the air. It forms salts by its union with the nitric, muriatic, and some other acids. It is a brittle metal, and requires a most intense heat even for its imperfect fusion.

Little else is known of its properties, as it has hitherto been produced but in very minute quantities, and in a very imperfect state of reduction.

482. Titanium is thought to be susceptible of three degrees of oxidizement. The first oxide is blue, the second red, and the third white. The proportion of oxygen in these different oxides has not been ascertained; but Vauquelin and Hecht have found that the white, or per-oxide, is composed of 89 parts of the red oxide and 11 parts of oxygen.

This metal, in the state of an oxide, has been employed in the porcelain manufactory at Sevres near Paris, and produces on china a brown of greater richness than can be obtained by any other means.

483. URANIUM was discovered by Klaproth, in the year 1786, in a mineral which he procured from Joachimsthal in Bohemia, called *pechblende;* and as the new planet discovered by the late Sir Wm. Herschel was known in Germany by the name of *Uranus*, Mr. Klaproth named this metal *uranite*, but he afterwards changed that name for *uranium*.

This metal is found in our own country in the county of Cornwall, in the state of an oxide, which frequently occurs of a brilliant green.

The planet above mentioned was named *Georgium sidus* by Sir W. Herschel, in honour of our king; but I believe it is not called by this name any where but in England.

484. Uranium is somewhat of the colour of iron, but of considerable lustre. It is hard and brittle, and internally of a reddish brown colour. It has hitherto been obtained only in small grains. It fuses with great difficulty, and does not tarnish by exposure to the atmosphere at its usual temperature. It dissolves in nitric acid, but is not soluble either in the sulphuric or muriatic acid. Its specific gravity is 8.1.

By dissolving the yellow oxide in weak nitric acid beautiful transparent oblong green crystals are obtained. When dissolved in acetic acid, it gives topaz-yellow crystals.

485. Uranium is susceptible of two degrees of oxidation, from whence result the black and the yellow oxide of this metal. The latter, which is the peroxide, has acid properties. It unites with potash, and neutralizes it. A sulphuret of uranium may also be obtained.

It is curious that the protoxide of this metal forms salts, by its union with some of the mineral acids; and that the peroxide forms salts of a different order, by its union with the alkalies. See Supplement to the *Annals of Philosophy*, vol. xiii. page 44.

486. NICKEL is a fine white metal, ductile and malleable, but of difficult fusion. It is attracted by the magnet, and has itself the property of attracting iron. Like copper, it is when converted to the state of an oxide soluble in ammonia. It bears a fine polish, but its colour changes to that of bronze when ignited. Its specific gravity is usually 8.38, but some specimens have acquired that of 8.932 after having been thoroughly hammered.

Nickel dissolves readily in several of the acids, and communicates to them a green colour; but sulphuric acid acts very slowly upon it, even with the assistance of heat. Nitric acid dissolves it more readily.

Exp. 1.—Dissolve nickel in nitric acid and a beautiful green solution will be formed. The oxide of this metal is used to give a delicate grass green to porcelain.

Exp. 2.—Melt some powdered flint glass in a crucible with a little of the oxide of nickel, and when the whole is in complete fusion it may be moulded into any form that may be desired. This glass when cold will have the colour of the hyacinth.

487. Nickel was discovered by Cronstedt in the year 1751, and about twenty years afterwards its properties were examined by Bergman. Its ore is very similar to that of copper; it is procured from the mines of Saxony and from various parts of Germany; and is also generally found with cobalt. Native nickel has been found in Saxony and Bohemia in small quantities. The nickel of commerce is always impure.

The most abundant ore of this metal is a sulphuret of nickel, called *kupfernickel*, which is generally a compound of nickel, arsenic, and sulphuret of iron. It has lately been raised from a mine in the parish of St. Ewe, Cornwall, where it occurs at the depth of about 25 fathoms.

It is a curious circumstance, that all the specimens that have been examined of the stones which have been said to fall from the atmosphere contain iron alloyed with nickel. These stones, which have at different periods been seen to fall on every quarter of the earth, are supposed by some writers to be cast from a volcano in the moon.

488. If purified nickel be exposed to atmospheric air in an intense heat, it is slowly converted to a dark brown oxide which is still magnetic. There are two oxides of this metal, but their composition is not perfectly known. What has been called the *green* oxide, is found to be a hydrated oxide, which

contains more than a fourth of its weight of water.

An oxide of nickel is more easily obtained by exposure to heat with nitre: it is of an apple green colour. According to Thenard, another oxide of this metal may be obtained of a black colour, by exposing the green oxide to a red heat, or by treating it with chlorine gas.

489. Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. A native arseniate of this metal called nickel-ochre has been found in Scotland and at several other places in Europe.

Nickel is also capable of combining with chlorine, sulphur, and phosphorus.

490. Nickel is employed in China in making *white* copper, which is a beautiful metallic compound; but it has not been much used elsewhere, except in the potteries, and at Birmingham. It might however be mixed with iron by fusion, to great advantage, as an alloy of these two metals is not liable to rust like common iron.

Some of the manufacturers of Birmingham have taken advantage of this knowledge: others have melted it with brass in such proportions as to form a handsome compound metal. In both these combinations it is exceedingly useful for many purposes. The Chinese also employ it in conjunction with copper and zinc for making children's toys.

491. COBALT when in a pure metallic state

is of a light gray colour, nearly resembling fine hardened steel. It is difficult of fusion and oxidizement; it is obedient to the magnet, and is harder than copper; but it is so brittle that it may easily be reduced to powder. It suffers little change when exposed to the air or to water at common temperatures, though when fused on charcoal by a stream of oxygen gas it burns brilliantly. Its specific gravity is 8.7.

Cobalt ores generally contain arsenic; they are so contaminated with it, that the workmen who are employed seldom live many years. It is to be hoped that some mode will be devised to protect these men from the baneful effects of this mineral.

492. Formerly all our cobalt came from Saxony; but it is now found abundantly in Sweden, in the Mendip hills in Somersetshire, and in a mine near Penzance in Cornwall. Metallic cobalt was first obtained by Brandt in 1733.

The cobalt ores of Hesse produce a net profit of 14,000*l.* a year, though formerly they were used for no other purpose than to repair the roads.

Cobalt ores may be analysed thus: Take 100 grains of the ore, dissolve them in nitrous acid, precipitate the iron by the addition of ammonia, and separate it from the solution by a filter. The nickel, which is always found in these ores, may afterwards be precipitated by the addition of a solution of potash, and separated in the same manner as the iron. The remaining solution may be evaporated to dryness, and the oxide reduced by the usual fluxes. A small quantity of cobalt for experiment may be readily procured from smalts.

Exp.—Cobalt may easily be obtained in a metallic state, by fusing *strewing smalt* with 6 or 8 times its weight of soda. The soda forms an union with the sand, and leaves the cobalt free. It may also be obtained from zaffre by fusing it in a crucible with three or four times its weight of black flux.

493. Cobalt may be oxidized by an intense heat. The oxygen prepares it for acquiring that beautiful blue colour which is seen on earthenware and porcelain. There are at least two oxides of cobalt, viz. the blue which is the protoxide, and the black which is considered to be the per-oxide of this metal.

The oxide of cobalt forms the most permanent blue colour that we are acquainted with. La Grange says that the old painters used this oxide mixed with oil in their paintings, which is the reason why the sky and drapery in some old pictures are of so durable a blue.

Zaffre, which we have long imported from Saxony, is an oxide of cobalt, mixed with three times its weight of ground silica. The oxide of cobalt for the potter's use, has generally been prepared from this article of foreign production.

494. A great variety of salts have been formed with the oxides of this metal; but the muriate of cobalt is that which has, perhaps, been longest known. An arseniate and a sulphate of cobalt have been found native. This metal is also capable of combination with phosphorus and sulphur; and a chloride of cobalt

may be formed by burning the metal in chlorine gas.

Muriate of cobalt much diluted has been long used in forming Hellot's sympathetic ink.

Exp. 1.—Write with a solution of muriate of cobalt, and the writing while dry will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant green colour.

Exp. 2.—Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful blue.

Exp. 3.—Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in Exp. N° 1, and some of the flowers with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape or winter scene, but on holding it near the fire it will be transformed to a beautiful summer landscape: this again will appear gradually to lose its verdure, and resume its winter dress, on being removed to a cold situation.

Exp. 4.—If oxide of cobalt be dissolved in ammonia, a red solution will be produced, different in colour from that of all other metallic oxides.

495. Cobalt has hitherto been chiefly used for making the different kinds of smalts for painting and enamelling. It is extremely valuable to the manufacturers of porcelain; for it not only produces a beautiful colour, but

endures the extreme heat of their furnaces without any deterioration. This colour is so intense, that a single grain of the pure oxide will give a deep tint of blue to 240 grains of glass.

The *strewing-smalt*, an article which was formerly much used by sign-painters, is made by melting the oxide of cobalt with flint-glass, and grinding the whole to a coarse powder. The same composition reduced to an impalpable powder forms the smalt sold under the name of powder blue, and which is now not only used by laundresses, but is made the basis of several pigments. It has also been much employed by paper-manufacturers to give a blue tinge to writing- and printing-papers.

The greatest consumption of cobalt is by the potters and porcelain manufacturers. The usual price of the prepared colour is two guineas the pound.

496. Copper is found in several parts of England and Wales, particularly in Cornwall, and in the Isles of Man and Anglesea. It is an abundant metal, and has been raised in various other parts of the world.

Copper mines have been worked in China, Japan, Sumatra, and in the north of Africa. Native copper is found in Siberia crystallized in cubes. The copper pyrites found in Cornwall are *sulphuret* of copper. Anglesea formerly yielded more than twenty thousand tons of copper annually.

Exp.—To ascertain whether an ore contains copper, pulverize some of it and then pour upon it a few drops of nitric acid, and wait an hour; then dip a feather into the acid and wipe it upon the clean polished blade of a penknife, and if copper be present it will immediately be precipitated on the knife of its natural colour.

497. Copper is a brilliant metal of a red co-

lour; extremely nauseous to the taste; very hard, sonorous, and elastic; and the most ductile of all the metals, except gold. Its malleability is also so great that it is hammered into leaves, and sold in thin paper books in imitation of leaf gold. The specific gravity of English copper is from 8.607 to that of 8.735. It melts at 27° of Wedgwood's pyrometer.

Copper, on account of its elasticity, is used by rope-dancers, &c. A wire 1-10th of an inch diameter will support nearly 300lbs.

Copper will not burn so easily as iron; which is evident from its not striking fire by collision like iron. On this and other accounts this metal has been substituted for iron in the machinery which is employed in gunpowder mills.

498. Copper will in some measure become oxidized by long exposure to atmospheric air, in which case its surface will be covered with a green or blue crust, similar in appearance to verdigris.

Copper is susceptible of two degrees of oxidizement, forming the red and the black oxide; the red or protoxide being a compound of 100 of copper and 12½ of oxygen, while the black or per-oxide consists of 100 of the metal and 25 of oxygen.

Oxide of copper is soluble in ammonia, and precipitable from its solution by sulphuretted hydrogen.

Exp. 1.—Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia. This will precipitate the copper of a blueish white. During its examination, however, the precipitate will be re-dissolved, and a beautiful blue liquid which has been called *aqua celestis* will be the result.

Exp. 2.—Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arseniate of potash. The addition of these two *colourless* solutions will produce very different effects; for the one glass will have an abundant precipitate of a beautiful grass green, and the other a precipitate of a brilliant sapphire blue.

Exp. 3.—Write upon paper with a diluted solution of muriate of copper; when dry, it will not be visible, but on being warmed before the fire the writing will become a beautiful yellow.

499. There are many salts of copper; but those most used are the sulphate of copper; acetate of copper; nitrate, muriate, and arsenite of copper; and the tartrate of potash and copper. Besides these, which are generally formed by art, the carbonate, the arseniate, the muriate, the phosphate, and the sulphate of copper are found in a native state. Two distinct combinations of copper and chlorine have also been formed; besides which, this metal is capable of being united with sulphur, phosphorus, and iodine.

Sulphate of copper is frequently found in the streams of water in copper mines: these waters were suffered to run to waste, till an attention to chemical affinities taught the proprietors of the mines how to turn them to a good account. The quantity of salt which they contain is not sufficient to reimburse the expense of boiling it to blue vitriol; but by throwing waste iron into these waters the salt becomes decomposed, and the copper is precipitated in a metallic form.

Exp. 1.—If a piece of bright silver be dipped in a solution of sulphate of copper, it will come out unchanged: but if the blade of a clean penknife, or any piece of *polished* iron, be dipped in the same solution, the iron will instantly put on the appearance of copper.

Exp. 2.—Take the piece of silver employed in the last experiment, hold it so that the silver and the polished steel may be *in contact;* then in this situation plunge them into the same solution, and in a moment BOTH will be covered with copper.

The ores of copper, called *malachite*, and mountain green, are native carbonates of copper. The green sand brought from Peru is a native muriate of copper. A phosphate of copper, containing 30 per cent. of phosphoric acid, has been found near Cologne, and the arseniate of copper occurs plentifully in the Huel Garland mine in Cornwall.

Exp. 3.—If a colourless solution of arseniate of potash be poured into a colourless solution of sulphate of copper, a *green* precipitate will be produced, forming an arseniate of copper similar to that found in the Cornish mines. These metals may be thus reciprocally detected.

Exp. 4.—Write with a solution of sulphate of copper, wash the paper with prussiate of potash, and the writing will be revived of a reddish brown colour. In this experiment the sulphate is converted to a true prussiate of copper.

500. The uses of this metal are too various to be enumerated. Besides its employment to make boilers and other vessels of capacity, and to sheathe the bottoms of ships, it enters as a component part into several of the most valuable metallic alloys; it is also combined with sulphuric acid to form Roman vitriol;

and its oxides are employed in enamel-painting, and in the manufacture of several colours.

The most important of these alloys is brass, which is formed by the union of copper and zinc, though brass is never made with pure zinc, but generally with calamine, which is a native oxide, or, rather, carbonate of zinc.

Pinchbeck is made by alloying copper or brass with a certain portion of metallic zinc. This alloy, which approaches nearest to the colour of gold, is also called *prince's metal*, and sometimes *Prince Rupert's metal*.

Bronze and gun-metal are formed by the union of copper and tin in the proportions of 100 parts of the former to 10 or 12 of the latter. This alloy has more tenacity than copper, and its surface is not so easily tarnished by the atmosphere.

Bell-metal is also an alloy of tin with copper, but this usually contains one-fourth of its weight of tin.

Copper is likewise capable of forming alloys with nickel, manganese, iron, and lead. With the latter metal it forms, according to Fourcroy, a very useful compound for making the larger kind of printers' types.

Oxide of copper is employed in making French green, mineral green, blue verditer, &c. and it is also used by the coloured-glass makers. It forms a beautiful *green* glass.

501. Lead is a metal of a blueish white colour, very brilliant when first cut with a knife, but it soon tarnishes by exposure to the air; it will mark writing-paper, though in a fainter manner than plumbago; and emits a peculiar smell when rubbed violently. It is malleable and ductile, but possesses very little tenacity. Lead is scarcely sonorous, is un-

elastic, and, being the softest of all metals, yields readily to the hammer. Its specific gravity is 11.35: it melts at 612°. The ore generally contains a small portion of silver.

Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased the lead rises to the surface combined with all heterogeneous matters. The art of refining the precious metals is built upon this property of lead.

Exp.—Alloy a piece of silver with a portion of lead, place the alloy upon a stick of charcoal, attach a blowpipe to a gasometer charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity.

502. Lead ore is very abundant in Scotland, in the western parts of Northumberland and Durham, in Derbyshire, and in many other parts of the world. Most of the lead of commerce is however procured from a common mineral (which is a sulphuret of this metal) known by the name of lead glance, or galena.

Lead ore is generally found in veins, both in siliceous and calcareous rocks. Galena, or sulphuret of lead, is very common both in masses and crystallized. That of the county of Durham has been analysed by Dr. Thomson, and found to consist of lead 83.18, sulphur 13.02, and iron 0.50. There is an ore found in Cornwall called *antimonial lead-ore*, which contains 24 per cent. of antimony, 13 of copper, 1 of iron, and 17 of sulphur.

Lead is also found combined with silver, antimony, and bismuth. Oxides of lead combined with various earths also occur in mining countries.

503. Lead presents us with three distinct oxides. It is capable also of combining with chlorine, with iodine, with phosphorus, and with sulphur.

There are only three well defined oxides of lead, viz. the yellow, the red, and the brown or puce-coloured oxide. According to Berzelius, the first of these is composed of 100 of lead and 7.70 of oxygen; the second of 100 of the metal and 11.08 of oxygen, and the brown of 100 parts of lead and 15.60 of oxygen.

When nitric acid of the specific gravity 1.260 is poured upon the *red* oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown, or brilliant flea-brown powder. This is the *brown* oxide of lead, containing 13½ per cent. of oxygen.

Lead may be converted into an oxide by heating it in a situation where it can have free access of atmospheric air. All the oxides of lead may, however, be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead which is combined with flint glass may be revived by melting the glass with any carbonaceous substance.

Exp. 1.—Take one ounce of red lead, and half a drachm of charcoal in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Place this in the middle of a common fire, and presently the lead will be reduced, when it may be poured out as metallic lead.

Exp. 2.—Take a little *red-lead*, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the vitrification of metals.

504. The salts of lead are very numerous, perhaps equal to the number of acids; but the muriate, nitrate, sulphate, carbonate, and acetate of lead are those most known. An artificial chromate of lead has been sold in considerable quantities as a pigment, and it possesses great beauty.

Lead forms an insoluble compound with sulphuric acid, and hence that acid is sometimes used to detect the presence of this deleterious metal; but the best test is a solution of sulphuretted hydrogen, or of some hydrosulphuret. To the suspected liquid add a little of this test, and if lead be present it will give it a dark brown or blackish tinge. The test is however somewhat ambiguous, for it also blackens solutions of bismuth, silver, and some other metals.

Exp. 1.—Write with a solution of nitrate or acetate of lead. When the writing is dry, it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing, by means of the glass stopper, within the decanter. By an attention to the paper the writing will become visible by degrees, as the sulphuretted hydrogen gas rises from the bottom of the vessel.

Exp. 2.—In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned. This is an effectual mode of detecting this and some other pernicious metals when in solution.

505. The carbonate, murio-carbonate, sulphate, phosphate, molybdate, arseniate, and chromate of lead are native productions.

Sulphate of lead or *lead vitriol* occurs at Leadhills and elsewhere in Scotland, in the Isle of Anglesea, and at Penzance. Its usual colours are yellowish gray and grayish white, and it is generally found crystallized.

The native phosphate of lead has two varieties, viz. the *brown* and the *green* lead ore. An arsenio-phosphate of lead is also found in several places in Europe.

Arseniate of lead occurs in France and in Siberia. Beautiful specimens of this native salt have been found in Huel Unity Mine, near Redruth in Cornwall, in six-sided prisms; colour wax yellow, splendent and translucent.

Chromate of lead has been found only in a gold-mine in Siberia; it occurs in prismatic crystals of a hyacinth red colour, inclining to aurora. In some of the specimens the crystals of chromate of lead are very pleasingly intermixed with the green phosphate of lead.

506. Lead is employed to cover buildings, to form water-pipes, to make a great variety of vessels for economical and chemical purposes; and its oxides in refining gold and silver. Its oxides are also used for dyeing and calico-printing; in the manufactures of glass, earthenware, and porcelain; and in the preparation of various pigments. The several alloys formed by means of lead, with copper, tin, and antimony, are now constantly employed in the arts.

The oxides of lead dissolved in various menstrua, are used as embrocations, and for several other preparations, by the practitioners of medicine and surgery.

Exp.—Mix one ounce of litharge of lead with one drachm of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup, and you will have a true muriate of lead of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called patent yellow.

507. **Antimony** is a brilliant, brittle metal, of a silvery white colour, which has not much tenacity, and is entirely destitute of ductility. It has a laminated or striated texture, and when rubbed on the hand communicates to it a peculiar smell. Its specific gravity according to Mr. Hatchett is 6.712. It melts at 810° of Fahrenheit, and on cooling crystallizes in the form of pyramids. At a still greater heat it may be entirely volatilized. It is also susceptible of vitrification, and produces a hyacinth-coloured glass.

Exp. 1.—If this metal be ground fine, and thrown into a dry glass jar filled with chlorine, it will inflame immediately, and continue to burn with great rapidity and with a brilliant white flame. The combustion affords a beautiful spectacle.

Exp. 2.—When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames with a sort of explosion, and presents while burning a very singular kind of white flame, forming what have been formerly called *argentine flowers*.

Exp. 3.—When antimony is well fused upon charcoal, and if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules, into which it divides in its fall, burn with a very lively flame, throwing out on all sides brilliant sparks, different from that of any other metal.

Exp. 4.—Mix five or six grains of sulphuret of antimony with half its weight of chlorate of potash, and then, if a sudden stroke be given to the mixture, upon a steel anvil, it fulminates with a loud report, emitting, according to Fourcroy, a flame as brilliant and rapid as lightning.

Antimony may be known from bismuth thus:—Bismuth is very soluble in nitric acid, but antimony dissolves in it with some difficulty.

508. Antimony is procured from an ore which is found chiefly in Sweden, Saxony, Hungary, and Norway; it is known in these countries by the simple name of ore of antimony.

There are several distinct ores of antimony, but the gray is the only one which is found in sufficient quantity for the manufacturer; it is a sulphuret of antimony. In mineralogical cabinets this ore is divided into four subspecies, viz. the compact, foliated, radiated, and the plumose. Besides these there is what is called the nickeliferous ore of antimony, the red antimony ore, the white ore of antimony, and antimony ochre.

509. We are acquainted with only three well-defined oxides of this metal; viz. the gray, the white, and the yellow. Antimony is also capable of combining with chlorine, iodine, phosphorus and sulphur.

Some solutions of the oxides of this metal are very powerful and even poisonous when taken internally, except in very small quantities. By different combinations of the oxides of this metal, various colours may be produced.

Exp. 1.—If oxide of antimony be precipitated by water from nitro-muriatic acid, the precipitate will be white; but if it be precipitated by a clear solution of galls, the precipitate takes a light yellow.

Exp. 2.—Prepare a colourless solution of tartrate of potash and antimony (the common emetic tartar), and pour into it a little liquid sulphuretted hydrogen. This will combine with the metallic oxide, and form an orange-coloured precipitate.

Exp. 3.—Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the colour of the violet.

Exp. 4.—If the gray sulphuretted oxide of antimony be fused in a crucible, we procure a beautiful transparent glass, which is called the *glass of antimony*. This takes the colour of the hyacinth.

510. Many different salts have been formed with the oxides of this metal; but those most known are the muriate of antimony, the phosphate of lime and antimony, and the tartrate of potash and antimony. The first has been found native.

Muriate of antimony is the common *butter of antimony*. The white oxide of antimony, called the *powder of algaroth*, is made by merely dropping this solution into pure water. Muriate of antimony has been found native in Bohemia.

The well-known medicine called *James's powder* is a phosphate of lime and antimony. It is a triple salt in the form of a white powder. For a method of preparing it, consult *Philosophical Magazine*, vol. xi.

Emetic tartar is a tartrate of potash and antimony, composed of about 56 parts tartrate of antimony, 36 tartrate of potash, and 8 of water.

511. Antimony is combined with some other metals in making printers' types, and specula for telescopes. Its oxides are employed in medicine, and in colouring glass. In times of remote antiquity its sulphuret was used by females as a black pigment, for staining the eyelashes.

Perhaps we have no metal more valuable as a medicine than antimony, or one that is applied in such various ways; and yet no medicine has ever undergone so many vicissitudes in reputation; as may be seen in a very curious history of antimony by Dr. Paris, in the *Pharmacologia*, page 72, 4th edition, 1820.

512. BISMUTH is of a reddish white colour, of a lamellated texture, and moderately hard, but neither ductile nor malleable. Its specific gravity is 9.822, but this degree of density may be increased by weak and cautious hammering; and yet it is so brittle that it breaks readily under a smart stroke of the hammer, and may be reduced by that means even to powder. This metal has but little taste or smell. It melts at 476°, and on cooling crystallizes in parallelopipeds. At a great heat it volatilizes; and when ignited, burns with a beautiful kind of lambent blue flame.

Bismuth has the singular property of *expanding* as it cools. Hence, probably, its use in the metallic composition for printers' types; as from this expansive property are obtained the most perfect impressions of the moulds in which the letters are cast. In manufactories this metal is known to the workmen by the name of *tin glass.* The larger kind of printers' types are generally made with lead and antimony only; in the proportion of four parts of the former to one of the latter.

If water be added to a solution of bismuth in nitric acid, the oxide will be precipitated of a pure *white* colour; but tincture of galls produces a very different kind of precipitate.

Exp.—If a colourless solution of galls be added to a solution of bismuth in nitric acid, equally colourless, a *brown* precipitate will be produced. This is a distinguishing characteristic of this metal.

513. Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England. Native bismuth and sulphuret of bismuth are also found at several places upon the continent; but this is not an abundant metal.

The ores of bismuth are found in veins in the primitive mountains on various parts of the continent of Europe. A sulphuret of this metal has been discovered in Cornwall.

514. Bismuth is gradually oxidized by fusion in atmospheric air; and may be thus converted into an oxide consisting of about 90 of bismuth and 10 of oxygen. At present we are acquainted with only one oxide of this metal. Bismuth is however capable of forming compounds with chlorine, iodine, and sulphur.

Pearl-white is an oxide, or rather a sub-salt, of this metal. Ladies have used it for whitening the skin; but it has the inconvenience of becoming black by the contact of sulphuretted hydrogen gas, or the fumes of fetid substances. The gas which arises from the burning of mineral coal will have the same effect upon it.

Exp.—A letter written with a diluted solution of bismuth becomes, when dry, illegible; but a feather dipped in a solution of sulphuret of potash will instantly blacken the oxide, and make the writing legible.

515. Several salts of bismuth have been formed, but their properties have not been much examined by chemists. Their chief characteristics are, that sulphuretted hydrogen will occasion a dark brown, and gallic acid a pale yellow precipitate in their solutions; and that, when the metal is held in solution by acids, a white oxide of bismuth is precipitated by the mere addition of water.

Nitrate of bismuth does not dissolve in water like most other metallic salts, but becomes decomposed, forming one of the most delicate white precipitates; hence, this metal is readily distinguished from most others. This precipitate, washed and dried, is what has been called *magistery* of bismuth, or pearl-white, before mentioned. The solution of bismuth in nitric acid has been used as a sympathetic ink. When first written, the letters are invisible; but if the paper be plunged in water, the characters become white and perfectly legible.

516. Bismuth is used with other metals not only to form printers' types, but also to make pewter, and for some other compounds. It

remarkably contributes to the fusibility of some alloys; hence it is employed to make solder. Bismuth is likewise given in medicine, though, now, very rarely.

The common mixture for *pewter* is 112 pounds of tin, 15 pounds of lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony to compose this metallic alloy. Bismuth is likewise generally mixed with tin for vessels of capacity, &c., as it gives to that metal a greater degree of brilliancy and hardness. From its property of rendering lead more fusible, it is too often employed with that metal to adulterate quicksilver.

Exp. 1.—If 8 parts of bismuth, 5 of lead, and 3 of tin be melted together, the mixed metal will fuse at a heat no greater than 212°. Tea-spoons made with this alloy are sold in London, to surprise those who are unacquainted with their nature. They have the appearance of bright pewter tea-spoons, but melt as soon as they are put into hot tea.

Exp. 2.—If lead, zinc and bismuth be taken in equal parts, the resulting alloy will melt with so small a portion of caloric, that it may even be kept in fusion upon paper over a lamp.

517. MERCURY, which is found in various states in the interior of the earth, is for the most part brought to Europe from the East Indies and from Peru; but it is found in still greater abundance at Almaden in Spain, where it is extracted from the ore by distillation.

The quicksilver mines of Idria, a town in the circle of Lower Austria, have been wrought constantly for 300 years, and are thought upon an average to yield above 100 tons of quicksilver annually.

Mercury is found also in Hungary and China; it occurs most commonly in argillaceous schistus, limestones, and sandstones. It is likewise found in Sweden amalgamated with silver, and frequently combined with sulphur. Running mercury is seen in globules, in some earths and stones in America, and is collected from the clefts of the rocks there.

518. Mercury, in the temperature of our atmosphere, is a white fluid metal having the appearance and brilliancy of melted silver: in this state it has neither taste nor smell, and is extremely divisible. It is the heaviest of all the metals except platinum and gold, having the specific gravity of 13.568, and when frozen, that of 14.465. This fluid metal freezes at 39 degrees below the zero of Fahrenheit, and is then malleable and ductile. It readily combines with several of the other metals, and forms with them what are called amalgams. It is also capable of combining with chlorine, with phosphorus, with iodine, and with sulphur.

We see mercury always in a *fluid* state, because it is so very fusible that a small portion of caloric is able to keep it in a state of fluidity; but it is as perfectly opaque as other metals. All metals require different portions of heat to fuse them. Tin melts at 442° and lead at 612° of Fahrenheit; whereas gold requires the heat of 32° of Wedgwood, or 1300° of Fahrenheit, to melt it, and platinum cannot be fused by the strongest heat of our best furnaces. Mercury, when submitted to a sufficient degree of cold, is similar in appearance to other metals, and may be beaten into plates. At the poles quicksilver would probably be always solid.

Exp.—By exposing mercury to cold of a proper degree of intensity, which may be accomplished easily by certain frigorific mixtures, it becomes a solid metal. If a lump of this be dropped into a cup of warm water, the solid metal will immediately become fluid, and the fluid water in the same instant will become solid. If a glass be used for the experiment, it should be infolded within a cloth to prevent accidents; for sometimes it will be shivered in pieces by the rapidity of the action.

519. Mercury does not readily combine with oxygen in the ordinary temperature of the atmosphere, even when an extended surface is exposed; but if heated to about 600° of Fahrenheit, it gradually becomes oxidized. It is capable of two degrees of oxidizement, forming the black, or protoxide, and the red, or per-oxide of this metal.

The first is composed of 100 of mercury and 4 of oxygen; the latter is of a bright scarlet, consisting of 100 of the metal and 8 of oxygen.

Mercury may readily be oxidized by dissolving it in nitric acid, and then the oxide may be separated by precipitating it from its solution by the addition of a pure alkali, or by exposing the solution to a proper degree of heat to expel the remaining acid.

The beautiful scarlet pigment called *vermilion* is prepared from mercury. It is the red sulphuret of mercury.

520. There is a great variety of mercurial salts; but the acetate, the sulphate, the nitrate, and the muriate of mercury are best

known. The latter is found native in the Palatinate.

Several salts are formed by art with this metal for medicinal purposes; viz. *Keyser's pill*, which is an acetate of mercury; *Turbith mineral*, a sub-sulphate of mercury; *Red precipitate*, or oxide by means of the nitric acid; *Calomel*, or protochloride of mercury; and the perchloride, or *Corrosive sublimate*.

Exp. 1.—Take equal parts of mercury and flowers of sulphur, add a drop or two of water, and grind the whole together in a glass mortar. Presently the mercurial globules will totally disappear and the mass assume a black colour. It thus becomes a black sulphuret of mercury, or the true *Ethiops mineral.*

Exp. 2.—If the black sulphuret of mercury formed in the last experiment be heated in an open vessel, part of the sulphur will pass off, sulphurous acid gas will be emitted, and the mass remaining in the vessel will have acquired the colour of the *violet.*

Exp. 3.—If the violet residuum of the last experiment be removed to a glass matrass or flask and heat gradually applied, the whole will sublime into a dark shining mass, which, by being reduced into powder, furnishes a most *brilliant scarlet.*

521. Mercury is used in large quantities for separating gold and silver from their several ores; for silvering mirrors, for water-gilding, for making barometers and thermometers; by the philosophical chemist for many purposes of the laboratory; and in the manufacture of vermilion. It has also various and important uses in medicine, besides its employment in the preparation of the mercurial salts.

In South America mercury is used to separate gold and silver from the extraneous matter found with those metals. By triturating the mass with mercury, the gold and silver become amalgamated with it; and afterwards this amalgam is submitted to heat, when the mercury sublimes, and the perfect metals are left in a state of purity.

A fulminating powder has been made with this metal, which might in some particular instances be employed for blasting rocks, as its immediate force is much greater than that of gunpowder, though it does not extend so far.

522. The sixth class of metals consists of those which do not decompose water, but yet are capable of absorbing oxygen, and are thereby converted into acids. They are arsenic, molybdenum, tungsten, chromium, and columbium.

523. ARSENIC, or some of its native combinations, was known to the ancients more than eighteen hundred years ago; but nothing was understood of its real nature until its properties were examined in a philosophical manner by Mr. Brandt in the year 1733.

Exp. 1.—If sulphuretted hydrogen be added to any of the oxides of arsenic in solution, a yellow-coloured precipitate will be produced. This precipitate is the same as that beautiful ore called orpiment (sulphuret of arsenic).

Exp. 2.—If metallic arsenic be previously inflamed in oxygen gas, it will burn till the whole is consumed. The combustion is very brilliant, and forms a striking experiment.

Whenever arsenic has been taken internally, by design or mistake, the best medicine is sulphuret of potash (liver of sulphur) dissolved in water. A few scruples should be dissolved in half a pint or a pint of water, and administered a little at a time as the patient can bear it.

524. Arsenical pyrites, from which the white oxide of arsenic is procured, is found in Bohemia, Norway, Sweden, Hungary, Saxony, and other places on the continent; at Alva in Stirlingshire; and abundantly in Cornwall and Devonshire. Arsenic is also united with, and contaminates, many of the other metallic ores in England.

The arsenic of commerce is prepared in Saxony in the operation of roasting the cobalt ores for the manufacture of zaffre; white arsenic, by mixing the common oxide with potash, and submitting it to sublimation. By this process the arsenic is separated, and sublimed, leaving its sulphur behind, united to the potash.

525. Arsenic is generally found in certain parts of Germany in combination with acids, sulphur, or oxygen; but when reduced to its pure metallic state it is a brilliant metal, of a blueish white colour, easily tarnishing, that is, oxidizing by exposure to the air, though so long as it is kept under water it will remain unaltered.

According to Lavoisier, the specific gravity of metallic arsenic is 5.7633. In all its states it is extremely poisonous.

526. Arsenic is extremely brittle, and at the same time the softest of all the metals. It has no smell while cold, but when heated it exhales a very strong odour, resembling that of garlic. This metal is volatile, and when sublimed it becomes the protoxide which crystallizes in tetrahedrons.

Arsenic may be known by the smell of garlic, and by the white fumes which it exhales when thrown on a piece of red-hot coal. If this experiment be made with *arsenious* acid (the white arsenic of commerce), it must be burnt in contact with charcoal or some other substance that has a powerful affinity for oxygen, as Dr. Paris has lately discovered that the oxide of arsenic in vapour is entirely inodorous, and that the alliaceous smell is wholly confined to *metallic* arsenic in a state of vapour.

527. Arsenic has a great affinity for oxygen, and two combinations of it are known, viz. the white oxide of arsenic, or *arsenious acid*, which is a hard and brittle substance with a glassy texture; and that with a further proportion of oxygen which constitutes *arsenic* acid, and which, according to the mode of its preparation, is either in the form of a white solid, or of the consistence of jelly. Both are poisonous.

The first of these oxides, which may be formed by the combustion of metallic arsenic, is the common white arsenic of commerce, and is composed of about 75 arsenic and 25 oxygen. The arsenic acid is procured by digesting the protoxide in nitro-muriatic acid and distilling to dryness. It may also be formed by dissolving arsenic in nitric acid and evaporating the solution to a white solid mass. Arsenic acid is a compound of about 67 of metal and 33 of oxygen.

528. The salts which have been formed with this metal are few; though muriate of arsenic, known by the name of *butter* of arsenic, was made by the old chemists. None of the salts of this metal, considered as a base, are found native.

Though there are no native salts in which arsenic forms the base, yet we are acquainted with several in which it is combined as an acid; such are the arseniates of lime, copper, iron, cobalt, &c.

529. Arsenic is capable of combining with hydrogen, with chlorine, with iodine, with phosphorus, and with sulphur.

When arsenic is introduced into chlorine gas it burns with great splendour, and the result is chloride of arsenic, the same with the article already mentioned under the old name of *butter of arsenic*.

Iodide of arsenic is a solid similar in colour to that of the vapour of iodine. It is soluble in water, and the solution will decompose nitrate of silver and produce a yellow precipitate of nitrate of silver.

Arsenic and phosphorus readily combine and form together a brilliant black powder.

Sulphur and arsenic readily unite by fusion, and form a red, vitreous, semitransparent mass, which is a true sulphuret of arsenic: but this compound occurs as a native production in various parts of Europe, and is used as a pigment under the name of *realgar*. There is also a yellow sulphuret of arsenic called *orpiment*.

530. Arsenic is used to whiten copper, and enters into most compositions for the specula of reflecting telescopes, and for other optical purposes. Its oxides are employed in many processes of the dyer; also in the manufacture of glass, and in several of the arts. The sulphurets of arsenic are also employed in various ways, and form likewise several valuable pigments.

Copper alloyed with arsenic forms a malleable and flexible metal that takes a fine polish. On account of these properties, this mixed metal is frequently employed for making sundry articles which are designed to be plated with silver.

Arsenic is also used in making small shot. The design of it is to render the lead more brittle, and better capable of granulating.

Orpiment and realgar are both sulphurets of arsenic. Realgar is of the colour of scarlet or dark orange: orpiment, which is formed with more sulphur, is of a beautiful lemon-colour. Realgar always occurs in primitive mountains, whereas orpiment is generally found in secondary mountains. They are both much used in dyeing and calico-printing. The pigment called *king's* yellow is made from yellow orpiment. Besides the several uses which have been enumerated, I am told that beautiful shades of different colours may be given to valuable furs by arsenical solutions.

531. **MOLYBDENUM** is obtained from a mineral found in Sweden and elsewhere called *molybdena*, which is a sulphuret of molybdenum. This metal, which has hitherto been obtained only in small grains, is very brittle,

of the colour of silver, and has a specific gravity of 8.611.

Molybdena is found at Glenelg in Inverness-shire, imbedded in chlorite-slate; also in granite at Shap in Westmoreland; at Coldbeck in Cumberland, and Huel Gorland in Cornwall. It occurs also in Norway and other parts of Europe; in Siberia and in Greenland. This mineral, in outward appearance, is very similar to plumbago. It is a compound of 60 of molybdenum and 40 of sulphur.

532. When heated in open vessels, it combines with the oxygen of the atmosphere and is converted into the white or peroxide. It is susceptible of three states of oxidizement, giving a brown, a blue, and a white oxide. The two latter having acid properties are known also by the names of the *molybdous* and the *molybdic* acids. Molybdenum is capable of forming alloys with many of the other metals.

The protoxide appears to consist of 100 molybdenum and 17 oxygen; the molybdous acid, of 100 molybdenum and 34 oxygen; the molybdic acid, of 100 molybdenum and 50 or 51 of oxygen.

533. **Tungsten** is a heavy metal, procured from a mineral which occurs in Sweden, and from an ore called wolfram found in Cornwall, Germany, and elsewhere. The pure metal is extremely hard, very brittle, and of the colour of steel; it possesses much brilliancy, and has a specific gravity of 17.40, which is but little inferior to that of gold.

This native substance, which is known to mineralogists by the names of *scheelium* or *tungsten*, is composed of tungstic acid 65, lime 31, and silica 4.

534. There are two oxides of the metal, viz. the *brown*, which consists of 100 of tungsten and 16.6 of oxygen; and the *yellow*, consisting of 100 of tungsten and 25 of oxygen. Tungsten will form alloys with several of the other metals, but none of these have yet been brought into use. Sulphuret of tungsten may also be formed by art.

Berzelius formed sulphuret of tungsten by the agency of sulphuret of mercury. It is a black powder, which he found to consist of tungsten 100 and sulphur 33.26.

535. CHROMIUM was unknown until the year 1797, when Vauquelin analysed some of the *red lead ore* of Siberia, and found it to consist of the oxide of lead and a peculiar acid possessing a metallic base. By exposing this acid to an intense heat in conjunction with carbonaceous matter, he succeeded in reducing it to a metallic state. The metal, which he named *chromium*, is white and brittle, and has a specific gravity of not more than 5.90. It is magnetic, though less so than iron or nickel; it takes a good polish, which remains unchanged by exposure to atmospheric air; and yet when heated it is slowly converted to an oxide.

The red lead ore of Siberia is a beautiful and rare mineral, which has been found to consist of 64 oxide of lead and 36 chromic acid. The chromate of iron varies according to the place whence it is obtained.

536. Chromium requires a most intense heat to melt it, and does not readily enter into combustion. It resists the action of all the mineral acids, except that of the nitro-muriatic acid; this, however, acts slowly upon it, and at length forms with it muriate of chromium. Chromium is susceptible of three degrees of oxidizement, whence arise the *green* or protoxide; the *brown* or deutoxide; and the chromic acid, or per-oxide, which is of a *deep scarlet.* The effects which chlorine, iodine, phosphorus or sulphur have upon this metal are unknown.

The green oxide consists of chromium 100 and oxygen 43.86; whereas the metal combines with a double portion of oxygen to form the chromic acid, which is a compound of chromium 100 and oxygen 87.72. The proportion of oxygen in the brown oxide is not yet accurately known.

537. COLUMBIUM, or tantalum as it has also been called, was discovered by Mr. Hatchett, in the year 1801, in a mineral belonging to the British Museum, supposed to be brought from Massachusetts, and which he found to consist of a metallic acid combined with oxide of iron. He gave it the name of *columbium.*

The mineral from which Mr. Hatchett obtained the first specimen of columbic acid has been described as being of a dark brownish gray colour, moderately hard and very brittle; its lustre vitreous inclining to metallic; its fracture imperfectly lamellated; its particles not attracted by the magnet; and its specific gravity 5.918.

538. Mr. Ekeberg, a Swedish chemist, detected a metallic substance in two minerals found in Sweden, different from any metal already known. This metal he named *tantalum.* In the year 1809, Dr. Wollaston submitted the two Swedish minerals to analysis; and discovered that columbium and tantalum are one and the same species. In the year 1815, Berzelius succeeded in reducing the oxide of tantalum to its metallic state, by intensely heating it in a crucible of charcoal.

Tantalite occurs in masses, but principally crystallized in acute octahedrons, with a square base. Its colour is iron black, sometimes with a shade of blue. Its lustre is metallic, inclining to resinous. Its constituent parts are, oxide of tantalum 83, oxide of iron 12, oxide of manganese 8.

539. When columbium] is converted to an oxide, it possesses acid properties; and when the oxide is converted to an hydrate, it becomes soluble in oxalic, tartaric, and citric acids. If metallic columbium be heated to redness, it takes fire, and slowly consumes without flame. In several respects it differs from all the metallic bodies yet discovered.

Columbic acid consists of columbium 100, oxygen 5.5; and the hydrate consists of oxide of columbium 100, water 12.5.

540. SELENIUM was discovered by Professor Berzelius. This substance is principally sulphur; but on burning it emits an odour, which induced Berzelius to suppose that it contained tellurium; he found, however, upon minute examination, that its peculiar smell was owing, not to tellurium, but to the presence of a new substance, to which he gave the name of selenium.

This substance is considered to be a metal, though in the opinion of some persons it might with more propriety have been classed with sulphur and phosphorus.

541. Selenium has a gray colour, its lustre is metallic and very brilliant, and it is slightly transparent. At 212° of Fahrenheit it softens, and at a few degrees higher it melts. When cooling it is ductile, may be kneaded between the fingers, and drawn into fine threads, the lustre of which is strongly metallic; when slowly cooled it has a granular fracture. It is a bad conductor of heat, and a non-conductor of electricity.

When heated before the blow-pipe, it tinges the flame of a fine azure blue, and gives out a strong smell resembling that of horse-radish.

542. When selenium is heated in nitric acid, it is dissolved; and by decomposing a

portion of the acid and combining with its oxygen is converted into selenic acid. This acid, after evaporation to dryness, may be volatilized by heat, or sublimed into needle-formed crystals which are often a foot in length. These are soluble in water, and have the taste and other properties of an acid.

543. Selenic acid unites readily with the fixed alkalies, and with them forms salts of the colour of vermilion. These alkaline seleniates crystallize with difficulty, and deliquesce when exposed to the atmosphere.

If a plate of zinc be immersed in an aqueous solution of any of these salts, the selenium will be precipitated in a metallic state.

544. The principal characteristics of the seventh and last class are, that the metals which constitute it neither decompose water, nor absorb oxygen from the atmosphere at any temperature. These are platinum, gold, silver, palladium, rhodium, and iridium.

545. PLATINUM is found in grains, in a metallic state, in various parts of South America. It has also been discovered in the island of St. Domingo, in a new mineral brought from the gold mines of Brazil, and in the province of Estramadura in Spain.

Platinum generally occurs in small roundish flattened grains of the size of sand; but there are instances of its being found in granular pieces as large as a pea.

546. This important metal was not known or heard of in Europe until the year 1748, and was not described as a peculiar metal, at least in England, before 1754; when Dr. Lewis published several papers upon it in the Philosophical Transactions for that year.

Platinum in the language of Peru means *little silver*. The ore of platinum contains no less than nine different substances, viz. silica, iron, lead, copper, platinum, iridium, osmium, rhodium, and palladium.

547. Platinum is the heaviest of all the metals; is nearly as white but not so brilliant as silver; and is difficultly fusible, though by great labour it may be rendered malleable, so as to be wrought into utensils like other metals. It has considerable tenacity, and is so ductile that it may be drawn into wire less than one-eighteen-thousandth part of an inch in diameter. Hence it may by means of powerful rollers be reduced to sheets of almost any thinness that may be desired.

The specific gravity of hammered platinum is nearly 22, which is double that of lead. It may always be known from other metals by this superior specific gravity, it being the heaviest body in nature.

Platinum may be distinguished from all other metals by adding a solution of muriate of ammonia to a solution of the metal in nitro-muriatic acid, when a red-coloured precipitate will instantly appear. This is the only means yet known to discover when gold has been alloyed with this metal. Gold is generally known, if weighed hydrostatically, by its specific gravity; but if it be alloyed with platinum, some other test is necessary, as platinum has a greater specific gravity than gold.

Exp.—Prepare a very dilute and colourless solution of platinum by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more delicate test than this of any metal, cannot be conceived.

548. Platinum has neither taste nor smell, nor is it oxidizable by the action of air or water. It is nearly as hard as pure iron, and is susceptible of a fine polish. It is a conductor of electricity, but conducts heat more slowly than any other metal. It will resist the strongest heat of our fires without melting, and, like iron, is capable of being welded when properly heated. A great variety of alloys have been formed with platinum. Its specific granity is 21.47.

The strongest of the pure mineral acids has no effect upon this metal, if employed separately; neither has the strongest fire, unless it be urged by a stream of oxygen gas. This metal may, however, be melted by a burning lens, or dissolved in chlorine or nitro-muriatic acid. If mixed with arsenic, and then exposed to a great heat, it fuses readily. By putting a platinum wire into the flame produced by the combustion of mixed hydrogen and oxygen gases, it burns with all the brilliancy of iron-wire, and emits sparks in abundance.

For an account of the most valuable alloys of platinum consult Mr. Hatchett's paper in the *Philosophical Transactions* for 1803.

By repeated hammering, Dr. Wollaston was enabled to increase the density of platinum to the specific gravity of 21.5313. The specific gravity of *crude* platinum is generally 17.70.

549. The oxygen in atmospheric air has no effect upon platinum, unless when assisted by an intense heat; but the oxide may be procured by dissolving the metal in nitro-muriatic acid, and then precipitating it by an alkali. From some late experiments it appears to be susceptible of two degrees of oxidizement, affording the black and the gray oxide; and that it is the latter oxide which enters into the composition of the salts of platinum, and which according to Berzelius contains twice as much oxygen as the former. Platinum is also capable of combining with chlorine, phosphorus, and sulphur.

Platinum may also be oxidized by the electric spark, or by heating it with nitre. The oxide, which is of a gray colour, consists, according to Mr. Chenevix, of 87 parts metal and 13 of oxygen. Native oxide of platinum is not known.

550. A variety of salts may be formed with the oxide of this metal; but none of them have yet been brought into much use, except the muriate of platinum, which is employed as a test to discriminate between potash and soda when these alkalies are in a state of solution.

No salt of platinum has yet been found native.

Exp.—In order to form any salt of platinum, the metal must be previously dissolved in nitro-muriatic acid or chlorine, these being the only menstrua that will act upon it. And in making the nitro-muriatic acid, three parts of muriatic acid should be mixed with one part of nitric acid; Proust having determined that this mixture dissolves the largest proportion of the metal. A solution of any other salt is then to be added, and by double affinity the new salt required may be obtained. Thus a solution of phosphate of soda when mixed with muriate of platinum would probably give a *phosphate* of platinum.

551. Platinum has hitherto been chiefly used for chemical utensils, such as crucibles, small tongs, rods, spoons, &c. also for retorts to concentrate sulphuric acid, and to make mirrors for reflecting telescopes. This metal has also been beaten into leaves, and applied to porcelain in the manner of leaf gold. Its oxide is used for certain articles of pottery, and in enamel painting.

The important uses to which this precious metal may be applied can be easily conceived, when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. There is however a disadvantage attending the use of this metal for chemical purposes, which is, that it is corroded by caustic alkalies.

A very neat method to cover other metals with platinum was lately discovered by Mr. Stodart, who found that, like gold, it may be taken up from its solution by sulphuric ether.

It is said that M. Strauss has, after many experiments, succeeded in applying platinum to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, will render this a most valuable discovery.

Exp.—If nitro-muriate of platinum be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platinum will float, and may then be poured off. If polished brass and some other metals be immersed in this solution, the surface will be instantly covered with a coat of platinum. This process may be applied to many useful purposes.

552. Gold is of a light yellow colour inclining to red; it is the heaviest of all the metals except platinum; it has neither taste nor smell; it possesses less tenacity than iron, copper, platinum, or silver: very few, however, of the metals have more lustre, and it is so malleable and ductile that it may be drawn into wire of extreme fineness, and beaten out into leaves thin enough to be carried away by the slightest wind.

When gold is heavier than 19.3, it must be combined with platinum; when lighter, and of a deep yellow colour, it is alloyed with copper; if of a pale colour, with silver.

Gold possesses a hardness between that of silver and tin. For purposes where the metal would be liable to wear, it is rendered much harder by the addition of a small portion of copper.

Such is the tenacity of gold, that a wire one-tenth of an inch in diameter will support a weight of 500 pounds without breaking.

Dr. Black has calculated, that it would take fourteen millions of films of gold, such as is on some fine gilt wire, to make up the thickness of one inch; whereas fourteen million leaves of common printing paper would occupy nearly ¾ths of a mile in thickness. The ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long.

553. Gold is not affected by long exposure either to atmospheric air or water; nor is it acted upon by sulphuric, nitric, or muriatic acid, whatever may be their states of dilution or concentration, its only solvents being a solution of chlorine or nitro-muriatic acid. The solution of gold imparts a purple stain to the skin, and its oxide when united with ammonia possesses strong fulminating properties. It melts at 1300° of Fahrenheit, and it is so fixed that it may be kept in fusion for any length of time without suffering diminution either in its weight or its qualities. When allowed to cool, it contracts in bulk and crystallizes in short quadrilateral pyramids.

Gold may be detected when in solution, by green sulphate of iron; this precipitates it of a brown colour, but it soon changes to the colour of gold.

Exp. 1.—Gold leaf, thrown into chlorine gas at the temperature of 70° or 80°, takes fire and burns with great brilliancy.

Exp. 2.—If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the last metal will be immediately precipitated. In this state it is often employed in gilding china.

554. Gold is however combustible; for although neither air, water, nor fire seems to have any effect upon it, it may be burnt by the action of a galvanic battery, or by exposing it in the state of wire to a stream of inflamed oxygen and hydrogen gases, whereby it becomes converted to an oxide. Gold is capable of forming alloys with other metals. Its specific gravity is upon an average 19.3.

Gold will form alloys with most of the metals. That with copper is the most useful, as it renders the gold harder, and when in small quantity does not impair its colour. For current coin the metal is alloyed with a mixture of gold and silver. Sterling gold is a compound of eleven parts pure gold and one part of some other metal. One pound of sterling gold is always coined into 44½ guineas. An alloy of silver and gold is employed in soldering the articles made with gold, as such an alloy is more fusible than pure gold.

555. Gold is found native in Peru, in Brazil, in Siberia, in North Carolina, in Hungary, and in several other parts of the world. It generally occurs in a metallic state, alloyed with a little silver or copper, and commonly in the form of grains. Most of the gold of commerce is at present brought to Europe from Africa and from the continent of America.

Gold frequently occurs in the ores of other metals, but it is chiefly found in the warmer regions of the earth. It abounds in the sands of many African rivers, and in India. Several of the rivers in France contain gold in their sands. It has also been discovered in Sweden, Norway, and Ireland.

556. Gold has so little affinity for oxygen, that it cannot be easily oxidized like the other metals: this may however be effected by amalgamating it with mercury, and applying heat; or by dissolving it in nitro-muriatic acid, and precipitating it with a solution of potash.

It was formerly imagined that gold could not be oxidized by atmospheric air, even in the highest temperature; it has however been proved, that the heat produced by an electrical or galvanic discharge is sufficient to effect it, and to convert a piece of leaf-gold to the *purple* oxide.

According to Berzelius, there are two oxides of gold, the green and the brown; the first containing 3.87 per cent. of oxygen, the second 10.775 of oxygen.

The attraction of gold and silver for oxygen is so slight, that the rays of the sun alone will deoxidize the oxides of these metals.

The oxides of gold may also be reduced by hydrogen gas or sulphurous acid gas. If white satin ribbon, or silk, be moistened with a diluted solution of gold, and, *while moist*, exposed to a current of either of these gases, the metal will immediately be reduced, and the silk become gilt with a regular coat of gold.

Exp. 1.—Dissolve a few crystals of muriate of gold in about 8 times their weight of pure water; place a thin slip of charcoal in the solution, and heat the whole by means of a sand-bath. When the solution has acquired nearly a boiling heat, the gold will precipitate itself on the charcoal, in its metallic splendour, forming a singular and beautiful appearance. This experiment is designed to show that metals become insoluble, the moment they impart their oxygen to foreign bodies.

Exp. 2.—Proceed as in the last experiment, and submit the vessel with its contents to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before. This is illustrative of the deoxidizing power of the sun's rays.

Exp. 3.—If a piece of white silk be dipped in an aqueous solution of muriate of gold, and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be covered with a coat of reduced gold.

Exp. 4.—If a piece of white silk be immersed in an aqueous solution of muriate of gold or nitrate of silver, and thoroughly dried in the dark, and then exposed to sulphurous acid vapours, it will suffer no change; nor, if it be wetted with *alcohol* and then replaced in the gas, will any sign of reduction appear: but if the silk be wetted with pure *water*, and then so exposed, metallic gold or silver, as the case may be, will immediately be seen on its surface.

A glass funnel is a convenient apparatus for these experiments. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour the match may be withdrawn. The vapour is confined by sliding the funnel back upon the table; and thus the phænomena of the experiment may be easily observed.

557. There is only one salt of this metal that is much known, viz. the *muriate of gold*, which is obtained in small crystals, and is very soluble in water. Many other salts may be formed by means of the muriate of gold, but nothing at present is known either of their pro-

perties or uses. Gold may also be combined with chlorine, with phosphorus, and with sulphur.

If ether be added to a solution of muriate of gold, the gold will leave the acid, and float upon its surface, combined with the ether.

Exp. 1.—To such a solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate: the upper stratum, or ethereal gold, is then to be carefully poured off into another vessel. If any polished steel instrument be dipped into this solution, and instantly plunged into water, the surface will have acquired a coat of pure gold, being a very elegant and economical mode of preserving polished steel from rust.

Exp. 2.—Drop a little leaf gold into nitro-muriatic acid, and it will instantly disappear. This experiment is designed to show the great solubility of the metals, when submitted to a proper menstruum.

Exp. 3.—Pour a little purified nitric acid into one wine-glass, and muriatic acid into another; and drop a little leaf gold into each. Here neither of these corrosive acids will act at all upon the metal, the gold will remain untouched. Now pour the whole contents of the two glasses together, and the metal will disappear, and be as effectually dissolved as in the last experiment.

558. Gold is used for jewellery, for plate, and for current coin; but for these purposes it is generally alloyed either with copper or silver. It is employed in various ways in the arts. Gold is also spread over other metals in the process called gilding, to preserve them from tarnishing or rusting, as gold does not become oxidized by exposure to atmospheric

air. The purple oxide of gold is employed in staining glass, and for ornamenting porcelain.

Gold employed in jewellery is generally alloyed with copper. What is called pale gold is alloyed with silver. Standard gold of Great Britain is twenty-two parts pure gold and two parts of copper, it is therefore called gold of "twenty-two carats fine."

Gold is also used in a state of solution, for staining ivory and ornamental feathers. It gives a beautiful purple red, which cannot be effaced; even marble may be stained with it. The nitro-muriatic acid is the menstruum used for this purpose. The potters dissolve gold in this way, to be applied to the common kind of porcelain. Bismuth or zinc will precipitate gold from this solution. Tin will precipitate it of a purple colour. This is used by the potters in printing on porcelain.

Exp. 1.—If a little muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated, forming that beautiful pigment called the purple powder of Cassius.

Exp. 2.—If a slip of zinc be immersed in a similar solution of gold, the latter metal will be precipitated in a metallic state.

559. SILVER is found in various parts of the world, particularly in Peru and Mexico, in a metallic state; also in the state of an alloy, of a sulphuret, of a salt, and in that of an oxide. A considerable quantity of silver has also been obtained from some of the lead mines in Great Britain and Ireland.

Silver was used in commerce eleven hundred years before the foundation of Rome. Genesis xxiii. 16.

Native silver is found chiefly in the mines of Potosi.

Sulphuret of silver occurs in the silver-mines of Germany, Hungary, Saxony, and Siberia. Oxides of silver are also common in some of the German silver mines. Native silver has lately been found in a copper-mine in Cornwall.

560. Silver is a heavy, sonorous, brilliant, white metal, without either taste or smell; it is only moderately hard, but exceedingly ductile, and of great malleability and tenacity. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper, or drawn out into wire as fine as a hair, without breaking. Under certain circumstances it is capable of combustion. Its specific gravity is 10.474. It forms alloys with many of the other metals.

Silver is the most brilliant metal we have. Nothing surpasses it in splendour, except steel when highly polished.

Silver possesses more hardness than gold, tin, or lead; but it is softer than iron, platinum, or copper.

Fifty square inches of silver-leaf weigh not more than a grain. The silver-wire used by astronomers is no more than half as thick as a fine human hair.

Silver has such an affinity for muriatic acid, that this acid is employed as a test for discovering silver in solution.

Exp.—Into a glass of water containing a small portion of common salt, drop some of a clear solution of nitrate of silver, and an insoluble precipitate of muriate of silver will be produced. This experiment is designed to give the pupil some idea of the method of analysing mineral waters. Every 100 grains of this precipitate, if weighed after it has been dried and passed through a red-heat, indicate 42 grains of common salt.

To know when silver is pure, heat it in a common fire, or in the flame of a candle: if it be alloyed, it will become tarnished; but if it be pure silver, it will remain perfectly white.

561. Silver cannot be oxidized by atmospheric air, unless exposed to an intense heat; but the oxide of silver may be procured by dissolving the metal in an acid, and then precipitating it by lime-water or by an alkali.

The grey or brown oxide of silver is the only one that is known with certainty; and this is composed of about 100 of silver and 7.3 of oxygen.

Silver is sometimes dissolved in nitric acid for forming the metallic tree. It is a pleasing experiment attended with very little expense. A metallic crystallization somewhat similar may be made by suspending a piece of zinc in a solution of acetate of lead.

Exp. 1.—Form an amalgam with four parts of silver leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards, in the form of a shrub. This appearance of arborescence is called the tree of Diana.

Exp. 2.—Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire; a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a metallic tree, of a nature different from the former.

Exp. 3.—Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of metallic revivification.

562. Of the salts of silver the nitrate is the one best known; but in analysis the sulphate of silver is also a most useful test: many other salts of this metal may likewise be formed. The muriate and the carbonate of silver are both found native. Silver may also be combined with chlorine, with iodine, with phosphorus, and with sulphur.

A solution of nitrate of silver mixed with a little gum water forms, in conjunction with an alkali, the *indelible ink* used in marking linen.

Nitrate of silver is kept in chemical laboratories as a test for the muriatic acid. When melted, and run in moulds, it forms the lunar caustic of the apothecary.

Exp. 1.—Prepare two glasses of rain water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of silver* into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of sulphate of silver will appear.

Exp. 2.—Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid*. Proceed as before, and a precipitate of muriate of silver will be produced.

Exp. 3.—Take two glasses, as in Experiment 1, and into one of them put a drop of sulphuric acid, and a rop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a mixed precipitate will be produced, consisting of muriate of silver and sulphate of silver.

Exp. 4.—Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be redissolved, and the muriate of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of separating these metallic salts whenever they occur in a state of mixture.

Exp. 5.—Nitrate of silver may be employed to dye human hair, and for staining marbles and jaspers; and though the solution is as pale as pure water it will stain animal substances of an indelible black. With a pen dipped in nitrate of silver draw any figure on the human skin, and the stain will continue as long as the cuticle remains.

563. Silver is used chiefly for ornamental work, for domestic utensils, and for current coin: but for these purposes it is generally alloyed with copper, without which it would not have sufficient hardness to sustain much wear.

Our standard silver is formed with about 37 parts pure silver and 3 parts copper. One pound of standard silver is coined into 62 shillings.

Silver is also used for plating other metals, for silvering dial-plates, &c. An account of these different processes may be found in Imison's *Elements of Science and Art*.

564. PALLADIUM was discovered by Dr. Wollaston in the year 1803. It exists in the ores of platinum, both those from Peru and the Brazils. It is procured by dissolving crude

platinum in nitro-muriatic acid, and precipitating the saturated solution by a solution of prussiate of mercury. The precipitate when washed, dried, and exposed to a strong heat, is converted into metallic palladium.

Dr. Wollaston has discovered a native ore of palladium, consisting of that metal alloyed with a minute portion of platinum and of iridium. It is found in grains, along with the grains of native platinum, in the alluvial gold districts in Brazil.

565. Palladium is a hard, malleable metal, of a white colour like platinum, and susceptible of being polished. It fuses with difficulty, and is not altered by exposure to the air in common temperatures. It has but little elasticity, and when broken discovers a crystalline texture. It enters into combustion when heated intensely by means of oxygen gas, and affords a brilliant spectacle.

Palladium is ductile as well as malleable; but it does not melt until it has acquired a heat greater than that at which gold melts.

566. The specific gravity of some specimens of palladium was found to be 11, of others 11.3 up to that of 12.0, according to the different methods by which they were prepared. It is soluble in nitro-muriatic acid, and affords a bright red solution. Its oxide assumes a chesnut brown colour, and is soluble in muriatic acid. This metal has hitherto been obtained

but in small quantities, and consequently has scarcely been applied to any use.

Palladium has been combined with gold by Dr. Wollaston for the graduation of the circular instrument constructed by Mr. Troughton for Greenwich observatory. It has the colour of platinum, but is much harder, which fits it peculiarly for receiving the graduations.

567. RHODIUM was discovered by Dr. Wollaston in the year 1804. He obtained it by a peculiar process from the ore of platinum, or rather from the nitro-muriatic solution which remained after the platinum had been precipitated as far as possible by means of muriate of ammonia. When the metal was obtained, the Doctor soon perceived that the salts formed with it gave rose-coloured solutions; and considering this to be the most striking characteristic of the new substance, he named it *rhodium.*

For a considerable time after Dr. Wollaston had announced the discovery of rhodium, it was very much doubted whether this was really a new metal, or merely a metallic alloy, until Descostils undertook the investigation and confirmed every thing which Dr. Wollaston had asserted.

568. Rhodium is a white metal, with a tint of yellow, somewhat similar to silver: it is as hard as iron, but more brittle; and, excepting iridium, it is more infusible than any other metal. It readily combines with arsenic or sulphur, and in either of these states of combi-

nation melts readily. It is insoluble in all the pure acids. It will form alloys with all the metals except mercury, and for the most part these alloys are soluble in nitro-muriatic acid. The specific gravity of rhodium is 10.649.

This metal is so infusible that Dr. Wollaston, who discovered it, has never been able to melt it so completely as to produce a solid button of metal free from cavities or hollows.

An alloy which had been formed with one part rhodium and two parts lead was found of the specific gravity of 11.3, from whence we may presume that the real specific gravity of rhodium is very nearly the same as that of lead.

569. When rhodium is reduced to powder and heated in an open crucible, it readily absorbs oxygen from atmospheric air and becomes converted to an oxide. By different modes of treatment three distinct oxides may be formed with this metal. The first, or protoxide, is *black*, the deutoxide is a light *brown*, and the peroxide dark *red*.

Berzelius supposes the oxygen in these oxides to be in the proportions of 1, 2, and 3, and conceives them to be composed as follows.

	METAL.		OXYGEN.
Protoxide of rhodium . .	100	+	6.71.
Deutoxide	100	+	13.42.
Peroxide	100	+	20.13.

570. Iridium was discovered in the year 1803 by Mr. Smithson Tennant, and also by a foreign chemist of the name of Descostils,

who soon afterwards published an account of his experiments in the *Annales de Chimie.* This peculiar substance was found, in connexion with another new metal called osmium, in the black powder which remains undissolved when the ore of platinum has been digested in nitro-muriatic acid. It was named iridium from *iris* the rainbow, in consequence of the variety of colours which are observable in the different solutions of its several salts.

For the method of obtaining iridium from this powder, see Sir Humphry Davy's *Elements of Chemical Philosophy*, page 436.

571. Iridium is a white metal, very similar in appearance to platinum. It is brittle, and extremely infusible. It is soluble in the muriatic acid, but neither the nitric nor sulphuric acid has any action upon it. It forms alloys with several of the other metals, and in all cases the hardness of the several metals is greatly increased by the addition of the iridium.

When iridium is digested in nitro-muriatic acid, it requires 300 parts of the acid to dissolve one part of that metal.

The sulphuret is a compound of 100 iridium and 33.3 of sulphur. It may be prepared by means of an ammoniacal muriate of iridium, as has been shown by Vauquelin. *Annales de Chimie*, tome lxxxix. page 236.

572. It is remarkable that a large portion of this singular metal may be united to gold

without the colour of the gold being sensibly impaired by it. It unites with oxygen in two proportions, forming a deep *blue* or protoxide, and a dark *red* which is thought to be the peroxide of iridium. A sulphuret of this metal may be also formed. The specific gravity of iridium is about 18.00.

Having thus examined the nature of the several metals, I shall now endeavour to recapitulate the general *properties of this class of bodies.*

573. The metals are simple substances, distinguishable from all other bodies by their lustre, and generally by their great specific gravity; by their perfect opacity; and by their superior power of conducting electricity.

The ancient chemists supposed the metals were *compound* bodies. Their undecompounded nature was first suspected by Mayow, an ingenious physician who flourished in the middle of the seventeenth century, and appears to have had a notion of oxygen nearly a hundred years before it was discovered by Scheele and Priestley.

574. They are the great agents by which we are enabled to explore the bowels of the earth, and to examine the recesses of Nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient in the progress of the human mind towards perfection.

The metals are seldom afforded by Nature otherwise than in a state of great impurity, It is to the use of our reasoning faculty that we owe the possession of any of them in a state fit for use.

575. These metals differ so much from each other in their degrees of hardness, lustre, colour, elasticity, fusibility, weight, malleability, ductility and tenacity, that Nature seems to have had in view all the necessities of man, in order that she might suit every possible purpose his ingenuity can invent, or his wants require.

The best information respecting the analysis of metallic ores may be had from Klaproth's *Essays*, to which I refer the reader.

Many of the salts by the abstraction of caloric shoot into peculiar forms; the metals in like manner crystallize, or rather exhibit distinct and determinate figures on cooling.

Exp.1.—Melt a portion of grain tin, and pour it into a metallic cup. Allow it to cool till it is congealed to some depth, then pierce the solid crust, and carefully pour out that portion which is still liquid. If what remains in the vessel be suffered to cool entirely, it will present rhomboidal crystals of considerable size, formed by the assemblage of a great number of small needles longitudinally united.

Exp. 2.—Treat silver in the same way, and we shall procure a metallic mass, crystallized in quadrangular or octahedral prisms. *These experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.*

576. We not only receive this great variety from the hand of Nature, but these metals are rendered infinitely valuable by various other properties they possess;—by their combustibility, their solubility in fluids, their combinations with hydrogen, chlorine, phosphorus, sulphur, and carbon, and by their union with each other, whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life.

Some of the metals are so combustible that they will burn before they acquire a heat sufficient to fuse them. This is the case with iron and zinc. A thin shaving of zinc will burn without melting, if held in the flame of a candle. The combustion of iron in oxygen gas is an interesting and beautiful experiment. See an account of the method of managing it in the chapter on Combustion.

A very singular phenomenon takes place on the mixture of the metals with melted sulphur; for, as soon as the union commences, the temperature increases, and a considerable glow of light is extricated, similar to what happens in combustion.

Exp. 1.—Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, light will be evolved.

All the metals except platinum and gold will unite with sulphur by fusion. But the natural sulphurets contain more sulphur than the artificial ones.

Several of the metals have a very strong affinity for each other, as may be shown by direct experiment. Thus mercury will dissolve lead, bismuth, zinc, and other metals.

Exp. 2.—Take a piece of bismuth and a piece of lead, each alloyed with mercury, melt them together, and they will form when cold a solid metallic mass; but from their affinity for mercury they have acquired so much fusibility that they will melt by the heat of boiling water.

577. Nature has furnished us with a variety of acids, in some of which the most refractory metals may be dissolved and purified, and thus rendered fit for a variety of purposes, to which they could not otherwise be applied.

Exp. 1.—Pour a drachm by weight of strong nitrous acid into a wine-glass containing two drachms of distilled water, and, when mixed, throw a few very small pieces of granulated tin into it. A violent effervescence will take place, the lighter particles of the tin will be thrown to the top of the acid, and be seen to play up and down in the liquor for a considerable time, till the whole is dissolved. This is an example of a transparent liquid holding a metal in solution.

Exp. 2.—To a colourless solution of nitrate of mercury, add an equally colourless solution of sub-borate of soda. This will produce a double decomposition, and form a bright yellow precipitate of borate of mercury; giving an instance of difference of colour in metals, by their union with different acids.

578. By combining the metals with oxygen we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine-arts, by imitating the master-pieces of creation in the production of artificial salts, gems, and crystals, of every colour and of every shade.

This is exemplified in a striking manner by the metal called chromium. When acidified and combined with lead, the metallic salt that results is of a beautiful orange yellow; whereas chromat of mercury is of the colour of vermilion; chromat of silver, of a carmine red; chromat of zinc and bismuth, a bright yellow. Indeed most of the metallic oxides may be combined with other substances so as to produce colours that may be useful in the arts. Take the following examples.

Exp. 1.—When colourless prussiate of potash is added to a solution of titanium, a precipitate of a green colour will be obtained.

Exp. 2.—If a solution of tungstate of potash be poured into a solution of the green sulphate of iron, a yellow precipitate will be procured. By this experiment the distinguishing characteristic of this metal is exhibited.

If phosphoric acid be united with silica by fusion, artificial precious stones may be prepared with the compound, which may be coloured to imitate any particular kind, by one or other of the metallic oxides.

579. Different metals, by their union with oxygen, acquire different colours, and the same metal attains a different hue, according to the portion of oxygen combined with it; so that this wonderful substance seems destined not only to render us the most important services, but to embellish the works of creation, by the beautiful tints which it imparts to almost all subjects, whether of the animal, vegetable or mineral kingdom.

The oxide of iron is an eminent example of this change of colour. Many distinct colours, besides a great variety of shades, are observed in minerals containing iron: and to the iron in most cases is the colour to be ascribed. Black in the obsidian. Green in the euclase. Blue in the lazulite. Red in the garnet and ruby. Yellow in the topaz. Brown in the tourmalin. While the somnite, which contains iron, is totally devoid of colour, it being a *white* mineral.

Exp. 1.—Procure some solution of sulphate of iron at the *minimum* of oxidizement, by digesting iron filings with the common sulphate. Into this, when filtered, drop a little of the solution of prussiate of potash, and a *white* prussiate of iron will be precipitated.

Exp. 2.—If a very little colourless nitric acid be added to a solution of sulphate of iron prepared as in the last experiment, the addition of the prussiate of potash will produce not the white, but the *blue* prussiate of iron.

The beautiful colours which are seen upon porcelain, are given by metallic oxides. Purple is given by gold, red by the oxide of iron, yellow by the oxide of silver, green by copper, blue by cobalt, and violet by manganese.

The following experiments are also designed to show the difference of colour that results from metallic oxides acquiring different proportions of oxygen.

Exp. 3.—Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich blue colour. By exposure to the air this gradually changes to a purple, and lastly to a violet. The addition of an acid will, however, convert the whole to a green.

Exp. 4.—Take the green solution of the last experiment, and pour caustic ammonia upon it. The original blue colour will now be re-produced.

Exp. 5.—If a little pure white calomel be rubbed in a glass mortar with a little colourless solution of caustic ammonia, the whole will become intensely black.

CHAPTER XI.

OF OXIDES.

580. Any metal or combustible body which is combined with less oxygen than is sufficient to render it *acid*, is usually called an *oxide.*

581. The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxides by an union with oxygen.

According to the old theory, metals were supposed to be converted to *calces*, as metallic oxides were then termed, by the loss of an imaginary substance called phlogiston; and when these calces were reduced to a metallic state, it was imagined that they recovered their phlogiston from the carbonaceous matter employed in their reduction: thus what they supposed to be owing to the loss of phlogiston, was really occasioned by the absorption of oxygen.

582. There are several ways in which metallic oxides are formed, the chief of which are by the access of atmospheric air, by the decomposition of water, and by the decomposition of acids.

Iron may be mentioned as a familiar example of a metal becoming oxidized by atmospheric air. It is well known that when this metal is exposed to air and moisture, it acquires rust, or in other words its surface is converted to an oxide, in which state the metal will be found to have acquired an increase of weight.

583. All metals will not become oxidized by exposure to the air; gold, silver, and platinum, cannot be oxidized, unless in a very high temperature; though iron, copper, and lead, merely by long exposure to the air, will become oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

Metals not only become oxidized by atmospheric air, but sometimes, by exposure to its action, pass from a lower to a higher degree of oxidizement. Thus, if a solution of the common sulphate of iron be exposed to the atmosphere, the oxide of iron acquires a further dose of oxygen, and by degrees a portion of the metal, in a higher state of oxidizement, is precipitated.

Some of the metallic solutions cannot be formed but in contact with atmospheric air or oxygen. Thus, copper or lead, placed in acetic acid, and excluded from the air, does not form any solution; but if the mixture be exposed, oxygen is absorbed, and the solution takes place.

Exp.—Procure a phial with a glass stopper accurately ground into it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its colour, which it will recover only by the re-admission of air. These effects may thus be repeatedly produced.

584. The common red lead of the shops, which is a true oxide of lead, is made by melting that metal in ovens so constructed as to have a free access of atmospheric air.

In the manufactories of red lead 20 cwt. of lead generally give 22 cwt. of red lead; so that 2 cwt. of oxygen is absorbed from the atmosphere during the process.

585. It is known that the change of common lead to red lead is caused by the absorption of oxygen not only from the increase of weight which the metal acquires during the operation; but, to confirm the fact, the oxide may be again reduced, and the original quantity of metal recovered unaltered.

This increase of weight may be shown by keeping a given weight of iron-wire red-hot for some time in an iron ladle, or in the bowl of a common tobacco-pipe, and weighing the iron before and after it has been submitted to the experiment.

586. All metals do not increase equally when converted into oxides, but as has already been mentioned each combines with a proportion of oxygen peculiar to itself; and this ori-

ginal quantity is in some metals subject to a regular increase.

Though all metals increase in weight by their union with oxygen, each metal combines with a proportion of oxygen peculiar to itself; and this original quantity is in some metals subject to a regular increase in definite proportions: thus, the protoxide of mercury is formed with 100 of mercury and 4 of oxygen, while the peroxide is composed of 100 of mercury and 8 of oxygen. In like manner the first oxide of copper is a compound of 100 of copper and 12½ of oxygen, while the peroxide consists of 100 of the metal and 25 of oxygen. Again, the protoxide of tin is composed of 100 parts of tin and 13½ of oxygen, and the peroxide of 100 of tin and 27 of oxygen.

587. They differ not only in their capacity for oxygen, but also in their attraction for it; so that one will often rob the other, thus reducing the first oxide to its primitive metallic form.

Exp. 1.—Dissolve some quicksilver in nitric acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the precipitation of one metal by another.

Exp. 2.—Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding a striking example of peculiar affinities.

588. Iron, zinc, tin, and manganese have the property of decomposing water, and they become oxidized by the process. Thus the rust which forms upon polished iron is occasioned by the iron imbibing the oxygen of the water which it decomposes, as it meets it in the atmosphere. This metal, when heated, decomposes water with great rapidity.

An increase of nearly 30 per cent. may be given to iron, by heating it red-hot, and passing a continued stream of the vapour of water over it when in that state. This increase of weight arises from its decomposing the water, and imbibing its oxygen.

Exp.—Pour concentrated nitric acid upon pieces of iron, and very little action will be seen; but if a few drops of *water* be added, a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect solution of the metal effected.

589. This decomposition of water, like most of the operations of Nature, depends on chemical affinity. These metals having a greater affinity for oxygen than oxygen has for hydrogen, the oxygen of the water unites with the metal to form a metallic oxide, while the hydrogen, the other ingredient of the water, escapes in the form of gas.

See an experiment at Axiom 115, page 52, which illustrates this principle.

In the oxidizement of metals by acids, though there be no oxygen gas sensibly present by which it is effected, oxygen exists in the acids, also in the water with which the acids are diluted; and the effect is owing to the passage of a portion of oxygen from one of these substances to the metal; and the increase in weight which the metal acquires, is always equal to the weight of the oxygen absorbed. Whenever a metallic oxide dissolves in an acid, it causes the acid properties to disappear exactly as if an alkali had been employed; and saturates corresponding quantities of the different acids.

590. Most of the metals are capable of uniting with different proportions of oxygen, according to the mode by which they are oxidized; and the energy with which a metal retains its oxygen is generally in an inverse ratio to the proportion of oxygen which is combined with it.

Since the publication of the atomic theory, a greater degree of attention has been paid to the nature of metallic oxides; and it is now universally admitted that no metal combines with an unlimited quantity of oxygen, or with variable proportions of it; the second or third proportion of oxygen being always a multiple or a divisor of the first:—thus to form the peroxide, copper unites with twice as much oxygen as to form the protoxide of that metal, and in this case the second quantity is a *multiple* of the first. The peroxide of lead consists of lead combined with one half more oxygen than the deutoxide, and the deutoxide with one half more than the protoxide; in this case the additional quantities are *divisors* of the first. For a further elucidation of this doctrine, I may refer to the composition of the oxides of mercury and tin, N° 586.

If the black oxide of manganese be exposed to a strong heat, it gives off oxygen gas, and becomes brown; but no heat as yet applied is capable of depriving it of the whole of its oxygen. Several similar instances may be enumerated. Thus, the carbonate of soda, which contains two proportions of carbonic acid to one of soda, gives off half its carbonic acid with great facility by heat, but obstinately retains the other half. Nitric acid is easily brought to the state of nitrous gas by the abstraction of oxygen: nitrous gas with more difficulty is converted into nitrous oxide; but nitrous oxide is still less decomposable than nitrous gas.

591. Many instances of the formation of metallic oxides by means of acids might be adduced: thus, common white lead is made by exposing sheet lead to the fumes of acetic acid; and the oxide of tin, by submitting that metal to the action of the nitric acid.

The method of making white lead is fully described in the *Chemical Catechism*. See 10th Edition, page 368.

592. Metallic oxides are in general friable and pulverulent; have greater absolute weight than the primitive metal; and with the alkalies and the different acids form metallic salts.

The nature of the combination of oxygen with a metal, the subsequent solution of the metal in an acid, and its revivification, may be shown in a satisfactory manner by the following process.

Exp. 1.—Take some clippings of copper, heat them in a mixture of 8 parts of water, 3 of sulphuric acid, and one of nitric acid, and when the copper is dissolved, dilute the solution with water, and set it aside to crystallize. The crystals thus produced will be the true sulphate of copper, and will exemplify the formation of a metallic salt.

Exp. 2.—If these crystals be now dissolved in a little water, and the polished blade of a knife be immersed in the solution, the copper will be revived, and appear of its natural colour upon the knife. The oxygen having a greater affinity for the iron than the copper, passes to the iron, by which the copper becomes deoxidized, and consequently insoluble in the acid; it therefore precipitates itself from the solution, and attaches itself to the knife in a metallic form.

593. In order to form metallic salts, it is necessary to oxidize the metals that are to be employed; for the metals are incapable of dissolving in acids, or alkalies, until they are combined with oxygen. This is a fact of great importance to be remembered: it is a truth to which there is no exception.

The metals are capable, however, of combining with chlorine when submitted to its action in a metallic state, and most of them with iodine when assisted by heat.

It is not only true that all metals must be oxidized before they can be dissolved in acids, but they must contain a certain proportion of oxygen, which proportion varies according to the nature of the metal to be dissolved, and the acid employed. On the other hand, if a metal has combined with more oxygen than is necessary for its solution, it will precipitate itself from the acid, and be incapable of forming a salt.

Exp. 1.—Pour some pure nitric acid on the black oxide of manganese, and no solution will be effected. But if a little sugar be added, the sugar will abstract a part of the oxygen from the oxide of manganese, and the acid will then be enabled to dissolve the metal.

Exp. 2.—Expose an ounce of nitric acid for an hour, in an open phial, to the direct rays of the sun, and pour another ounce of the same acid, that has not been so exposed, into another phial. If a little of the black oxide of manganese be now put into each, the oxide in the *first phial* will be dissolved, while that in *the other* will not be affected by the acid.

594. The stronger acids are sometimes made use of in large quantities by manufacturers to dissolve metals; thus the makers of sulphate of copper, commonly called Roman vitriol, boil the oxide of copper in strong sulphuric acid, and dissolve it by that operation.

This is common blue vitriol. The mode of its manufacture may be collected from a former note. See also Exp. 2, page 58.

595. Silver is dissolved in nitric acid, by the refiners, in the business of parting; gold is dissolved in nitro-muriatic acid, for painting china; and the dyers use large quantities of tin dissolved in a peculiar acid prepared for that purpose.

For an acccount of the business of refining, consult Lewis's *Commerce of the Arts*, page 135, &c.

596. The attraction of the different metals for oxygen is so various, that several of them, when dissolved, may be precipitated, even in a metallic form, by the addition of metals that have a greater affinity to oxygen than the dissolved metal.

This is exemplified by the refiners in their operations. When the silver is dissolved in aqua-fortis, they recover it by placing plates of copper in the solution. The copper absorbs oxygen from the silver, and the latter is precipitated in a metallic state. All metals have the power of de-oxidizing gold and silver; copper will take oxygen from mercury; and iron will reduce an oxide of copper. The degree of attraction for oxygen, which the different metals possess, seems to be in the following order: manganese, zinc, iron, tin, antimony, arsenic, nickel, cobalt, copper, bismuth, mercury, silver, gold, platinum.

Exp. 1.—Dissolve some mercury in pure nitric acid, and when the solution is complete, immerse a slip of clean copper in it. This will soon be dissolved by the acid; and as the solution of the copper takes place, the mercury will be precipitated in its original state.

Exp. 2.—To the solution of copper formed in the preceding experiment add some strips of iron; this metal will now be taken up, and an oxide of copper will be precipitated.

Exp. 3.—If a thin plate of zinc be next added, this will also be partly dissolved, and the iron will precipitate.

597. Charcoal, on account of its superior affinity for oxygen, is the agent usually employed for this purpose.

The usual mode of procedure is to mix a quantity of charcoal with the metallic oxide, and subject the mixture to an intense heat in crucibles. The oxygen combines with the charcoal, and with a portion of caloric, and goes off in carbonic acid gas; the metal then falls to the bottom of the crucible, and runs into a solid mass.

Exp. 1.—If a morsel of the dried crystals of nitrate of silver (not the lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the charcoal will be richly coated with metallic silver.

Exp. 2.—Take an ounce of red lead and a drachm of fresh-made charcoal in powder; rub them well together and submit the whole to a hot fire in a small crucible. In a short time the charcoal will be seen to have absorbed the oxygen, and metallic lead will be regenerated.

598. Some other combustibles have also the property of decomposing metallic oxides.

Exp. 1.—Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a splendid coat of metallic gold.

Exp. 2.—Proceed as in the last experiment, and instead of the solution of gold, apply, with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its metallic brilliancy, and frequently attended by spangles of a beautiful blue.

Exp. 3.—If a bit of white silk be immersed in an ethereal solution of gold, and dried, the application of phosphorized ether will only impart a brown colour to the silk; but if, as soon as the phosphorus begins to fume, it be placed on the palm of the hand, and breathed on for a considerable time, the brown will be succeeded by a purple tinge, and the metallic lustre of the gold will soon begin to appear.

Exp. 4.—"An aqueous solution of nitro-muriate of gold," says Mrs. Fulhame, "was poured into a china cup containing some phosphorized ether; instantly the gold began to assume its metallic splendour, attended with a variety of colours, as purple, blue, and red, the beauty of which cannot be described; but which depend on the different degrees of the reduction."

Exp. 5.—Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully silvered, the revived metal forming a metallic ring, extending quite round the phial.

599. Oxygen has so slight an union with some of the metals, that even light will separate it and reduce the oxides to their original metallic state. Hydrogen gas and some other compounds will effect the same purpose, when assisted by heat.

Oxygen gas is composed of oxygen, caloric, and *light.* Without a chemical union with light it would not be in the state of gas.

Sennebier discovered that the rays of light have not all the same chemical effects; that the violet rays, for example, will blacken recent muriate of silver in 15 seconds, though the red will not produce the same effect in less than 20 minutes. Sir Humphry Davy has found that "a solution of chlorine in water becomes a solution of muriatic acid most rapidly, when placed in the most refrangible rays in the spectrum."

Exp. 1.—Dissolve some crystals of muriate of gold in pure water, then immerse a piece of charcoal in the solution and place the whole in the direct rays of the sun. In a short time the salt will be decomposed, and the charcoal will be covered with a film of metallic gold.

Exp. 2.—If the red oxide of lead be put into a receiver of hydrogen gas, and the oxide be heated by means of a glass lens, the oxygen of the metal will combine with the hydrogen to form water, and the metal will be completely revived.

Exp. 3.—Write with dilute nitrate of silver, which when dry will be entirely invisible; hold the paper over a vessel containing a hot solution of sulphuret of ammonia, and the writing will appear very distinct. The letters will shine with the metallic brilliancy of silver.

600. We have many instances of the metallic oxides being, by exposure to the sun, altered, in their state of oxidizement, even where they have not been completely reduced by the deoxidizing rays. This is always the case when a metallic oxide experiences merely a change of colour by such exposure.

Exp. 1.—Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water to prevent the crystallization of the metallic salt. Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent. It will first take a faint violet hue, and in a few hours the whole will have acquired a very deep purple.

Exp. 2.—Moisten a little magnesia with some of the solution as before, and then dry the mixture in the *dark*. If it be then submitted to the action of the sun's rays, it will acquire only a faint violet, even by several hours exposure.

Exp. 3.—If the mixture employed in the last experiment be now thoroughly *wetted* with pure water, and again placed within the rays of the sun, its colour will rapidly change, and will acquire a deep purple approaching to crimson.

Exp. 4.—Moisten a piece of white riband with the aqueous solution of the crystals of muriate of gold, and dry it thoroughly in the dark: then suspend it in a clean, dry, transparent phial, and cork it close with a dry cork. Expose the riband, thus secured, to the strong light of a bright sun, for half an hour, and only a faint appearance of change of colour will be perceived.

Exp. 5.—Take the riband out of the phial that was employed in the last experiment, and *wet* it well with distilled water. If it be now exposed to the sun's rays, it will instantly change colour, and will quickly be stained of an indelible purple.

Exp. 6.—A little of the solution of sulphate of manganese being exposed in a glass phial to the light of the sun, its rose colour will be entirely destroyed. This is another experiment to show the de-oxidizing power of the sun's rays. If the phial be removed into a dark room, the original colour of the solution will be restored.

601. We are acquainted with an oxide of each of the following simple combustibles, phosphorus, hydrogen, and carbon, and with two oxides of nitrogen.

All the products arising from the union of the simple combustibles with oxygen are either oxides or acids.

602. If phosphorus be not preserved entirely from the access of atmospheric air, it soon becomes first white, and then of a dark brown colour, by its union with oxygen. In this state it is *oxide* of phosphorus.

Phosphorus, when newly prepared, always contains some oxide of phosphorus mixed with it; but this may be easily separated by plunging the mass into water heated to about 100. The phosphorus melts, while the oxide remains unchanged, and swims upon the surface of the melted phosphorus.

603. Hydrogen differs from the other two simple combustibles in being capable of forming *oxides* by its combination with oxygen, whereas *they* form acids as well as oxides. The combination of oxygen with its usual dose of hydrogen produces water.

For the nature and properties of water, see Chapter iv. page 46.

604. Water may however be united with a larger proportion of oxygen, as was discovered by Thenard in his attempts to oxidize the mineral acids. This compound contains twice as much oxygen as is required for the composition of water, and is called the *peroxide of hydrogen.*

The peroxide of hydrogen is devoid of colour and inodorous. Its specific gravity is 1.450. For its other properties see Brande's *Manual of Chemistry,* vol. ii. page 78—81, or Dr. Thomson's *Annals,* vol. xiii. Introd. page xxvii.

605. The oxide of carbon is in a gaseous form, and is called *carbonic* oxide.

606. Carbonic oxide, which was one of the latest discoveries of Dr. Priestley, is procured by heating charcoal with metallic oxides, or with earthy carbonates; by which means the

charcoal absorbs sufficient oxygen to convert it to the state of gas.

Dr. Priestley first exhibited the carbonic oxide; but we are indebted to Mr. Cruickshank for the true explanation of its nature and properties.

607. The difference between the composition of carbonic oxide and carbonic acid is, that carbonic *oxide* contains about 57 and carbonic *acid* about 72½ per cent. of oxygen.

Carbonic oxide is composed of 57 parts oxygen and 43 carbon. A hundred cubical inches of this gas weigh about thirty grains. Carbonic acid contains 72½ oxygen and 27½ carbon.

608. Carbonic oxide, like most other gases, is invisible and elastic; its specific gravity is somewhat less than that of atmospheric air; its smell is offensive; it has the property of uniting with chlorine, and it is highly combustible; but it is a gas that will not of itself either support combustion, or animal respiration.

Carbonic oxide burns with a lambent blue flame in atmospheric air; but it burns with more rapidity and brilliancy when mixed with oxygen gas.

According to some French chemists, birds drop down dead immediately on being put into this gas. These chemists attempted to breathe it themselves; but it produced giddiness and faintness.—*Annales de Chimie*, tome xxxix. page 56.

609. With regard to the oxides of nitrogen; the first degree of oxidizement produces *nitrous* oxide;—a further portion of oxygen

forms *nitric* oxide. Both these oxides are in the state of gas.

Nitrous oxide, or the gaseous oxide of nitrogen, as it is sometimes called, is composed of 63 parts nitrogen and 37 oxygen by weight. Nitric oxide is formed with 47 parts nitrogen and 53 parts oxygen.

610. Nitrous oxide is another of the gases discovered by Dr. Priestley. It is readily procured by exposing crystals of nitrate of ammonia, in a retort, to the heat of a lamp, by which means the ammoniacal salt is decomposed, and this gas evolved.

Dr. Priestley discovered this gas about the year 1776, and called it *dephlogisticated* nitrous gas. For further information respecting its properties consult Davy's *Chemical and Philosophical Researches*. Sir Humphry Davy investigated it with great care, and pointed out its nature and properties.

The heat employed should not be less than 340°, nor above 400°. One pound of dry nitrate of ammonia, well decomposed, will produce rather more than four cubic feet of air, or about 32 gallons wine measure. Its specific gravity, according to Sir Humphry Davy, is to that of hydrogen, nearly as 21 to 1. 100 cubical inches of it weigh about 49 grains.

611. This gas, in the proportions of its constituent parts, bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air; it is respirable for a short time; it is absorbed by water: and is capable of forming salts of a peculiar nature, by its combination

with alkalies and metals. Its specific gravity is much greater than that of common air.

Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion and a propensity to leaping and running; on others, involuntary fits of laughter; and in all, high spirits, and the most exquisitely pleasurable sensations, without any subsequent feelings of debility.

Exp. 1.—Fill a glass jar similar to that described, Plate 2, fig. 7, with nitrous oxide, and immerse in it a piece of phosphorus previously inflamed. This gas parts with its oxygen so readily, that the phosphorus will burn with the same brilliancy as though it were plunged in a jar of oxygen gas.

Exp. 2.—In a similar jar of nitrous oxide, suspend a piece of sulphur in a state of combustion; this will burn with a beautiful pink-coloured flame.

612. Nitric oxide, or nitrous gas as it has usually been called, was also discovered by Dr. Priestley, during some of his first experiments on air. It is procured by dissolving copper, or mercury, in diluted nitrous acid, and collecting the gas which rises during the solution.

This gas was used by Dr. Priestley for purposes of eudiometry.

613. Nitric oxide is an invisible gas, which assumes an orange colour whenever it comes in contact with atmospheric or any other air that contains oxygen. It produces suffocation in those animals which are made to

breathe it, though some substances will burn in it. Its specific gravity is somewhat greater than that of common air.

The first eudiometer was made in consequence of the discovery, that when nitrous gas is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, from the combination of the gas with the oxygen of the air, and the absorption of the nitric acid, thus formed, by the water. Whenever nitrous gas is thus mixed with atmospheric air, the diminution will be in proportion to the quantity of the oxygen; of course this gas will always indicate the measure of oxygen present in any portion of air.

If phosphorus be previously inflamed, it will continue to burn in this gas with as much splendour as in oxygen gas.

614. Nitric oxide gas, when mixed with oxygen gas, forms nitric *acid*. The nitric acid of commerce owes its red colour to its holding this gas in solution.

Dr. Priestley found, that 100 measures of nitric acid, of a moderate strength, absorbed, in two days, 90 of nitrous gas; that, when about 7 parts were absorbed, the acid assumed an orange colour, when 18 parts were absorbed a green colour, and when the 90 were combined it became red and fuming.

Exp.—Paste a slip of litmus paper within a glass jar, near the bottom; then fill the jar with water, and invert it on the shelf of a pneumatic trough. If as much nitrous gas, previously well washed, be passed into the jar as will displace the water below the level of the paper, the colour of the litmus paper will still remain unaltered; but on passing up atmospheric air it will immediately be reddened; showing the formation of an acid, by the mixture of two gases.

615. Sugar and indigo are both vegetable oxides; and common soap owes its perfection to the absorption of oxygen.

Indigo may be deoxidized by a mixture of lime and sulphate of iron. This changes its colour to a green.

In the Essay prefixed to the first edition of the Chemical Catechism, page 19, I suggested to the manufacturers of soap an advantage that would arise from properly oxidizing the soap while boiling: the experiments of some French chemists have established the truth of this theory, and demonstrated that this curious compound of oil and alkali is indebted entirely to oxygen for its consistence.

Exp.—Dissolve 4 drachms of sulphate of iron in one pint of cold water; then add about 6 drachms of lime in powder, and 2 drachms of finely pulverized indigo, stirring the mixture occasionally for 12 or 14 hours. If a piece of white calico be immersed in this solution for a few minutes, it will be dyed green; and by exposure to the atmosphere only for a few seconds, this will be converted to a permanent blue.

616. Moreover, butter, dried salt meats, and most of the oils, become rancid by absorbing oxygen from the atmosphere; so that oxygen not only performs for us an infinite number of valuable and important offices, but appears to be one of the grand agents of decomposition and destruction.

Seed oils are sometimes oxidized artificially for the purposes of painting. Linseed oil is thus boiled with the red oxide of lead. In this operation, the oxygen of the metal combines with the oil, imparting to it the property of drying quickly. Oil thus prepared is called *drying* oil.

CHAPTER XII.

OF COMBUSTION.

617. Combustion may be defined to be a process by which certain substances decompose oxygen gas, absorb its base, and suffer its caloric to escape in the state of sensible heat. It has, however, of late years been discovered that combustion may take place without the agency or intervention of oxygen.

To render the explanation of this phenomenon more perspicuous, it may be said that oxygen exists in the state of gas in atmospheric air; that when a combustible is heated, to a certain degree, it possesses such an attraction for oxygen, that it absorbs it from the air and fixes it in a solid form; while the light and caloric, the solvents which gave the oxygen its aëriform shape, escape and diffuse themselves among the surrounding bodies. Potassium, however, in combining with arsenic and tellurium produces heat and light by their mutual chemical action, without the aid of oxygen or any substance that can be supposed to contain oxygen.

618. All substances are not capable of being burnt; some are combustible, others incombustible.

The term *combustible* is applied to every body that is capable of being burnt in atmospheric air, or in oxygen gas, and, consequently, of uniting with oxygen and liberating caloric.

619. Combustible bodies are divided by

chemists into simple combustibles, compound combustibles, and combustible oxides. In consequence of modern discoveries, the *chlorides* and *iodides* may now be added to this list.

The combustible oxides consist of combinations of the combustible bodies, which have not undergone combustion, or their compounds, with oxygen. This class of bodies is very numerous, as it includes the greater part of animal and vegetable substances.

620. Those combustible substances that have resisted every attempt to decompose them are called simple combustibles.

For an account of the nature and properties of the simple combustibles, see Chapter ix. page 177.

621. The simple combustibles with which we are acquainted are hydrogen, sulphur, phosphorus, carbon, boron, and the metals.

We may be satisfied that metals are really combustible, by repeating the following simple and beautiful experiment of Dr. Ingenhousz.

Exp.—Twist a small iron wire into the form of a corkscrew, by rolling it round a small stick; fix one end of it into a cork (which will fit a glass jar previously filled with oxygen gas) and lap round the other end a small bit of cotton thread dipped in melted tallow. Set fire to the cotton, and immediately plunge the whole into the jar of oxygen gas. The wire will take fire from the cotton, and burn with great brilliancy.

622. Compound combustibles are all such as are formed by the union of two or more of

the simple combustibles. Common coal is an instance of this combination.

The compound combustibles have been arranged under the five following heads: 1st, Sulphurets; 2d, Phosphurets; 3d, Carburets; 4th, Alloys; 5th, Sulphuretted, phospuretted, and carburetted Hydrogen.

623. The nature of combustion is understood very imperfectly. Sir Humphry Davy describes it to be "the 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 is communicated to the corpuscles or minute atoms of bodies."

See the *Elements of Chemical Philosophy*, page 226.

624. Combustion appears to be a double decomposition, in which the combustible and the supporter of combustion divide themselves each into two portions, which combine in pairs, the one forming the product, the other the fire which escapes.

To the old chemists, the process of combustion was quite inexplicable; its nature, indeed, was not at all understood until within these forty years. It is now known to be merely a play of affinities between oxygen, light, caloric, and the base of the combustible body; so that nothing is really lost, but new modifications of the same ingredients take place.

The component parts of the oxygen which is furnished by the supporters of combustion are two; viz. *oxy-*

gen and *caloric.* The component parts of all combustibles are likewise two; viz. the *base* and *light.* If the two first are called N^{os} 1 and 2, and the two latter N^{os} 3 and 4, the product of combustion will be formed by the union of N^{os} 1 and 3; and the compound which we call fire will arise from the combination of N^{os} 2 and 4.

625. The substances which are called supporters of combustion are not of themselves combustible, but are necessary to the process; that is, no combustion can ever take place without one or other of the supporters of combustion being present.

Some modern chemists have discarded the term "supporters of combustion," but I think without sufficient reason.

626. There are only three *simple* substances which are supporters of combustion; viz. oxygen gas, chlorine gas, and iodine.

To these three, fluorine, the base of fluoric acid, has been added as a supporter of combustion; but it does not appear to me that there is evidence enough at present to justify me in giving it that appellation.

The chief properties of oxygen have been described in the foregoing sheets; the following experiments may however be added to those already detailed.

Exp. 1.—If oxygen gas be forced out of a bladder, or a gasometer, upon a piece of ignited charcoal, the combustion will be so much increased, that the light thrown off will be too vivid for the eye to endure. Rock-crystal that has been exposed to an intense heat in atmospheric air, for a very long time, and has suffered nothing in its hardness, transparency, or any other quality, will fuse like other substances when submitted to a stream of oxygen gas.

Exp. 2.—If one ounce of strong nitrous acid, a compound of oxygen and azote, be mixed with about half its weight of concentrated sulphuric acid, and poured into a little oil of turpentine, the whole will immediately burst into flame. In this experiment it is the oxygen of the nitric acid which produces the combustion. *The phial from whence the mixed acid is poured, should be tied to the end of a long stick, to preserve the operator from being injured by the splashing of the materials.*

Exp. 3.—Spread a piece of tinfoil, such as is used for coating electrical jars, upon a piece of thick paper; pour a small quantity of strong solution of nitrate of copper upon it. Fold it up quickly, and wrap it round carefully with the paper, more effectually to exclude the atmospheric air. Place it then upon a tile, and in a short time *combustion* will commence, and the tin will inflame.

627. The agency of oxygen in combustion is attributable to its affinity for combustible bodies. For, whenever such bodies are ignited, in circumstances favourable to combustion, they absorb oxygen from the air, or from other contiguous substances, till the combustible is converted to an incombustible body.

Combustion, like all other chemical processes, may be explained by the laws of chemical affinity. The combustible having a greater affinity to oxygen than oxygen has to caloric, the oxygen gas is decomposed, and its oxygen combines with the ignited body, while its caloric, becoming free, produces the heat which is diffused among the surrounding bodies.

628. In general, the heat produced by

combustion arises from the decomposition of the oxygen gas of the atmosphere; for, as the oxygen combines with the combustible body, it disengages the caloric which it held when in the state of a gaseous substance.

Though every case of combustion requires that heat should be evolved, yet this process proceeds very differently in different circumstances. Hence the terms *ignition, inflammation, detonation*, &c.

629. To explain this operation with more precision, it may be said that the act of combustion effects a real analysis of atmospheric air; for, while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction.

We have incontestable evidence that combustible substances unite with oxygen during combustion: thus, if iron which has been burnt in oxygen gas be examined analytically, it will be found to consist of iron and oxygen; in like manner it will be discovered that burnt phosphorus consists of nothing but phosphorus and oxygen; burnt charcoal of charcoal and oxygen; and burnt sulphur of sulphur and oxygen.

630. Whenever we burn a combustible body, a continued stream of atmospheric air flows towards the fire-place to occupy the vacancy left by the air that has undergone decomposition, and which, in its turn, becomes decomposed also. Hence a supply of caloric is furnished without intermission, till the whole of the combustible is saturated with oxygen.

Upon the principle, that a current of air hastens combustion, the Argand's lamp is constructed; for, in consequence of this perpetual supply of oxygen, the air is renewed every moment, and produces heat sufficient to burn the smoke as it is formed. The smoke which arises from a common fire is chiefly water in the state of vapour, with a mixture of carburetted hydrogen and bituminous substances; part of the water comes from the moisture of the fuel; the other part is formed during combustion, by the union of the hydrogen of the combustible with the oxygen of the atmosphere.

631. As the combustible burns, LIGHT is disengaged, and the more subtile parts of the combustible, now converted by caloric into gas, are dissipated in that state. When the combustion is over, nothing remains but the earthy parts of the combustible, and that portion which is converted, by the process, into an oxide, an acid, a chloride, or an iodide.

The product of combustion is always either an *oxide*, or an *acid*, or both, except when the new metals potassium or sodium are ignited, and then an alkali is the produce. But the alkalies are indeed now proved to be metallic oxides.

632. It is now generally supposed that the light and flame which appear during this process proceed from the combustible body, though some philosophers have imagined that the light comes in part from the decomposition of atmospheric air.

If the light arose from the decomposition of oxygen gas, those combustibles which absorb most oxygen would give out most light; but this is not the case. *Pure* hydrogen in burning combines with more oxygen than any other body, and gives out more heat; yet the light is barely perceptible.

Some time ago Sir H. Davy discovered that if a fine platinum wire be rolled up in a small coil, and when made red-hot be plunged into the vapour of alcohol, ether, or camphor mixed with common air, it will continue red-hot, and furnish light so long as the combustible producing the vapour is unconsumed. Thus a lamp may be formed which will burn without flame, the heat produced being of itself sufficient to keep the wire of platinum red-hot.

633. Light, which is an extremely attenuated fluid matter, is constantly transmitted from the sun to the earth. It is also found combined with several terrestrial substances.

Light is transmitted to us from the sun in little more than eight minutes, which is a velocity almost equal to 200,000 miles in a second of time; but the rays of light and the rays of caloric are distinct from each other. It has been demonstrated that some rays from the sun produce heat, which have no power of communicating light.

634. Light is a peculiar substance, the nature of which is little understood; but it possesses several very singular and striking properties.

Light is decomposable into seven distinct rays of different colours. Some bodies absorb one coloured ray, others another, while they reflect the rest. This is the cause of colour in bodies. A red body, for instance, reflects the red rays, and absorbs the rest. A white body reflects all the rays, and absorbs none; while a black body, on the contrary, absorbs all the rays and reflects none.

635. Until lately it was supposed that no combustible body could burn without atmospheric air, or at least without *oxygen* gas, which is a component part of the atmosphere. It has however been discovered that this axiom must be received with some limitations; as will presently be explained.

The agency of oxygen in combustion may be demonstrated by placing a lighted candle under a glass jar inverted upon a plate of water. It will be seen, that the candle will go out as soon as it has consumed all the oxygen contained in the included air.

It is necessary to inquire on what account CHLORINE GAS *is now arranged with the supporters of combustion.*

636. When copper or gold, in thin leaves; or tin, zinc, and some other metals in filings, are thrown into chlorine gas, they burn spontaneously; and the compound, which is produced by the combustion, is denominated, in modern language, a *chloride.*

Exp.—If a bit of phosphorus, or a morsel of potassium, be suspended in this gas, a similar effect will be produced, without either of these substances being previously ignited, and the combustion will be vivid and pleasing. If a lighted taper be plunged into a jar of chlorine gas, it will continue to burn with a red flame, and a small portion of light will be evolved.

637. A chloride is therefore a compound

body formed by the union of a combustible substance with chlorine. By this process the chlorine gas is deprived of its latent heat, and the combustible is entirely altered in its appearance and properties.

638. The chlorides are similar to the dry muriates. Thus, if the muriatic salts be heated red or in any other way deprived of water, they will in general be converted to true chlorides.

This is not universally the case, because there are instances in which a metallic muriate may be heated and the muriatic acid driven off without decomposition; though in general the hydrogen of the acid unites with the oxygen of the metal to form water, and the chlorine thus divested of its hydrogen unites with the metal and forms a metallic chloride. Thus it is with common salt, or muriate of soda, when heated to dryness; for the hydrogen of the muriatic acid unites with the oxygen of the soda and they pass off together in the form of water, while the chlorine of the muriatic acid combines with the sodium of the soda, and a chloride of sodium is formed.

639. Iodine is also a supporter of combustion. If the crystals of iodine and phosphorus come in contact, at the common temperature of the atmosphere, combustion will ensue, and much heat will be evolved, but no light. Iodine combines also with oxygen, with chlorine, with sulphur, with most of the metals, and with some other substances. These compounds are called *iodides*.

If, instead of mixing solid iodine and phosphorus, a bit of the latter substance be suspended in the *vapour* of iodine, the propriety of classing iodine with the supporters of combustion will be still more evident; for in this case the phosphorus will burn with great freedom and evolve much heat without the intervention of oxygen, or any substance containing oxygen. Potassium will also burn in its vapour under similar circumstances, emitting a pale blue light.

640. The nature and properties of the iodides are at present but little known, and their employment in the arts has been extremely limited. The compound of iodine and mercury is a red powder of considerable beauty; that of iodine and starch is a substance which takes a brilliant blue colour inclining to purple. Ere long these iodides will probably be brought into use.

In the first volume of the new edition of my *Chemical Essays* now in the press, at page 630, will be found an account of an important trial in the Court of Exchequer, in which a verdict of the value of some thousand pounds was obtained by exhibiting to the Court and Jury the effect produced on the mixture of the solutions of starch and iodine.

641. Combustible bodies differ from each other principally in the rapidity with which they absorb oxygen or the other supporters of combustion; and in the proportions of them which they can take up, to form the new compounds.

Exp.—Burn a piece of iron wire in a deflagrating jar of oxygen gas, as directed page 323, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the relative combustibility of different substances.

642. In general, the greater the quantity of oxygen gas which any combustible body is capable of decomposing, the greater will be the degree of heat that is produced by the combustion.

Almost all the simple substances are capable of combining with various doses of oxygen. Thus sulphur forms sulphurous acid and sulphuric acid; phosphorus forms oxide of phosphorus, phosphorous acid, and phosphoric acid; carbon also unites with different portions of oxygen, and forms carbonic oxide and carbonic acid.

643. If a substance be burnt in a sufficient quantity of oxygen gas, in a close vessel, and the product preserved, the whole will be found to be increased in weight exactly in proportion to the oxygen gas consumed, and the combustible body will then have become incombustible.

Phosphorus is an eminent instance of this increase by combustion. If an ounce of phosphorus be properly inflamed, it will produce more than two ounces of phosphoric acid; the increase in weight arises from its absorption of oxygen.

644. It becomes incombustible because it is incapable of combining with any more oxygen, or with more of that supporter of combustion in which the process took place: some bodies, however, may be rendered combustible again by depriving them of the oxygen which they absorbed in their former combustion.

A series of curious experiments of this kind may be seen in Lavoisier's *Chemical Elements*, page 495 and following pages.

645. In the decomposition of *atmospheric* air by combustion, it is natural to ask, what becomes of the nitrogen gas? As the oxygen becomes fixed in the combustible body, its caloric is disengaged, a part of which combines with the nitrogen and carries it off in the form of rarefied nitrogen gas.

646. Whenever bodies are fully burnt, such substances are said to be *oxygenized* or *oxidized*; that is, changed into acids or oxides. But these terms will not apply to the new substances called *chlorides* and *iodides*.

Whenever a substance is converted to an oxide, we say it is *oxidized*: but if it becomes an acid by its union with oxygen, we say it is *oxygenized*. We are indebted to Mr. Chenevix for this lucid definition of terms too often used indiscriminately.

647. It is a characteristic property of a combustible body, to form a chemical combi-

nation with the oxygen that is furnished by the supporter of the combustion; and so intimate is this union, in many instances, that it is only with extreme difficulty we can again separate the oxygen from the combustible body.

When oil is burnt in an Argand's lamp, its carbon unites with the oxygen of the atmosphere and forms carbonic acid gas; while its hydrogen unites with another portion of oxygen and forms water. Every 100 ounces of oil, thus burnt, produce 130 ounces of water.

648. These compounds may, however, be deoxidized in various ways; and, in some cases, the oxygen may be transferred from the burnt body to a fresh combustible body, and be made the means of producing a fresh combustion; or it may sometimes be completely separated, and shown in its primitive or gaseous state.

Water, as we have shown, is a product of combustion, and its base is hydrogen, the most combustible substance we are acquainted with. To restore the combustibility of the hydrogen, we have only to abstract its oxygen, which may readily be done by mixing iron or zinc filings, and sulphuric acid, with the water: by which means the metal becomes oxidized, and the hydrogen gas is evolved as combustible as ever.

649. In some instances this may be done with the greatest ease, as no part of bodies that we know of is destroyed by combustion.

This is frequently done for the purpose of procuring oxygen gas. The oxide of manganese, or of mercury, is exposed to a proper degree of heat, and the gas received in a suitable apparatus as it is extricated.

When bodies are burnt, none of their principles are destroyed; they had previously formed together one kind of compound, and they now separate from each other, at the high temperature to which they are exposed, in order to form others with the vital air in contact with them: and such of the principles as cannot unite with the vital air, viz. the earth, some saline and some metallic particles, compose the cinder.

650. We have reason indeed to think that every particle of matter is indestructible, and that the process of combustion merely decomposes the body, and sets its several component parts at liberty, to separate from each other, to form other new and varied combinations.

"It was said of old, that the Creator *weighed* the dust, and *measured* the water, when he made the world. The first quantity is here still; and though man can gather and scatter, move, mix, and unmix, yet he can destroy nothing: the putrefaction of one thing is a preparation for the being, and the bloom, and the beauty of another. Something gathers up *all* fragments, and nothing is lost."

CHAPTER XIII.

OF ATTRACTION, REPULSION, AND CHEMICAL AFFINITY.

651. Attraction is that unknown force which causes bodies to approach each other.

Attraction has, by some philosophers, been attributed to an inherent property of matter, and by others to the influence of some foreign agent. The former is perhaps the most probable supposition.

652. The most obvious instances of attraction are: the gravitation of bodies to the earth; that of the planets towards each other; and the attractions of electricity and magnetism.

Sir Isaac Newton demonstrated that the planetary attraction is the same principle as gravitation.

For some account of magnetism see note, page 220. In addition to that, it may be remarked that if a steel needle be rubbed *from* its eye *to* its point, a few times over the north pole of a magnet, and then stuck in a small cork, to swim on water; the eye will veer towards the north, and the point to the south.

653. Attraction subsists likewise between the *particles* of bodies; and it is this kind of attraction which comes under the more immediate cognisance of chemists.

If common flowers of sulphur and potash be mixed and thrown into water, the sulphur will separate and the potash be dissolved; but if they be previously melted together, the union will then be so perfect, that the compound will be completely soluble. The design of this experiment is to show that chemical affinity has no sensible action but on the mere elementary particles of bodies.

All the operations of chemistry are founded on the force of attraction which Nature has established between the particles of bodies, and by which force all bodies cohere. The art of dyeing is also entirely dependent on this principle. Take one example.

Exp.—Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of *carbonate of potash*. If a piece of white cloth be dipped in this mixture, it will come out a blue. If a piece of yellow cloth be dipped in, it will become a green, or a red will be converted to a purple. A slip of blue litmus paper immersed in it will immediately become red.

654. Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion* or the attraction of *aggregation*; but when between the particles of different substances, it is called the attraction of *composition* or chemical *affinity*.

It is from the attraction of cohesion that a drop of water is always spherical, and that small particles of quicksilver are constantly of a globular figure. In consequence of the same species of attraction, particles of water and other liquids ascend in capillary tubes.

Exp. 1.—If a small plate of glass be laid upon a globule of mercury, the globule, notwithstanding the pressure, continues to preserve its round figure. If the plate be gradually charged with weights, one after another, the mercury becomes thinner and thinner; but, as soon as the weights are removed, its globular figure is restored.

Exp. 2.—In order to exemplify the latter kind of attraction, a little caustic soda may be put into a glass, and muriatic acid added to it. Both these are corrosive substances; but the compound resulting from them will be found to be our common table salt. Here we have an instance of two heterogeneous bodies producing, by their action on each other, a distinct substance, possessing the properties of *neither* of the bodies which compose it.

If several salts be dissolved in the same water, each particle, when they crystallize, will find its own kind, by a sort of innate polarity.

Exp. 3.—Dissolve separately equal weights of sulphate of copper and crystals of carbonate of soda in sufficient quantities of boiling water: pour them together while hot into a flat pan, and when the water has evaporated a little, and the whole is suffered to cool, the salts will shoot;—the sulphate of copper in *blue*, the soda in *white* crystals, similar to what they were before they were dissolved.

655. To explain with more precision what is meant by attraction of aggregation, it may be said that the particles of all bodies are possessed of the inherent property of attracting each other; this causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

There are different kinds of aggregation; viz. solid, soft, liquid, and gaseous. A stone is an instance of the first, jelly of the second, water of the third, and atmospheric air of the last.

656. The particles of every simple sub-

stance have not only an attraction among themselves, forming the aggregation of that body or substance, but they have also another attraction to substances with which they have an affinity, called elective attraction; and these bodies, when presented to each other, unite and form a new compound.

This power was by Bergman called *elective* attraction, as though matter were endued with the ability to prefer one substance to another. *Chemical attraction* is a more definite term, and is now in general use.

657. Chemical attraction can only exist between the particles of opposite and distinct substances; and this species of attraction is exerted with a different force, according to the nature of each substance.

There are several laws of chemical affinity; but these may be studied with more effect when the elements of the science are thoroughly understood. They are well explained by Fourcroy, in his *System of Chemical Knowledge*, vol. i. page 96, &c. But one of the best general views of the present state of our knowledge respecting chemical affinity will be found in Dr. Henry's *Elements of Experimental Chemistry*, vol. i. p. 14—64.

Sir Humphry Davy has shown that all bodies which have a chemical affinity for each other are in *opposite* states of electricity; and that chemical affinity depends so much upon electricity, that these natural affinities may be modified or destroyed by inducing a change in the electrical states of bodies by artificial means.

658. Most bodies combine, however, only in certain proportions:—the new combinations acquire new properties, and they are incapable of separation by mechanical means.

Thus oxygen and hydrogen, except by a tedious process, combine only in one proportion, and the result is water; nitrogen and hydrogen combine also in one proportion, and ammonia is the result.

Exp. 1.—Melt together equal quantities of tin and iron, two malleable and ductile metals; the compound produced will have totally lost the properties which its constituent parts possessed before their union; for the alloy formed will be a very brittle metal.

Exp. 2.—If liquid ammonia and muriatic acid, both fluids of a strong odour, be mixed in proper proportions, a fluid will be produced entirely devoid of smell; viz. muriate of ammonia.

Exp. 3.—If nitrate of ammonia and sulphate of soda, both in crystals, be rubbed together in a stone mortar in equal proportions, the mixture will be converted to a fluid.

659. Chemical attraction is of three kinds; viz. simple attraction, compound attraction, and disposing attraction.

660. When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of simple attraction or affinity.

The following experiments will serve to exemplify some cases of simple affinity.

Exp. 1.—Take a portion of acetate of soda, pour muriatic acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater affinity for muriatic acid than it has for the acetic.

Exp. 2.—If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriati acid will be again disengaged, and the nitric acid will be in possession of the soda.

Exp. 3.—Lastly, if to the nitrate of soda sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical attraction.

661. The action of two compound substances, whereby they mutually decompose each other, and produce two or more new compounds, is called *compound affinity*.

Exp. 1.—If into a solution of sulphate of ammonia there be poured nitric acid, no decomposition is produced, because the sulphuric acid has a stronger affinity than nitric acid for ammonia. But if a solution of nitrate of potash be poured in, we obtain by evaporation two new bodies, viz. *sulphate of potash* and *nitrate of ammonia.* In this case, the sulphuric acid of the sulphate of ammonia attracts the potash of the nitrate of potash at the same time that the ammonia attracts the nitric acid; and to the agency of these united affinities the double decomposition must be attributed.

Exp. 2.—In like manner acetate of alumina, which is used by the dyers and calico-printers, cannot be formed by the direct mixture of its component parts: for acetic acid exerts no action upon alumina, however its parts may be divided by mechanical means. But if we mix sulphate of alumina with acetate of lead, a mutual decomposition will take place, and the article required will be produced.

Exp. 3.—If *concentrated* nitric acid be poured upon tin, there will be no union. The component parts of the nitric acid have so great an attraction for each other, that the tin has no power to effect a decomposition. But if a few drops of water be added, the union between the oxygen and nitrogen of the nitric acid will be weakened, part of its oxygen will combine with the tin, a violent action will take place, clouds of nitrous gas will be disengaged in abundance, and the tin will soon be entirely dissolved in the acid.

Exp. 4.—Into distilled water drop a little spirituous solution of soap, and no chemical effect will be perceived; but if some of the same solution be added to hard-water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ascertaining the purity of spring water.

662. When bodies, which apparently have no tendency to unite of themselves, combine in consequence of the addition of another substance, the union is said to be produced by means of *disposing* affinity.

See the last Experiment at page 89, which affords an instance of the nature of this affinity. Again, if concentrated sulphuric acid be poured upon iron, no action will ensue; but if a little water be added to dilute the sulphuric acid, an action will instantly commence and the iron will soon be dissolved.

663. Other terms are also employed on the subject of chemical affinities. There are what are called *quiescent* attractions, and *divellent* attractions.

664. When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated the *quiescent* affinities.

Exp.—If a few drops of nitrate of silver be poured into a solution of muriate of soda, two new substances will be formed, viz. nitrate of soda, and muriate of silver; the latter of which, being insoluble in water, will be precipitated. In this experiment the affinity of the nitric acid to the silver, and the muriatic acid to the soda, are the *quiescent* affinities; whereas the affinity of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* affinities.

665. Those attractions which tend to destroy the original compound, and to form new arrangements, are called the *divellent* affinities.

It will be evident, from a due consideration of this subject, that no new arrangement of parts in any mixture can take place, unless divellent attraction exists.

666. The study of the chemical attractions seems to be beyond doubt the most important part of chemistry; for, it is only from a thorough knowledge of the attractions which different substances have for each other, that we shall ever attain a complete analysis of the productions of nature.

Among the affinities of any substance, there is generally at least one peculiar to that substance which stamps it as one of its generic characters; and it is of the utmost importance to the student, in the more early stage of his progress, to imprint these characteristics upon his mind as often as he happens to meet with them. It is these predominating affinities which are more particularly serviceable in the classification of the chemical properties of different substances, and of the chemical phenomena derived from them. Thus, affinity for oxygen distinguishes inflammable substances; and the reciprocal affinity of acids and alkalies constitutes acidity and alkalinity. Thus, barytes has a superior affinity for sulphuric acid, and lime for the oxalic acid, &c.

667. The student must practise as well as study the various tables of affinities of Bergmann, Pearson, Berthollet, and others; and endeavour to make himself acquainted with the changes which take place in the properties of bodies, in consequence of their chemical union with each other.

668. In these tables the name of the substance whose affinities are required, is always placed at the head of the column, and separated generally by a line; below this the other bodies are placed in the order of their attraction to the first substance.

The following single example may serve as a specimen of the tables of affinities, and will be sufficient to explain the nature of all others. Let the question be Sulphuric Acid, and it will be formed thus:

SULPHURIC ACID.

Barytes.
Strontites.
Potash.
Soda.
Lime.
Magnesia.
Ammonia.
Alumina.
Metallic oxides.
Water.

Here we are taught that if sulphuric acid be combined, for example, with ammonia, the acid may be separated by any of the preceding substances, *magnesia*, *lime*, &c.; and, consequently, *barytes* being the first in this column, will attract sulphuric acid from any of the succeeding bodies with which this acid may be combined.

669. These tables, notwithstanding some exceptions, are so extremely useful, that the study of them cannot be too strongly inculcated; for in most cases they may be safely trusted by the practical chemist.

The affinities of bodies are however affected by the circumstances in which they are presented to each other, by the cohesion of their parts, by chemical repulsion, &c.

670. The opposite principle to attraction is repulsion. Repulsion is a peculiar property, inherent in the particles of all matter, which gives them a constant tendency to recede from each other.

Sir Isaac Newton found that when a convex lens was put upon a flat glass, it remained at the distance of the one-hundred-and-thirty-seventh part of an inch; that a very considerable pressure was required to diminish this distance, and that no force which can be applied will bring them into actual mathematical contact. The particles of all gases and of atmospheric air evidently repel each other. It is to repulsion that they are indebted for their elasticity.

Some bodies have such a repulsion for water, that it is difficult to wet them. The specific gravity of steel is much greater than that of water; yet if a dry steel needle be placed with care upon the surface of a bason of water, the repulsion of the water will prevent its sinking. Thus, some insects will walk upon water without any of it adhering to them.

671. This peculiar property of matter operates both at sensible and at insensible distances.

672. The only kinds of repulsion that can be exhibited to the senses, are those of electricity, and magnetism; but it is *insensible* repulsion with which chemists are more particularly concerned.

Sir H. Davy has very satisfactorily shown, that those substances which are incapable of chemical combination are uniformly in the *same* electrical states; and that, according to the common laws of electricity, such bodies might be expected to repel, but cannot attract each other.

Exp. 1.—If two small pith balls be suspended from an insulated body with fine thread so as to touch each other, and we charge that body with electricity, the pith balls will separate immediately. The balls of course *repel* each other.

Exp. 2.—If we present the north pole of a magnet A to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B recedes as the other approaches; and by following it with A at a proper distance, it may be made to turn round on its pivot with considerable velocity.

673. The chief example of this latter kind, that we are acquainted with, is the repulsion of the particles of caloric amongst themselves; which repulsion would constantly tend to infinite separation, were it not for a chemical

union, which, by an irrevocable law of nature, they form with the first surrounding body; for by that law, it seems, the particles of caloric cannot exist in an isolated state.

It is now generally imagined that what is called insensible repulsion is owing to the presence of caloric. It is well known that the elasticity of air and all other gaseous bodies is increased by heat; that is, that the repulsion between the particles of air, the distance remaining the same, increases with the temperature, so that at last it becomes so great as to overcome every obstacle which can be opposed to it. A single example will be sufficient.

Exp.—Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a bason of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, affording an example of simple sublimation.

674. This repulsive force diminishes the cohesion of the integrant particles of all heated bodies, in consequence of the particles of caloric repelling each other; so that chemical unions, as well as chemical decompositions, are wonderfully facilitated by this species of repulsion.

It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must also tend to facilitate their chemical union with the particles of other bodies. One reason why some bodies require a high temperature to cause them to combine, is, that at a low temperature the attraction of cohesion is in them superior to that of affinity: accordingly it becomes necessary to weaken that attraction by caloric, till it becomes inferior to that of affinity. In like manner, bodies combine more easily when held in solution by water, or when they have previously been reduced to a fine powder, as these operations diminish the cohesion which exists among the primitive or integrant particles.

Exp.—Drop a lump of fluate of lime into some sulphuric acid, and no action will be perceived; but if that earthy salt be reduced to powder, a violent action will ensue on the addition of the sulphuric acid, and the fluate of lime will be decomposed.

675. To explain this action of caloric with more precision, it may be said, that as chemical affinity takes place only between the ultimate molecules of bodies, while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever caloric has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies.

Exp. 1.—If mercury be submitted to a heat little superior to that of boiling water, the metal will remain unaltered. If the heat be increased to 600°, or thereabouts, the attraction of cohesion of the mercury will be broken; its particles will unite with the oxygen of the atmosphere; and a new substance, *red oxide of mercury,* will be produced.

Exp. 2.—If this new substance be again submitted to the operation of caloric, and the heat be raised to 1000°, the combination will again be broken, and new affinities will take place. The affinity of oxygen for caloric will now be greater than that of oxygen for mercury; the oxygen will quit the mercury, unite with the caloric, and be expelled as oxygen gas; and the mercury will once more appear in its metallic state.

676. In order that the attraction of composition may take place between two bodies, it is generally necessary either that one of the substances should be in a state of fluidity, or that heat should be applied; so that caloric acts an important part, either sensibly or insensibly, in all cases of chemical affinity.

This is so generally the case, that a chemical adage has been founded upon it, CORPORA NON AGUNT NISI SINT SOLUTA. But there are exceptions. Crystallized muriate of lime and snow, if cooled to 0°, will act so upon each other as to form a liquid. Crystals of oxalic acid and dry lime will also combine on mixture.

677. We have reason indeed to believe that every new compound is produced by virtue of the attraction to which all matter is subject, and which is equally operative on the most minute atom, as on a planetary system.

To read or practise the numerous experiments detailed in this little volume, merely for the sake of amusement, may occasionally have its advantages; but a resolution to repeat them, and examine all the phænomena, for the sole purpose of receiving instruction, is what the author would principally inculcate. Let it never be forgotten, that *no effect*, however extraordinary, or even trivial, it may appear to us, can ever happen but in consequence of some previously established law of unerring Nature.

AN EXPLANATION

OF

CHEMICAL TERMS.

A.

AERIFORM fluids. This term is applied to denote any substance that is invisible and permanently elastic. See *Gas.*

Affinity, chemical. A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species. See Chap. xiii.

Aggregates. Substances whose parts are united by cohesive, and not by chemical, attraction.

Alloys. A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with silver or copper, for the purposes of coinage.

Amalgam. A combination or mixture of mercury with any other metal, is called an amalgam.

Ammoniacal salts. Salts formed by the union of an acid with ammonia, or volatile alkali. See page 99.

Analysis. The re-solution of a substance into its constituent parts, for the purpose of examination. See page 3.

Annealing. The art of rendering substances tough which are naturally hard and brittle. Glass and iron are annealed by gradual cooling; brass and copper by heating, and then suddenly plunging them in cold water.

Areometer. A graduated glass instrument with a bulb, by which the specific gravity of liquids is ascertained.

Argillaceous. A term descriptive of that class of stones and earthy matters in which clay or alumina abounds.

Atmospheres. We use this term to express the degree of additional pressure given to fluids. Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon a square inch of surface, I am said to give it *one* atmosphere; if 30lbs. *two* atmospheres, &c. See page 12, &c.

Attraction. Chemical attraction is a term synonymous with *affinity*; which see.

Azote. See *Nitrogen.*

B.

Barometer. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate.

Base. A chemical term usually applied to denote the earth, the alkali, or the metal which is capable of neutralizing an acid so as to form a salt.

Baths. Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

——— *sand.* Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works iron plates are used instead of vessels of capacity. They are often called *sand-heats.* See Plate IV. fig. 14.

——— *water.* Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

Bath, salt-water. A saturated solution of muriate of soda, first used in this country for the purposes of pharmacy, and which is capable of receiving a higher temperature than common water, is very useful in many chemical operations.

Bitumen. A generic term, applied to a variety of fossil inflammable substances. See page 197.

Blow-pipe. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes. See figs. 36 and 37, Plate VIII.

Bolt-head. A round chemical vessel with a long neck, usually employed for digestions. It is also called a matrass. See Plate II, fig. 10.

Button. A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

C.

Calcareous. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid. See page 71.

Calcination. The application of heat to saline, metallic, or other substances; so regulated as to deprive them of moisture, &c., and yet preserve them in a pulverulent form.

Calorimeter. An instrument for ascertaining the quantity of caloric disengaged from any substance that may be the object of experiment. See page 34.

Capillary. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

Capsules. Small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value. See fig. 26, Plate VI.

Caput-mortuum. A term signifying *dead-head*, being that which remains in a retort after distillation to dryness. See *Residuum*, which is the modern term.

Carburets. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron. See page 194.

Causticity. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity. See page 92.

Chalybeate. A term descriptive of those mineral waters which are impregnated with iron.

Coal. A term applied to the residuum of any dry distillation of animal or vegetable matters. See page 197.

Cohesion. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity.*

Combination. A term expressive of a true *chemical* union of two or more substances, in opposition to mere mechanical mixture.

Comminution. The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.

Concentration. The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

Condensation. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

Crucibles. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made in various forms, of baked earth, or metal. See Plate I, figures 4, 5, and 6.

Crystallization. An operation of nature, in which various earths, salts, and metallic substances pass from a fluid to a solid state, assuming certain determinate geometrical figures. See page 162.

——— *water of.* That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of such saline substances. See page 164.

Cupel. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

Decomposition. The separation of the constituent principles of compound bodies by chemical means. See page 3.

Decrepitation. The sudden decomposition of salts attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

Deflagration. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. See page 148.

Deliquescence of solid saline bodies, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid. See page 165.

Deliquium. Is the state of potash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid.

Deoxidize (formerly *Deoxidate*). To deprive a body of oxygen. See Chap. xi.

Dephlegmation, Is the act of separating the water from chemical liquors.

Depuration. The separating any liquid in a state of purity from its fæces or lees.

Detonation. A species of explosion commonly applied to that of nitre when thrown upon burning charcoal. See page 146.

Digestion. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

Digestor Papin's. A strong close vessel generally made of iron, in which animal bones and other substances may be exposed in water to a degree of heat sufficient to reduce them to a pulp or jelly expeditiously.

Distillation. A process for separating the volatile or fluid part of a substance from the more fixed, and preserving them both in a state of separation.

Ductility. A quality of certain bodies, particularly some of the metals, in consequence of which they may be drawn out to a certain length without fracture. See page 281.

Dulcification. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

E.

Edulcoration. Expressive of the purification of a substance by washing with water.

Effervescence. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

Efflorescence. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization. See page 166.

Elastic fluids. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

Elements. The simple, constituent parts of bodies, which are incapable of decomposition; they are frequently called principles. See *Simple Substances.*

Empyreuma. A peculiar and indescribably disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

Essences. What are called essences, in chemistry and pharmacy, are the essential oils obtained by distillation from odoriferous vegetable substances.

Essential Salts. The saline substances found in plants, and which are held in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

Ethers. Volatile liquids formed by the distillation of some of the acids with alcohol.

Eudiometer. An instrument invented by Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of *investigating the* different kinds of gases is called *eudiometry.*

Expression. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

Exsiccation. The act of drying moist bodies.

F.

Fermentation. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature.

Filtration. A chemical process for the depuration of liquid substances. Bibulous paper supported by a funnel is commonly made use of; but for dear and expensive liquors we use a little carded cotton lightly pressed into the tube of a glass funnel.

Flowers. In chemical language are solid dry substances procured by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

Flux. A substance which is mixed with metallic ores or other bodies, to promote their fusion; as an alkali is mixed with silica in order to form glass.

Fossil. A term employed to denote those animal and vegetable remains of a former world, which have preserved their original forms, though converted in some some measure into substances similar to the matrices in which they are found.

Fulmination. Thundering or violent explosion. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated.

Furnaces. Chemical vessels of various forms for the fusion of ores, or other operations which require heat. See A. fig. 13, Plate III. and fig. 16, Plate IV.

——— *blast.* Are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

——— *wind.* Chemical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows. See Plate V. figs. 18 and 20.

Fusion. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

Galvanism. A science comparatively new, which offers a variety of phænomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body. See page 27.

Gangue. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

Gas. A term used to express any elastic fluid, or air which remains permanently elastic in all temperatures. See page 16.

Gaseous. Having the nature and properties of gas.

Gasometer. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines. See Plate III. fig. 12.

Gasometry. The science of measuring the gases.

Gelatine. A chemical term for animal jelly. It exists particularly in the tendons and the skin of animals.

Gluten. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat-flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

Graduation. The division of a scale or measure into decimal, or other regular parts.

Grain. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

Granulation. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

Gravity absolute. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth. See Chapter xiii.

——— *specific.* This differs from absolute gravity inasmuch as it is the weight of a given *measure* of any solid or fluid body, compared with the *same measure* of distilled water. It is generally expressed by decimals. See page 6.

H.

Hepar. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potash, lime, &c., according to the base employed.

Hermetically. A term applied to the closing of the orifice of a glass tube, by fusion, so as to render it air-tight.

Hydrogenized sulphurets. Certain bases combined with sulphuretted hydrogen.

Hydro-oxides. Metallic oxides combined with water.

Hydrometers. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

Hygrometers. Instruments for ascertaining the degree of moisture in atmospheric air.

Hyperoxygenized. A term formerly applied to substances which are combined with the largest possible quantity of oxygen. It is now disused. See page 145.

I.

Incineration. The burning of vegetables for the sake of their ashes. The burning of kelp on the sea coasts is an example of this process.

Inflammation. A phænomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid produces an instance of this peculiar chemical effect.

Infusion. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

Integrant particles. See page 174.

Intermediates. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity to water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

Kali. A genus of marine plants, which is burnt to procure mineral alkali by afterwards lixiviating the ashes. See page 85.

L.

Laboratory. A room fitted up with apparatus for the performance of chemical operations.

Lamp Argand's. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke. See Plate VI. A. fig. 23.

Levigation. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

Lixiviation. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

Lixivium. A fluid impregnated with an alkali or with a salt.

Lute. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation.

M.

Maceration. The steeping of a solid body in a fluid, in order to soften it, without impregnating the fluid.

Malleability. That property of metals which gives them the capacity of being extended and flattened by hammering. See page 209.

Matrass. Another name for a bolt-head; which see.

Matrix. The bed in which a metallic ore is found. See page 209 &c.

Menstruum. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c., and spirit of wine for resins.

Metallurgy. The art of extracting and purifying metals.

Mineral. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

Mineralizers. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c.

Mineralogy. The science which treats of fossils and minerals.

Mineral Waters. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

Molecule. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means. See page 174.

Mordants. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

Mother-Waters, or *Mothers.* The liquors which are left after the crystallization of any salts. See page 168.

Mucilage. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in oils or spirit of wine. It consists of oxygen, hydrogen, and carbon.

Muffle. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

N.

Neutralize. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

Neutral Salt. A substance formed by the union of an acid with an alkali, an earth, or a metalic oxide, in such proportions as mutually to saturate each other.

Nitrogen. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air. See page 19.

O.

Ochres. Various combinations of the earths with the oxide or carbonate of iron.

Ores. Metallic earths, which frequently contain several extraneous matters, such as sulphur, arsenic, &c.

Oxide. Any substance combined with oxygen, in a proportion not sufficient to produce acidity. See Chap. xi.

Oxidize. To combine oxygen with a body without producing acidity.

Oxygenize. To acidify a substance by oxygen. Synonymous with *Oxygenate;* but the former is the better term.

P.

Parting. The operation of separating gold from silver by means of nitric acid, and other media.

Pellicle. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

Phosphurets. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c. See page 193.

Pneumatic. Any thing relating to the airs and gases.

Pneumatic trough. A vessel containing a shelf, and nearly filled with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one receiver to another. See Plate V. fig. 19.

Precipitate. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

Precipitation. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

Pyrometer. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires.

Pyrophori. Compound substances which heat of themselves, and take fire on the admission of atmospheric air.

Q.

Quartation. A term used by refiners of gold and silver in a certain operation of parting.

Quartz. A name given to a variety of siliceous earths, mixed with a small portion of lime or alumina. Mr. Kirwan confines the term to the *purer* kind of silica. Rock crystal and the amethyst are species of quartz.

R.

Radicals. A chemical term for the *Elements* of bodies; which see.

Reagents. Substances which are added to mineral waters or other liquids as tests to discover their nature and composition. See *Test.*

Receivers. Globular glass vessels adapted to retorts for the purpose of preserving and condensing the volatile matter raised in distillation. See D. fig. 1, Plate 1; and C. fig. 23, Plate VI.

Rectification, is nothing more than the re-distilling a liquid to render it more pure, or more concentrated, by abstracting *a part* of it only.

Reduction. The restoration of metallic oxides to their original state of metals; which is usually effected by means of charcoal and fluxes. See page 311, Chap. xi.

Refining. The process of separating the perfect metals from other metallic substances by what is called cupellation. See page 310, Chap. xi.

Refrigeratory. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tub is a refrigeratory. See fig. 41, Plate VIII.

Registers. Openings in chimneys, or other parts of chemical furnaces, with sliding doors, to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

Regulus. An old term, which in its chemical acceptation signifies a pure metallic substance freed from all extraneous matters.

Repulsion. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric*, which has been called the repulsive power. See Chap. xiii. page 346.

Residuum. What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potash which remains in the pot after the distillation of nitric acid is called the residuum. It is sometimes called the *caput mortuum*.

Retort. A vessel in the shape of a pear, with its neck bent downwards, used in distillation, the extremity of which neck fits into that of another bottle called a receiver. See figs. 2 and 3, Plate I.

Reverberatory. An oven or furnace in which the flame is confined by a dome, which occasions it to be reflected down upon the floor of the furnace before it passes into the chimney. Some are so contrived that it returns or reverberates upon the matter under operation.

Revivification. See *Reduction*, which is a synonymous term: though "revivification" is generally used when speaking of quicksilver.

Roasting. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c., with which a metal may be combined.

S.

Salifiable Bases. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

Saline. Partaking of the properties of a salt.

Salts neutral. A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable base. See page 136.

—— *triple.* Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potash (Rochelle salt) is an instance of this kind of combination. See page 159.

Sand-bath—Sand-heat. See *Bath.*

Saponaceous. A term applied to any substance which is of the nature or appearance of soap.

Saturation. The act of impregnating a fluid with another substance, till no more can be received or imbibed. A solid may in the same way be saturated with a fluid.

Selenite. A salt existing in spring water, formed by sulphuric acid and lime. Its proper chemical name is Sulphate of Lime. See page 171.

Siliceous earths. A term used to describe a variety of natural substances which are composed chiefly of silica; as quartz, flint, sand, &c.

Simple Substances. Synonymous with *Elements;* which see.

Smelting. The operation of fusing ores for the purpose of separating the metals they contain, from the sulphur and arsenic with which they are mineralized, and also from other heterogeneous matter.

Solubility. A characteristic of most salts. See *Solution.*

Solution. The perfect union of a solid with a fluid.

Stalactites. Certain concretions of calcareous earth found suspended like icicles in caverns.

Sub-Salts. A term formerly employed to denote those salts which contain less acid than is sufficient to neutralize their radicals. See page 140.

Sublimation. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. See *Flowers.*

Sulphures or *Sulphurets.* Combinations of alkalies, or metals, with sulphur. See page 180—183.

Super-Salts. Salts with an excess of acid, as the supertartrate of potash. See page 140.

Synthesis. When a body is examined by *dividing* it into its component parts, it is called analysis; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

Syphon. A bent tube used by chemists for drawing liquids from one vessel into another.

T.

Temperature. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body. See page 35.

Tenacity, is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another.

Test. Another name for the vessel called a cupel, which see. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition. See *Re-agent.*

Test-Papers. Papers impregnated with certain chemical re-agents, such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids or alkalies.

Thermometer. An instrument to show the relative heat of bodies. See page 34.

Tritorium. A vessel used for the separation of two fluids which are of different densities. The same operation may be performed by a common funnel.

Trituration. A chemical operation whereby substances are united by friction. Amalgams are thus made.

Tubulated. Retorts which have a hole at the top for inserting the materials to be operated upon, without taking them out of the sand-heat, are called *tubulated* retorts. See fig. 3, Plate I.

V.

Vacuum. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means. The space above the mercury in a barometer is called the *Torricellian* vacuum.

Vapour. This term is used to denote such exhalations only as can be condensed and rendered liquid again by change of temperature, in opposition to those which are *permanently* elastic.

Vats. Large chemical vessels, generally of wood, for making infusions, &c.

Vitrification. When solid substances have undergone very intense heat, so as to be fused thereby, they frequently have an appearance resembling glass. They are then said to be vitrified.

Volatile Salts. The commercial name for carbonate of ammonia. See page 98.

Volatility. A property of some bodies, which disposes them to assume the gaseous state.

Volume. A term made use of to express the space occupied by gaseous or other bodies.

Union, Chemical. When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

W.

Way. A term used in chemistry, similar to *analysis:* it is however understood in two senses, the *dry* and *humid*, and relates chiefly to metallic and earthy substances. In the dry way, the decomposition is conducted by fire; and in the humid analysis, the operation is effected by acids and chemical tests of various kinds.

Worm-tub. A chemical vessel with a pewter worm fixed in the inside, and the intermediate space filled with water. Its use is to cool liquors during distillation. See *Refrigeratory.*

Woulfe's apparatus. A contrivance for distilling acids and other gaseous substances with little loss; being a train of receivers with safety pipes, and connected together by tubes. See fig. 1, Plate I.

Z.

Zaffre. An oxide of cobalt, mixed with a proportion of siliceous matter. It is imported in this state from

Saxony, and is employed in making that rich blue colour which is used on earthenware and porcelain.

Zero. The point from which the scale of a thermometer is graduated. The Celsius's and Reaumur's thermometers have their zero at the *freezing* point, while the thermometer of Fahrenheit has its zero at that point at which it stands when immersed in a mixture of snow and common salt.

Zirconium. The pure base of the earth called zirconia. This peculiar earth has been found only in the zircon and hyacinth, two precious stones from the island of Ceylon. Sir H. Davy has pronounced this earth to be a metallic oxide, and has named the metal zirconium.

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