CHEMICAL RECREATIONS:

A SERIES OF

Amusing and Instructive

EXPERIME[illegible]

[illegible]

Easily, Safely, and at Little Expense.

TO WHICH ARE PREFIXED,

FIRST LINES OF CHEMISTRY;

WHEREIN

The principal facts of the Science, as stated by the most Celebrated Experimentalists, are familiarly explained.

WITH A

MINUTE DESCRIPTION

OF

CHEAP AND SIMP[illegible] APPARATU[illegible]

ILLUSTRATED BY

Seventy Engraved Figures

OF THE DIFFERENT PARTS OF IT.

PRINTED FOR

RICHARD GRIFFIN AND CO. GLASGOW;

[illegible] WEST AND CO. [illegible]DINBURGH; AND [illegible]HOMAS TEGG, [illegible]ONDO[illegible]

1828

ABS.1.80.298

£21

Miss Sophia Batter.

NATIONAL LIBRARY OF SCOTLAND

R. Gray Sc.

CHEMICAL RECREATIONS:

A SERIES OF

Amusing and Instructive

EXPERIMENTS,

WHICH MAY BE PERFORMED

Easily, Safely, and at Little Expense.

TO WHICH ARE PREFIXED,

FIRST LINES OF CHEMISTRY;

WHEREIN

The principal facts of the Science, as stated by the most Celebrated Experimentalists, are familiarly explained.

WITH A

MINUTE DESCRIPTION

OF A

CHEAP AND SIMPLE APPARATUS;

ILLUSTRATED BY

Seventy Engraved Figures

OF THE DIFFERENT PARTS OF IT.

PRINTED FOR

RICHARD GRIFFIN AND CO. GLASGOW;

E. WEST AND CO. EDINBURGH; AND THOMAS TEGG, LONDON.

1823.

LIBRARY OF SCOTLAND NATIONAL

James Starke, Printer.

TO THE MEMBERS

OF

THE MECHANICS' CLASS,

OF THE

Andersonian Institution,

GLASGOW.

GENTLEMEN,

The following work, written by one of your number, was undertaken for the purpose of furnishing to junior students of Chemistry, a *text-book* at a moderate price.

The contents of the work, are, an introductory view of Chemistry, and a collection of interesting experiments, with such directions for the performance of them, as, I hope, will render the understanding of the processes perfectly easy. For the materials of the work, I must (like the author of every elementary work) acknowledge myself chiefly indebted to the writings of others; and more particularly to those of the eminent chemists of the present day. In the arrangement of the different subjects, I have studied simplicity, and in language, conciseness. My readers, I trust, will neither find themselves puzzled by confusion in theory, nor wearied by circumlocutory details.

To none can I dedicate this work with more propriety than to yourselves. When I first sat on the same benches with you, and felt (what many young members of the class still feel) the want of a book of this nature, and the impossibility of obtaining it, I determined to compile such a one, as soon as my attainments in science rendered me capable of so doing. Since then, some time has elapsed, and now I have endeavoured to perform what I had projected. The result of this undertaking, I beg leave to present to you, and hope it may be found not unworthy of your patronage.

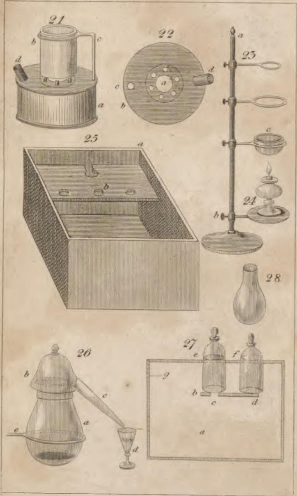
I am,

GENTLEMEN,

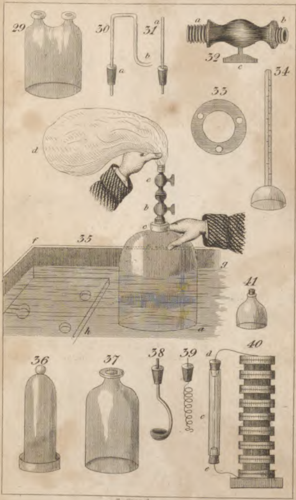
Your obedient Servant,

J. G.

Glasgow, September 18th, 1823.



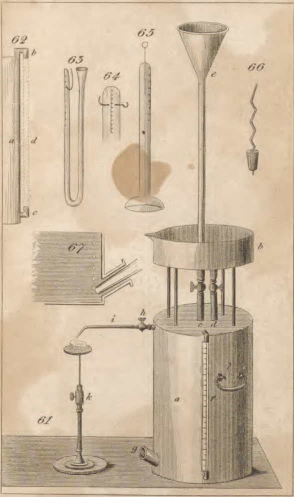
R. Gray Sc.



R. Gray Sc.

R. Gray Sc.

R. Gray Sc.



R. Gray Sc.

First Lines of Chemistry;

IN WHICH

THE PRINCIPAL FACTS OF THE SCIENCE, AS STATED BY THE MOST CELEBRATED EXPERIMENTALISTS, ARE FAMILIARLY EXPLAINED.

---

1. "WHAT is CHEMISTRY?—is it *interesting?*—is it *useful?*—*how am I to proceed* in studying it?"

2. Chemistry is the science which makes known to us the nature and properties of all natural bodies, whether they be simple or compound—solid, liquid, or aëriform:—a science which, as its objects are inexhaustible, and infinitely varied, furnishes us with continual entertainment; and which is essentially useful in many of the arts upon which depend the comforts, and even the very existence, of civilized life.

3. As Chemistry is a science that is founded entirely upon experiment, no person can understand it, unless he performs such experiments as verify its fundamental truths. The hearing of lectures, and the reading of books, will never benefit him who attends to nothing else; for Chemistry can only be studied to advantage *practically*. *One experiment*, well-conducted, and carefully observed by the student, from first to last, will afford more knowledge, than the mere perusal of a whole volume. It may be added to this, that chemical operations are, in general, the most interesting that could possibly be devised—Reader!—what more is requisite to induce you to

MAKE EXPERIMENTS?

4. It has been found, that all the marvellous diversity of appearance under which bodies are presented to the eye, and the changes of state to which they are incessantly subjected, are occasioned by the reciprocal actions and combinations of a few unchangeable primary bodies. The properties of these bodies, and the nature of the laws which regulate their actions, are, therefore, the objects of which the chemical student is to enter into an investigation.

5. Formerly, fire, water, air, and earth, were regarded as—and as the only—simple bodies. But the three last have been proved to be compound ones, (the nature of fire is still unknown,) and there are many substances which have no place at all in the list. This system, thus shown to be very erroneous, has been long given up.

6. When we say that a body is *simple*, it is to be understood, that it has not yet been *decomposed*, that is, resolved into other different substances. It is probable that we are not yet acquainted with any one of the *elements* of matter; but yet, as long as the bodies with which we are acquainted continued *undecomposed*, they are to be regarded as *simple*, or *elementary* bodies. It is surely needless to give any account of what is meant by a *compound* body, for the term is self-explanatory.

7. The metal *gold* affords a very good idea of a *simple* body; for, though that substance may be melted by heat, or dissolved in a corrosive menstruum, yet it is recovered unchanged in its properties; but, on the other hand, *Marble* is, by a strong heat, converted into two other bodies,—one of which is *lime*, the other, an *elastic fluid* (or *air*) that is disengaged during the process. *Marble*, therefore, is a *compound* body.

8. There are two methods by which chemical knowledge is acquired, *analysis* and *synthesis*;—the former signify the *separating* of the constituent parts of a compound body; the latter, the formation of a compound body, by the *putting-together* of its component principles. Both *analysis* and *synthesis* are effected by means of certain processes or operations, thence called *chemical operations*.

9. It is evident, from what has been said, that the whole subjects of Chemistry are resolved into—*First*, the art of

performing the necessary chemical operations, (that is, *of making experiments*,)—and, *Secondly*, the obtaining, through experiments, a knowledge of the nature and properties of all natural bodies, simple and compound; so as to be enabled to apply these bodies to useful or ornamental purposes. But it would be going blindly to work, to attempt to make discoveries, without previously becoming acquainted with what has been discovered already. And, now, in order to afford the young experimentalist this necessary knowledge, we shall immediately proceed to describe the most important of those bodies, that are recognised by modern chemists to be in existence.

10. The number of hitherto-undecompounded bodies is *fifty-three*. Four others,—light, heat, electricity, and magnetism, called the *imponderable* bodies,—have, by some, been added to these; but, as their separate identity has not been clearly ascertained, they are not generally reckoned with the others. As, however, they produce, by their various and important actions, very remarkable effects in other substances, we shall hereafter take such notice of them as may be deemed necessary. The whole of these fifty-three bodies may be *weighed* and *measured*, and hence (in contradistinction to the four bodies just mentioned, which cannot be weighed and measured) are called *ponderable* bodies. These, in order to facilitate the acquirement of a knowledge of their properties, have been arranged as shown in the following

11. TABLE OF SIMPLE BODIES.

1. Oxygen, 2. Chlorine, 3. Iodine, 4. Flourine,		Class 1.	Bodies having an intense affinity for the other forty-nine simple bodies, which they dissolve, and, by uniting with them, form substances differing entirely from their simple principles.
5. Hydrogen, 6. Nitrogen,	Gaseous bodies,	Class 2.	Simple non-metallic acidifiable or inflammable substances.
7. Carbon, 8. Boron,	Fixed and infusible solids,		
9. Sulphur, 10. Phosphorus,	Fusible and volatile solids,		
11, to 53.	Metals, see 24.	Class 3.	Metallic inflammables, which, when united to oxygen, form Acids,..in number 7. Oxides, Alkalies,........................ do. 3. Oxides, Earths,........................ do. 10. Oxides, Ordinary metallic oxides, do. 23.

Note.—It is not expected that this "Table" will be perfectly intelligible to the person who is just entering upon the study of Chemistry. Perhaps, in the present state of the science, no tabular view of the simple bodies, including descriptions of their properties, which should not be liable to exception, could be devised. The principal use of the above Table, is to exhibit in connection, such bodies as, in some of their properties, bear a relationship to each other; and, farther, to point out the order in which separately they may be studied to advantage. By referring back to the "Table," as he finishes the individual articles, the student will soon perceive the use of it.

12. We shall now give an account of the characteristic properties of these simple substances; passing over, with few words, such as are of minor importance.

13.—I. OXYGEN.—This is one of the most important agents in nature. Scarcely a process of any description takes place, in which it has not a share. In a simple state, it is obtained only in the form of *gas*. It is an exceedingly abundant body: the air of the atmosphere contains one-fifth of its bulk of it; and water, 75 parts in every 100. It also exists in most natural products, animal, vegetable, and mineral. Its name (oxygen) signifies the *generator of acids*. It was adopted because acids are, in general, formed by an union of oxygen with particular bases. *Oxygen gas* is, like common air, colourless, invisible, tasteless, inodorous, and elastic. But it is heavier than common air, in the proportion of $11\frac{1}{2}$ to 10. It is slightly soluble in water. It is a powerful supporter of combustion; that is to say, when any inflamed body, as a lighted taper, is put into it, it burns very vigorously. Its presence is also essential for the continuance of animal life. We cannot breathe air which has been deprived of its oxygen; and it must be noticed, that an animal lives much longer in a definite quantity of oxygen gas, than it could in the same quantity of atmospherical air. Hence it is evident, that oxygen is the *vital principle*, or supporter of life. It is to the presence of oxygen that the red colour of the blood is owing.—When a combustible body is burnt in oxygen gas, the oxygen enters into an union with that body; increasing thereby its weight, and changing its properties. If a *large* quantity of oxygen combines with the inflammable base, the product is an *acid* (119); but if a *small* quantity, an *oxide* (177).

14. *Note.*—Properly speaking, *oxygen gas is not a simple body*, because the gaseous form is given by the presence of caloric (98). But as we know of no substance that is *separated* from caloric, it is customary to apply the term simple to such as are combined with caloric only. *Gas* is the name given to all permanently elastic fluids, both simple and compound; except the atmosphere, to which the term *air* is appropriated. It is necessary to distinguish between *gas* and *vapour*. The latter is elastic, and fluid, but not permanently so. The vapour of water (steam) upon cooling becomes a liquid: it is therefore not a *gas*, for *gases* are bodies whose aeriform state is permanent. The methods of obtaining and exhibiting the properties of oxygen, and other gases, is minutely described in a succeeding part of this work.

15.—II. CHLORINE is a *gas*, possessing the mechanical properties of common air. Its colour is greenish-yellow (which its name literally signifies). Its taste is very disagreeable, and its smell exceedingly strong and suffocating. It would kill the person who presumed to breathe it; it is dangerous, even when largely diluted with common air. Though not respirable, it is an eminent supporter of combustion; some bodies indeed inflame in it spontaneously. It mixes very readily and largely with water, and *then* acquires the property (for it has it not in its dry gaseous state) of destroying vegetable colours. This has rendered it useful in some *bleaching* operations. The weight of chlorine gas is to that of common air, as 5 to 2. The compounds of chlorine are generally *chlorides*; it forms, however, a few *acids*. Perhaps its most important compound is that with hydrogen—muriatic acid (137).

16.—III. IODINE is a solid body which has the colour and lustre of plumbago. It is capable of crystallization. It is slightly soluble in water. When exposed to a heat about that of boiling water, it becomes a violet-coloured vapour, nearly nine times heavier than air. Iodine has an acrid taste, and is strongly poisonous. In its smell and its action on vegetable colours it resembles chlorine; but its effects are less violent than those of that substance. It is incombustible; but, in combining with several bodies, the intensity of mutual action is such, as to produce the phenomena of combustion. It is obtained from sea-weed, but it can only be got in small quantities, and its preparation requires considerable skill. *Acids* and *iodides* are the products of its combinations.

17.—IV. FLUORINE.—So strong are the tendencies of this substance to combination, that as yet no vessel has been found, that is capable of containing it in its pure state. When united to hydrogen, it produces an intensely-acid compound, called fluoric acid.

18.—V. Hydrogen is only known in the state of *gas*, and is sometimes called *inflammable air*. It is the lightest species of ponderable matter with which we are acquainted: compared to oxygen, its density is as 1 is to 15. It is the basis of *water*, from which body only can it be procured. Hydrogen gas, when pure, is possessed of all the physical properties of common air; a slight odour, which it sometimes has, is produced by some substance that is held in solution by it. It does not support combustion, though it is itself one of the most combustible of all bodies; being that which gives the power of burning with flame to all the substances used for the economical production of heat and light. But it only burns in the presence of oxygen. It is not fit for respiration; for animals which breathe it, die almost instantaneously. If pure oxygen and hydrogen gas be mixed together, they remain unaltered; but if a lighted taper be brought into contact with the mixture, it explodes with astonishing violence; and, if the two gaseous bodies have been mixed in certain proportions, the whole is condensed into water: hence we see the origin of the term *hydrogen*, which literally signifies *the water-former*. Hydrogen gas is the substance which, on account of its rarity, is employed to inflate air-balloons.

19.—VI. Nitrogen, called also *azote*, (or *life-destroyer*,) is a gaseous body, rather lighter than common air; of which it forms 4-5 parts in bulk, the remaining 1-5th being oxygen. It has no smell. It extinguishes flame, and is fatal to animal life. It combines with oxygen in various proportions, forming (besides atmospherical air) four very important compounds, see 135, 136, 179, 180. With hydrogen, it forms the alkaline body ammonia (163); and with chlorine and iodine, two very formidable detonating compounds.

20.—VII. Carbon is the name given to the pure inflammable part of *charcoal*, of which substance, the diamond is only a variety in a pure crystallized state; for pure charcoal and diamond, when treated in the same manner, produce precisely the same results. Carbon is insoluble in water, and infusible by the most intense heat. Carbon has a powerful affinity for oxygen, and is thence useful in several operations, to be hereafter described: it is employed with advantage to purify various substances. The substance called black-lead, or plumbago, is a compound of iron and carbon, chemically called carburet of iron, so likewise is steel. Carbon, when burnt in oxygen gas, combines with the oxygen which supports its combustion, and produces a gas possessed of the properties of acids, and called carbonic acid (133). Carbon, when combined with hydrogen gas, forms carburetted hydrogen gas—the same that is now used to light up shops. Animal and vegetable oils, are composed almost entirely of carbon and hydrogen; the difference in their properties resulting chiefly from the variation in the proportions of these two bodies. The same may be observed of gum, sugar, and starch. All these bodies, however, contain oxygen.

21.—VIII. Boron is a solid of a dark olive colour, procured from boracic acid (134). It is infusible; but when heated takes fire, and burns with a red light, and brilliant scintillations. It was lately discovered, and is difficultly prepared.

22.—IX. Sulphur, a well-known substance, distinguished commonly by the name of brimstone. It is a hard brittle body, of a yellow colour, destitute of smell, and of a weak taste. It is volatilized by heat in the form of a white powder, called very absurdly *flowers of sulphur*. It is liquified by a low heat. It is insoluble in water, but when poured in a state of fusion into that liquid, becomes ductile. At a heat of about twice that of boiling water, it takes fire, if in contact with the air, and burns with a flame of a pale blue colour. In this process, it dissolves in the oxygen of the atmosphere, and produces an elastic fluid acid. It is a substance of great importance in chemistry and the arts. Oxygen unites with it in four proportions, its compounds forming an interesting series of acids, see 128, 129, 130. The compounds of sulphur with metals are called sulphurets. With hydrogen it forms sulphuretted hydrogen gas.

23.—X. PHOSPHORUS is a semi-transparent yellowish matter, of the consistence of wax. It is procured, in general, by the decomposition of bones. It is so inflammable, that it is set on fire by a heat of about one-third that of boiling water. Indeed, it has a luminous appearance, arising from a slow combustion, at the common temperature of the atmosphere. During its combustion, it emits a dense white smoke, which has the smell of garlic, and in the dark, is luminous. When heated to five times the height necessary to inflame it, (air being excluded,) it boils. On account of its very combustible nature, it requires to be handled with great caution. It is a violent poison. Alcohol, oils, and ether, dissolve it in small quantities, forming solutions, which are possessed of some curious properties, as will be shown among the *experiments*. Phosphorus, when burnt in oxygen, forms, by combining with it, in different proportions, a series of acids.

Note.—The compounds of carbon, are called *carburets;* those of boron, *borurets;* those of sulphur, *sulphurets;* and those of phosphorus, *phosphurets.*

24. The forty-three elementary substances which now remain to be described, are all METALS. They composed the most numerous class of undecompounded chemical bodies, and are distinguished by the following general characters:—

25.—I. They possess a peculiar lustre.

26.—II. They are opaque.

27.—III. They are fusible by heat; and in fusion retain their lustre and opacity.

28.—IV. They are excellent conductors of electricity and heat.

29.—V. Many of them may be extended under the hammer, and are called malleable; or under the rolling press, and are called laminable; or drawn into wire, and are called ductile.

30.—VI. When exposed, highly-heated, to the action of oxygen, chlorine, or iodine, they take fire, and are converted by the combustion into oxides, chlorides, or iodides; bodies destitute of lustre, and other metallic characteristics.

31.—VII. They will combine, in almost any proportion, with each other, when in a state of fusion, and thus form compounds, which are termed alloys, bodies that *retain* the properties of metals.

32.—VIII. From their brilliancy and opacity, conjointly, they reflect the greater part of the light which falls on their surface; hence they form excellent mirrors.

33.—IX. When combined with simple bodies of the second class (11), they produce bodies of very peculiar characters, some of them being gaseous, others semi-metallic, &c.

34.—X. Many of them may by peculiar management be crystallized.

35.—XI. They are very heavy: to this character, however, (though it was till lately considered one of their most prominent features,) these are important exceptions; since *metals* have been obtained, (potassium and sodium, for instance,) which are lighter than water.

The relative weights, or specific gravities, of the different metals, are noted in the general table of specific gravities, at the end of the book.

36. The acquirement, retention, and application of knowledge, is much facilitated by a methodical distribution of its different parts. The relations of the metals, however, to the various objects of chemistry, are so complex and diversified, as to render their classification a task of peculiar difficulty. In the following "Table," they are arranged according to their perfectibility. Those at the head of the list are scarcely at all affected by the power of oxygen. But as we progressively descend, the influence of that beautiful element progressively increases; so that among those near the bottom, it exercises an almost despotic sway, which the magical pile of Volta, directed by the genius of Davy, can only suspend for a season. The emancipated metal soon relapses under the dominion of oxygen.

In an annexed column, is described the nature of the products of an union with oxygen. These combinations will be duly considered hereafter.

37. GENERAL TABLE OF THE METALS.

Names.	United to Oxygen form	Names.	United to Oxygen form
1. Platinum,.........	Ordinary Metallic Oxides, or Neutral Salifiable Bases.	24. Osmium,..........	Metallic Oxides, not much known.
2. Gold,...............		25. Rhodium,..........	
3. Silver,..............		26. Iridium,....... ...	
4. Paladium,.........		27. Uranium,.........	
5. Mercury,.........		28. Titanium,.........	
6. Copper,............		29. Cerium,............	
7. Iron,.................		30. Wodanium,......	
8. Tin,...................		31. Potassium,........	Alkalies.
9. Lead,................		32. Sodium,............	
10. Nickel,.............		33. Lithium,..........	
11. Cadmium,.........		34. Calcium,..........	Earths.
12. Zinc,................		35. Barium,...........	
13. Bismuth,...........		36. Strontium,........	
14. Antimony,.......		37. Magnesium,......	
15. Manganese,......		38. Yttrium,..........	
16. Cobalt,............		39. Glucinum,........	
17. Tellurium,........	Acids.	40. Aluminum,......	
18. Arsenic,...........		41. Thorinum,........	
19. Chromium,.......		42. Zirconium,.......	
20. Molybdenum,...		43. Silicium,..........	
21. Tungstenum,....			
22. Columbium,......			
23. Selenium,.........			

38. Two of the classes of bodies which the above Table points out as *compounds of metals with oxygen*, the *alkalies*, and the *earths*, were, till very lately, supposed to be *simple* substances; and were, consequently, in every system of chemistry, arranged with the other simple bodies: as, however, it has been fully proved that they are *not* such, they are now, of course, treated of with the compounds. But their great importance entitles them to claim, and obtains for them, a very conspicuous place in every work on chemistry: we shall shortly treat of them; in the mean time, we proceed to give a sketch of the individual characteristics of the metals.

39.—I. Platinum, a metal of a dull white colour, the heaviest body in nature. It requires an intense heat for its fusion; and has so little affinity for oxygen, that it may be exposed for any length of time to the atmosphere, without being oxidised (rusted or tarnished): hence it would make very useful utensils, could it be obtained in large quantities. But it is scarce. Two red hot pieces of it may, by hammering, be joined into one. This operation is termed *welding*, and is peculiar to itself and iron. It is extremely malleable and ductile—may be hammered into thin plates, and drawn into wire 1-3000ths of an inch in diameter. It is unacted upon by all acids, except such as contain chlorine.

40.—II. Gold is a beautiful yellow metal, and, next to platinum, the heaviest of all known bodies. It bears the same relation to acid *menstrua* that platinum does; requiring those containing chlorine to dissolve it. Of all metals, gold is the most ductile and malleable; it is also soft, very tough, and unalterable even by the strongest heat of a furnace. It does not oxidise when exposed to the air. Most metals unite to gold by fusion. Mercury is very strongly disposed to do so without fusion. Lead makes it brittle. Copper deepens its colour, and, by rendering it harder and more fusible, makes it more fit for coin, and other articles used. The gold coins of Great Britain contain 11 parts of gold and 1 of copper.

41.—III. Silver. This is the whitest of all metals, and in brilliancy only inferior to polished steel. It is softer than copper, but harder than gold. It is very ductile and malleable, though less so than gold: it may, however, be beat into leaves 1,160,000 of an inch thick, and a single grain of it has been drawn into a wire 400 feet long. It is also very tenacious: a fine wire will support a very great weight without breaking. Silver melts when it is heated completely red bot; and, by means of an intense heat, that produced by a galvanic battery, for instance, it may, like any other combustible body, be burnt. Its inflammation is attended by a green light, of great beauty and brilliancy. Silver is oxidised by ignition in an open vessel, but not by exposure to the atmosphere. It is rapidly tarnished by the vapour of sulphur. To render it harder, and more fitting for the purposes of coin than it is in its pure state, it is alloyed witb copper. Nitrate of silver, produced by dissolving silver in diluted nitric acid, (the particulars of which process are given in anotber part of this work,) is of great use in the arts. Some of the compounds of this metal are possessed of fulminating properties: they are curious, but prepared with great difficulty, and attended by much danger.

42.—IV. PALLADIUM, a metal that is very scarce. Its colour is greyish-white. It is ductile, malleable, and harder than iron. It takes a fine polish.

43.—V. MERCURY, a heavy metal, of a blueish-white colour. It is also called quicksilver. Its chief characteristic is that of always being fluid at the common temperature of the atmosphere. But it becomes solid, when exposed to a sufficient degree of cold. The temperature necessary for freezing it, is 39° below 0° of Fahrenheit's thermometer. At 600° it boils, and volatilizes; so that it may be distilled from one vessel into another. By this process it is purified. It is strongly inclined to unite with metals: its metallic compounds are termed *amalgams.* Among the preparations of mercury, are the bodies usually termed vermillion, calomel, and corrosive sublimate; the last is a most violent poison, but is, as well as the one preceding it, frequently employed in medicine. Looking-glasses are silvered by an *amalgam* of tin. Mercury is easily dissolved in nitric acid.

44.—VI. COPPER is a reddish-brown metal; hard and sonorous; very malleable and ductile; and of great tenacity. It is one of the most useful, and most abundant of metals. It is about nine times as heavy as water. It is melted by a heat seven times greater than that of boiling water. By a still greater heat, it evaporates in visible fumes. It is easily oxidised by exposure to the air. By making a plate of copper red hot, and plunging it in that state into cold water, oxide, in small scales, will separate from the metal: any quantity of it may be thus obtained. When copper is exposed to a very violent heat, it burns with a vivid green-coloured flame. Copper combines with most other metals. With zinc, it forms the very useful compounds, called *brass,* pinchbeck, prince's metal, &c. With tin it forms bell-metal, bronze, the alloys used for cannons, mirrors of telescopes, &c. Blue vitriol is a sulphate of copper, formed by the dissolution of copper in sulphuric acid, and crystallization of the solution. Nitric acid dissolves copper with great rapidity, producing a transparent blue solution, from which may be obtained, by evaporation, beautiful blue crystals. Muriate of copper, formed by dissolving oxide of copper in muriatic acid, is of a green colour.

45.—VII. Iron is the most useful, and most abundant, of all the metals we are acquainted with. Its colour is blueish-white. It has the properties of hardness, tenacity, and ductility, in a very eminent degree. It is malleable also, but less so than silver. It requires an intense degree of heat for its fusion. One of its most advantageous properties, is that of *welding*. By undergoing this process, (peculiar to itself and platinum,) two pieces of this metal may be joined into one. Susceptibility of magnetism, in a very high degree, is also one of its distinguishing properties. The *loadstone* itself (in which the power of magnetism chiefly resides) is an iron ore. Iron is widely diffused: it is found in animals, vegetables, and minerals. It has a strong affinity for oxygen. When exposed to the air, its surface gradually becomes covered with a brown, or red powder, commonly called *rust*. This powder is an oxide of iron. Carbon and iron united, form the exceedingly useful compound, called *steel*. Iron unites with other metals. The most useful of its alloys, is that with tin, called *tin-plate*. Iron enters into the composition of the beautiful pigment, called *prussian-blue*. Green vitriol, or copperas, is a sulphate of iron.

46.—VIII. Tin is a yellowish-white metal, possessed of great brilliancy, harder than lead, and very malleable. It may be beat into leaves, 1-2000ths of an inch thick. But it is neither very tenacious, nor very ductile. It is very flexible. It melts, at a low heat; by a great heat, it may be evaporated. Tin soon tarnishes when exposed to air, becoming slightly oxidated; and, when it is melted in an open vessel, its surface is soon covered with an oxide, in the form of a grey powder. The alloys of tin (one of which is pewter) are of considerable use; but, as well as the uses of tin in general, are too well known to need pointing out. The combinations of tin with acids, are used as chemical re-agents, and in the art of dyeing.

47.—IX. Lead is a pale blueish metal, very soft, very heavy, and very malleable; but, though it may be drawn into wire, not very ductile. It melts at a low heat, and at a strong heat boils and evaporates. When rubbed on paper, it leaves a black mark. Lead unites to oxygen in different proportions, forming differently-coloured oxides. *Massicot*, a yellow pigment, and *red lead*, also a pigment, are two of its oxides. *White lead* is a compound of the yellow oxide and carbonic acid, formed by exposing thin plates of lead to the vapour of warm vinegar, whereby they are corroded, and converted into a white powder. The oxides of lead are, by heat, converted into glass. Most of the acids attack lead. The well-known substance called *sugar of lead*, is an *acetate*. Lead, and all its compounds, are poisonous. The proper counter-poison for a dangerous dose of sugar-of-lead, is a solution of Epsom or Glauber salts, swallowed in considerable quantity; either of which medicines instantly converts the *poisonous acetate* of lead, into the inert and *innoxious sulphate*.

48.—X. Nickel is a fine white metal, hard, ductile, malleable, and very difficult of fusion. It is magnetical, but not so much so as iron. It is scarce, and little used. The combinations of nickel with acids, are distinguished by their fine green colour.

49.—XI. Cadmium bears a considerable resemblance to *tin*, but it is more tenacious, and more fusible. It is rare, and not applied to any use.

50.—XII. Zinc is of a brilliant blueish-white colour, and has a crystallized appearance. It is hard, ductile, tenacious, and malleable, but only in a slight degree. It melts readily: just before melting, it is so brittle, that it may be pulverized. It is very combustible: when the fused metal has become red hot, it takes fire, continues to burn with a dazzling white flame, and is oxidised so rapidly, that it flies up in light filaments, called *flowers of zinc*, or *philosophical wool.* Zinc precipitates lead, tin, copper, silver, and some other metals, from their solutions. The substance known by the name of *white vitriol*, is a sulphate of zinc, and is, as are several of the alloys of this metal, exceedingly useful.

51.—XIII. BISMUTH is of a reddish-white colour, hard, brittle, and very fusible. When heated considerably, it evaporates. When raised to a strong red heat in contact with the air, it takes fire, and burns with a light blue flame, emitting a dense yellow smoke, which is an oxide of zinc. When the metal, after being melted, is cooled gradually, it crystallizes. The alloys of bismuth (*pewter* is one of them) are all very fusible. The nitrate of bismuth affords, upon the addition of water, a white powder, which is used as a paint, under the name of *flake-white*.

52.—XIV. ANTIMONY is of a dusky-white colour, very brittle, but so soft, that, like lead, it may be cut with a knife. When heated to redness, it melts. If after this the heat be increased, the metal volatilizes in the form of white fumes, consisting of an oxide, formerly called *flowers of antimony*. A variety of useful alloys have antimony for one of their constituents: the metal for printers' types, that on which music is engraved, and pewter, belong to this class. Antimonial preparations serve also as paints and medicines.

53.—XV. MANGANESE has much the appearance of cast-iron. Its attraction for oxygen is so powerful, that it is preserved in the metallic state with great difficulty. The oxide of manganese is of great utility in the arts. The chemist, too, frequently uses that substance for the procuration of oxygen gas.

54.—XVI. COBALT is of a reddish-grey colour; brittle, rather soft, possessed of little lustre, and difficultly fusible. It is slightly susceptible of magnetism. The *salts* of cobalt are interesting, from the remarkable changes of colour which they exhibit.

55.—XVII. TELLURIUM is a tin-coloured highly-lustrous metal, very brittle, and very volatile. It may be inflamed, and burns with a vivid blue light. It forms, with hydrogen, a gaseous acid, called telluretted hydrogen gas. But little is known, either of tellurium, or its combinations.

56.—XVIII. ARSENIC is a metal of a blueish-white colour, subject to become black by exposure to the air. It is the softest, most brittle, and most volatile of all the metals that are known. Its fusing-point cannot be discovered, because it evaporates without melting. It is exceedingly poisonous. It combines with two proportions of oxygen, forming *arsenious acid*, and *arsenic acid*. It combines with hydrogen, forming a very noxious gas, called *arsenuretted hydrogen gas*. The common arsenic of the shops is the above-named arsenious acid.

57.—XIX. Chromium, a very rare metal, which is slightly magnetical. Its colour is white. It is brittle, and lustrous. Acids act upon it with great difficulty. It unites with three different doses of oxygen, forming *green* oxide, *brown* oxide, and with the largest proportion *chromic acid*, which is obtained in small ruby-red crystals.

58.—XX. Molybdenum has only been obtained in very small quantities. It appears in the form of small blackish, lustrous, and brittle globules. It is the base of the molybdic acid.

59.—XXI. Tungstenum, the base of the tungstic acid, is a metal much like steel. It is so hard that a file can scarcely make an impression on it, and in weight it is only inferior to gold. It is scarce, and not used for any thing.

60.—XXII. Columbium, one of the acidifiable metals, is of an iron colour, hard, and brittle: other of its properties are not known. It is unacted upon by the strongest acids.

61.—XXIII. Selenium, the base of the selenic acid, is a grey metal, lustrous, brittle, soft, fusible, and volatile. It is distinguished by having the smell of *horse-raddish*. It alloys with other metals.

62.—XXIV. Osmium has a dark-grey colour. When heated in the open air, it is readily oxidised; but it resists the action of the strongest acids. It has not been melted, and is little known. The oxide of osmium is very volatile, has a peculiar pungent smell, a sweet taste, is very soluble in water, and gives a yellow precipitate upon the addition of potass.

63.—XXV. Rhodium is a whitish metal, very brittle, and as hard, and infusible, as iron. It is insoluble in acid. It unites to oxygen in several proportions, forming different-coloured oxides. With the malleable metals, it forms malleable alloys. It is very little known.

64.—XXVI. Iridium is a heavy whitish metal, malleable, and infusible. It alloys with other metals. It has its name from the striking variety of colours it affords, while dissolving in muriatic acid. But little is known of its several combinations.

65.—XXVII. Uranium is a hard, glittering, grey metal, obtained with great difficulty, and in very small quantities, from a mineral body resembling *pitch*.

66.—XXVIII. Titanium, a rare metal of a dark copper colour, very heavy, lustrous, brittle, elastic, and highly-infusible. It is tarnished by air, and readily oxidised by heat. When thrown into melted nitrate of potass, it detonates. All the dense acids act upon it energetically. It has three oxides, the *blue*, the *red*, and the *white*.

67.—XXIX. Cerium, a metal but little known, being scarce, and obtained with difficulty. It dissolves in acids, forming *sweet* salts. There are two oxides, one, the protoxide, being *white*; the other, the peroxide, *red*.

68.—XXX. Wodanium, a metal of a bronze-yellow colour; hard and malleable. It is strongly attracted by the magnet. Its acid solutions are colourless; but its hydrated oxide, precipitated by caustic ammonia, is *indigo* blue.

69.—XXXI. Potassium.—This marvellous metal was first revealed to the world by Sir Humphrey Davy, in 1807. He produced it, by means of voltaic electricity, from a substance which had been, till that time, considered simple, namely, the fixed alkali *potass*, which substance, however, he then proved to be a metallic oxide.

The properties of potassium are very extraordinary. It is lighter, not only than all other metals, but even than water. It is solid, soft, and of the colour and lustre of silver. But its metallic nature is not retained a single minute when it is exposed to the air: it instantly absorbs oxygen, and becomes covered with a crust of *potass*. This oxide absorbs water, which is rapidly decomposed, and in a short time the whole becomes a saturated solution of potass. Potassium is exceedingly inflammable; it fuses at 136°. and rises in vapour at a heat below redness. When heated in oxygen gas to the temperature at which it begins to evaporate, it burns with a brilliant white light, and an intense heat. When thrown upon the surface of water, it acts with great violence. The liquid is rapidly decomposed: its hydrogen is evolved, and spontaneously inflames in the air; it then communicates the combustion to the potassium, and the whole burns (while swimming about on the water) with a beautiful light of a violet-red colour: meantime, the oxygen of the water, and that drawn from the atmosphere by the combustion, unite with the potassium, and produce an oxide; which, as it is produced, dissolves in the water, and the final result is a *solution of pure potass.* Potassium likewise burns with a kind of explosion, when placed (in a perfectly cold state) upon a piece of ice, dissolving tbe ice, and forming a little hole, in which it burns, till entirely consumed, forming, as before, a solution of potass. It spontaneously inflames, when put into chlorine gas, burning with great brilliancy, and producing chloride of potassium; a substance which upon solution becomes muriate of potass.

Upon all fluids containing water, or much oxygen or chlorine, potassium acts with great rapidity; and, in its general powers of chemical combination, that substance, says its illustrious discoverer, may be compared to the *alkahest*, or *universal solvent*, so much talked of and longed for by the alchemists.

Potassium has, of all known substances, the strongest affinity for oxygen; and it can only be preserved in the metallic state, by keeping it immersed in naphtha, a liquid of which oxygen is not a constituent.

70.—XXXII. Sodium, the base of the alkali *soda*, was discovered hy Sir Humphrey Davy, a few days after he discovered potassium. It was obtained in a similar manner, and is possessed of the following properties.

In several respects it bears a great resemblance to potassium, but it is much less energetic in its actions. It is lighter than water, has the colour of silver, is solid, very soft, malleable, and a conductor of electricity; but it is heavier than potass; and requires a greater heat to fuse it, and a much higher still to volatilize it, than potassium does. When sodium is thrown upon water, it effervesces violently, produces a hissing noise, and swims about in a state of great agitation; but it does not inflame. The water, however, is decomposed, and its oxygen combines with the sodium, and produces oxide of sodium, or soda. This product is dissolved by the water; and the operation closes with the formation of a solution of pure soda. The combination of sodium with chlorine, is well known as *common table salt*, which substance, however, is, by the smallest addition of water, changed to muriate of soda. It must be observed, in explanation of this, that the water is decomposed: its oxygen unites to the sodium, forming soda; and its hydrogen to the chlorine, forming muriatic acid. It is evident, from this, that the aqueous compound is not chloride of sodium and water, but muriatic acid and soda, or the salt produced by their combination. When the solution of the salt is evaporated, the solid obtained is not dry muriate of soda, but chloride of sodium.

Sodium must, like potassium, and on the same account, be kept in naphtha.

71.—XXXIII. Lithium is a metal obtained by voltaism from a newly-discovered mineral alkali, called *lithia*. The quantity hitherto obtained has been much too small, to allow of a full examination of its properties. From what is known, however, we conclude it to resemble sodium.

72.—XXXIV. Calcium, the metallic base of *lime*, has been obtained, by a voltaic process, *from* that base, but only in quantities too small to admit of an examination of its nature. It is of a bright white colour, burns brilliantly when heated in the air, and produces white oxide, which is pure dry *lime*, a well known and very important substance.

73.—XXXV. Barium was procured by Sir Humphrey Davy, from its oxide *barytes*, by subjecting that earth to powerful electricity. It is of a dark-grey colour, is lustrous, heavy, and fusible. When exposed to the air, it rapidly attracts oxygen, and its surface becomes covered with a crust of barytes. It burns with a deep red light, when gently heated in the air. When thrown upon water, it effervesces violently; and, as it is heavy, it sinks into the fluid, which is decomposed with great rapidity; hydrogen gas is emitted, and the barium becomes barytes.

74.—XXXVI. Strontium, base of *strontia*,
75.—XXXVII. Magnesium, base of *magnesia*,
76.—XXXVIII. Yttrium, base of *yttria*,
77.—XXXIX. Glucinum, base of *glucina*,
78.—XL. Aluminum, base of *alumina*,
79.—XLI. Thorinum, base of *thorina*,
80.—XLII. Zirconium, base of *zirconia*,
81.—XLIII. Silicium, base of *silica*,

have, like barium, been procured in such minute quantities, that, as yet, their properties are but little known.

82. Having thus presented to the notice of the student, the various simple or elementary bodies, we are now to perform a like office for the substances which result from their various combinations. Before, however, we commence the examination of the properties of the compound bodies, it will be proper for us to enter into an investigation of the nature of those Grand Powers, which, by their continual action upon common matter, change its form, and produce arrangements fitted for the purposes of life.

83. Attraction.—This is that unknown force, which causes bodies to approach each other. The instances of its exertion, exhibited in the phenomena around us, are exceedingly numerous, and continually present themselves to our observation.

84. Attraction exemplifies itself in a great variety of modes: gravitation, the wonders of electricity and magnetism, the ascension of liquids in narrow tubes, or porous substances, all point out the exertion of this power. But, besides these here named, there is another kind of attraction—a kind which comes immediately under the chemist's cognisance—that of *cohesion*. *This* operates among the *particles* of bodies, causing them to cohere, and form a whole.

85. The attraction of cohesion is differently named, when spoken of with regard to different substances. If it causes the fixing-together of homogeneous particles, it is called the attraction of aggregation. But when it acts upon particles of different kinds, it is called the attraction of composition, or *chemical affinity*.

86. The study of chemical *affinity* is of vast importance; in fact, the whole science rests upon a knowledge of its modes of taking place. From the careful observance of

the effects produced by certain experiments, chemists have deduced the following *laws*.

87.—I. The attraction of composition, or chemical affinity, takes place only between bodies of a different nature.

88.—II. It takes place only between the most minute particles of bodies.

89.—III. It can take place between two, three, four, or a greater number of bodies.

90.—IV. A change of temperature always takes place at the moment of combination.

91.—V. The properties which characterize bodies, when separate, are altered or destroyed by combination.

92.—VI. The force of chemical affinity, between the constituents of a body, is estimated by that which is required for their separation.

93.—VII. Every substance, though it has a certain affinity for all other substances, has different degrees of affinity for different substances.

94. This last law is the grand principle of all chemical operations; for it is by a proper arrangement of bodies which differ in their degrees of affinity, that all chemical decompositions and compositions are effected.

95. When a simple substance is presented or applied to another substance, compounded of two principles, and unites to one of those principles, so as to separate or exclude the other, the effect is said to be produced by *simple elective affinity*.

96. Double elective attraction, or *compound affinity*, (the terms are synonymous,) takes place when two bodies, each consisting of two principles, are presented to each other, and mutually exchange a principle of each, by which means two new bodies, or compounds, are produced, of a different nature from the original compounds.

97. Upon the principle, that "bodies differ in their degrees of affinity," chemists have constructed *tables of affinity:* these, though, like most other things, liable to objections, are so extremely useful, that the study of them cannot be too strongly recommended. Some of the best of them will be found in another part of this volume.

98. Repulsion—Caloric.—The opponent power of *attraction*, is that which causes bodies to *recede* from each other, and which is known by the name of *repulsion*. That substance, possessed of this power, to which the attention of chemists is chiefly directed, is *caloric*.

99. The appellation of *caloric* has been given, by modern chemists, to that which produces the well-known sensation called *heat*.

100. Caloric penetrates all bodies; separating their particles from each other, and thus increasing their bulk. Solids, by an increase of heat, become fluids, and fluids, gases. Thus ice is converted, by an accession of caloric, into water, and by a still farther accession, it becomes steam.

101. Different bodies have different capacities for caloric: those bodies which have the least capacity for it, are the best conductors of it.

102. As in various operations, it was found of great importance to know how much caloric a certain substance contained, an instrument was contrived to determine this, and the name *thermometer*, signifying *the measurer of heat*, was applied to it. The mode in which the degrees of heat are measured, is by the expansion of fluids in narrow glass tubes: the fluid generally used for this purpose is the metal mercury.

103. The subject of heat is an important one, but much too difficult to be forced upon the attention of the student in this place. He will derive most advantage from the study of it, when he has become acquainted with some other things, which, if less striking in their natures than it, are more tangible.

104. Combustion—Combination.—Combustion is considered as the general result of intense chemical action. When oxygen and chlorine unite with the simple combustibles, compounds possessed of most remarkable properties are formed: the combinations take place with astonishing energy, and with the evolutions of light and heat.

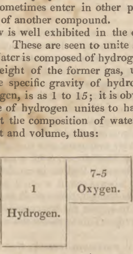
105. In all common cases, *combustion* is the process of the solution of a body in oxygen; as when sulphur or phosphorus are burnt in it, or when it forms water, by combining with hydrogen.

106. The union of considerable quantities of oxygen and chlorine with combustible bodies, generally produce acids; thus sulphuric, phosphoric, and boracic acids, are formed by the union of considerable quantities of oxygen with portions of sulphur, phosphorus, and boron,—and muriatic acid gas is formed by the union of chlorine and hydrogen.

107. When these solvent substances, oxygen and chlorine, unite with combustible bodies in *smaller* quantities, they produce compounds, not acid, and, in a greater or less degree, soluble in water. A vast number of compounds are thus formed by oxygen: the earths, the fixed alkalies, and the metallic oxides, bodies connected by analogies with each other, are all of this class.

108. Atomic Theory, *or Doctrine of Definite Proportions.*—One of the latest and most important chemical discoveries, is, that the elementary bodies enter into combination in *definite* proportions; that is to say, if two simple bodies combine and form a particular compound, they always unite in the same proportions to form that compound: they, however, sometimes enter in other proportions into the composition of another compound.

109. This law is well exhibited in the combinations of gaseous bodies. These are seen to unite in simple ratios of volumes. Water is composed of hydrogen and oxygen, and 1 part by weight of the former gas, unites to 7·5 of the latter. The specific gravity of hydrogen, compared with that of oxygen, is as 1 to 15; it is obvious, therefore, that one volume of hydrogen unites to half a volume of oxygen, and that the composition of water will be represented by weight and volume, thus:



No other proportions of these gases than those here represented, can ever combine and form water; nor is it known that they form any other body, by combining in other proportions. This, however, is not the case with all bodies.

110. The metallic oxides in general consist of the metals, united to from one to four proportions of oxygen; and there are, in some cases, many different oxides of the same metal: thus, there are three oxides of lead,—the yellow oxide, or massicot, containing two proportions of oxygen; the red oxide, or minium, three; and the puce-coloured oxide, four proportions. Again, there are two oxides of copper, the black and the orange; the black contains two proportions of oxygen, the orange, one.

111. When a metal is oxidised in different degrees, the several compounds have a prefix to their names, to distinguish them. The smallest addition of oxygen forms a *protoxide*, the second quantity gives rise to the *deutoxide*, and the third the *tritoxide*;—farther, the oxide which contains the largest quantity of oxygen, is generally called the *peroxide*.

112. Crystallization.—When fluid substances are suffered to pass with adequate slowness to the solid state, the attractive forces frequently arrange their ultimate particles, so as to form regular geometrical solids, to which has been given the name of *crystals*.

113. Perfect mobility among the corpuscles is essential to crystallization. The chemist produces it either by igneous fusion, or by solution in a liquid. When the temperature is slowly lowered in the former case, or the liquid slowly extracted by evaporation in the latter, the attractive forces resume the ascendency, and arrange the particles in symmetrical forms. Bodies, in crystallizing from their watery solution, always retain a small portion of water, which remains confined in the crystals in a state of solidity, and does not re-appear till the crystalline form of those bodies is destroyed. This is called the *water of crystallization*.

114. It is well worthy of remark, that every individual salt has a certain determinate figure, which it assumes upon crystallization.

115. The operation of crystallizing is of great utility in the purifying of various saline substances.

116. Combinations of Elementary Bodies.—These are innumerable, and some of them are of vast importance. The list of those with which chemists are intimately acquainted, is very extensive; but as, in this small volume, nothing can be expected but the *Rudiments* of the science, and a familiar account of the most important bodies, it would be ridiculous, were we to present the student with a large catalogue of compounds, without (for we should have no room to include) descriptions of their properties. Such a course of proceeding, instead of directing him in his pursuit of the facts of chemistry, would serve only to perplex him. We shall, therefore, confine our attention to such as, by their great utility, or striking peculiarities, seem especially to require it.

117. Atmospheric Air, is the term applied to that immense mass of permanently elastic fluid, which surrounds the globe we inhabit. This substance was for a long time supposed to be simple, but recently it has been proved, by experiment, to be a compound of oxygen and nitrogen. 100 parts of common air, contain 21 parts by measure of the former body, and 79 of the latter. The density of air is 1-820th of that of water. Its pbysical properties, as its transparency, and so on,—are so obvious, as not to require description. Air which has been breathed, is found to have lost its oxygen, and is then no longer fit to support life. This principle is retained in the lungs, where it is absorbed by the blood, from which it expels *carbonic acid gas*, and to which it gives its fine red colour, and renders it fitting to support life. As air which will not support combustion is not fit for respiration, we hence have recourse to the efficacy of air in supporting combustion, in order to determine its purity.

118. Water, a fluid of which the most useful properties are universally known, and properly appreciated. Without it, neither vegetable nor animal life could be supported. Like common air, *water*, which was formerly considered a simple body, has been found to be a compound one. Its principles being *hydrogen* and *oxygen*; in the propor-

tions of, by weight, 1 part of the former to 7·5 of the latter, or, by measure, of 2 of the former to 1 of the latter.

Pure water is perfectly transparent, tasteless, inodorous, and not liable to change. Rain water is the purest we see in nature. Spring water has always some mineral impurities. By distillation, it is freed from whatever contaminates it.

119. Acids.—The most important class of chemical compounds. They are generally produced by the combination of particular substances with oxygen; but oxygen, however, is not the only acidifying principle, for hydrogen, chlorine, and iodine, are producers of acids likewise. The following are the general properties of the acids.

120.—I. The taste of these bodies is, as their name denotes, *sour;* and in the stronger species, it is acrid and corrosive.

121.—II. They combine with water in every proportion, with a condensation of volume, and evolution of heat.

122.—III. They are volatilized or decomposed at a moderate heat.

123.—IV. They change the blue, green, and purple colours of vegetables, to a bright red.

124.—V. They unite in definite proportions with the alkalies, earthy and metallic oxides, and form the important class of bodies termed *salts* (197). This may be reckoned their characteristic and indispensable property.

125. Acids, in order to give to students general views of such as have analogous properties, have been classified as follows:—

Division 1st.—Acids from inorganic nature, or such as are procurable without having recourse to animal or vegetable products.

Division 2d.—Acids elaborated by means of organization.

126. The first group is sub-divided into three families.

I. Oxygen acids, $\begin{cases}\text{non-metallic.}\\ \text{metallic.}\end{cases}$

II. Hydrogen acids.

III. Acids containing neither oxygen nor hydrogen.

127. The number of the animal and vegetable acids

(those belonging to the second division) is 56. The total number of acids now proved to exist, is 87. As many of these are, however, but little known, are of no importance, and may be found particularized in any large work on chemistry, we shall not here describe them; but confine our attention to such as are much employed, and which it is necessary for the young chemist to become early and fully acquainted with.

128. Sulphuric Acid.—When sulphur is burnt in oxygen gas, and the gaseous combination of sulphur and oxygen is mixed with water, the liquid product is found to possess the distinguishing properties of acids. This liquid has, therefore, from its nature, and from the name of its base, acquired the appellation of sulphuric acid. It was formerly called oil of vitriol. Sulphuric acid is one of the strongest of that class of bodies. It is composed of two parts of sulphur to three of oxygen. When in the pure concentrated liquid state, it is without smell or colour, appears of an oily consistence, and is twice the density of water; for which body it has a very strong attraction. It is violently caustic: the person who unfortunately swallows it, speedily dies in dreadful agonies. Here it may not be amiss to observe, that the best antidote to the poison of a strong acid is chalk, a substance which unites to the acid, and forms a compound not poisonous. When sulphuric acid is mixed in certain proportions with water, it produces heat; but, if it is mixed with ice, cold is produced. Sulphuric acid is prepared in the large way, by burning sulphur mixed with a small portion of nitre, in close chambers lined with lead. The nitre furnishes oxygen to the sulphur, and the acid, as it is produced, combines with a quantity of water, with which the floor of the chambers is previously covered. This liquid acid is afterwards distilled, to free it from impurities.

The use of sulphuric acid in chemistry, metallurgy, bleaching, dyeing, medicine, and other arts, is very extensive. Its combinations with the various base, are a class of salts, called *sulphates*. They will be described under the head "*salts.*"

129. Sulphurous Acid.—This is sulphur, combined

with a less degree of oxygen than is necessary to form sulphuric acid. In the ordinary temperature of the atmosphere, it is a gas, composed of 1 volume of oxygen, and 1 of vapour of sulphur. It has a strong suffocating smell. It possesses the property of destroying vegetable colours: this renders it useful in some bleaching operations. Its combinations with salifiable bases, are termed *sulphites*. They are of little use.

130. Hyposulphurous Acid.—This is composed of sulphur, united to a less portion of oxygen than sulphurous acid. Hyposulphuric Acid.—This contains more oxygen than the sulphurous, but less than the sulphuric. These acids are not of much importance.

131. The following table of the just-described acid compounds of sulphur and oxygen, may serve to fix their compositions in the learner's memory.

Acids.	*Parts of Sulphur.*	*Parts of Oxygen.*
Sulphuric, ...	2	3
Hyposulphuric,..........	2	2.5
Sulphurous, ...	2	2
Hyposulphurous,........	2	1

132. Phosphoric Acid.—This is a compound of oxygen and phosphorus. It may be procured by burning the latter body in the former, but is much more cheaply obtained from calcined bones. The mineral, vegetable, and animal kingdoms abound, either with the base of this acid, or the acid itself. Pure phosphoric acid is in a solid state, but it is soluble in all proportions in water. It has no smell, is sour, but not corrosive. Its salts are termed *phosphates*.

133. Carbonic Acid.—This is a compound of oxygen and carbon. It may be obtained by burning carbon in oxygen gas; but it exists ready formed, in great abundance,

in nature. It composes 0.044 of the weight of all limestone, marble, &c.; from which it may easily be separated, as almost every other acid has a superior affinity for the bases of these stones.

Carbonic acid is *aerial*, and cannot be condensed into a liquid. But water is capable of absorbing it, and it thereby becomes converted into a weak acid. Carbonic acid gas extinguishes flame, and destroys animal life. It is much denser than common air, and hence always occupies the lower part of places where it is formed. Miners call it the *choke-damp*. It is emitted in large quantities, by bodies that are *fermenting*, and is the principle that gives to bottled porter, ginger-beer, &c. the effervescing, or frothing property. It has a peculiar sharp taste, and reddens infusion of litmus. 100 parts of carbonic acid gas, contain 72 oxygen, 28 carbon. The salts of this acid, which are an important class, are called *carbonates*.

134. Boracic Acid.—This is a compound of oxygen and a lately discovered solid body, called boron (21). A body well known by the name of borax, is composed of this acid united to soda. Boracic acid is obtained in the form of thin crystals, (or scales,) of a silvery-white colour; having a greasy feel, no smell, but a very strange taste—being first sourish, then bitterish, cooling, and at last agreeably sweet. It is soluble in water, but only in a slight degree. It is more so in alcohol, and gives to the flame of that body, when burning, a green colour. It is fusible, and is converted by fusion into a kind of glass, which is used in the composition of false gems. The salts of boracic acid are called borates.

135. Nitric Acid.—This body, which is of a deadly poisonous nature, has for its component principles the same bodies as common air, namely, oxygen and nitrogen. They are united in it, however, in different proportions. Atmospheric air is composed of 1 volume of oxygen, and 4 of nitrogen: nitric acid gas of $2\frac{1}{2}$ volumes of oxygen to 1 of nitrogen. Nitric acid gas combines with water very eagerly, and communicates to the water its properties.

Strong pure nitric acid is about one-half denser than water, and colourless. It is eminently corrosive: of this property, its old name aquafortis (strong water) is very expressive. The aquafortis of commerce, is nitric acid in a state of impurity. Nitric acid is of considerable use in the arts: being employed for etching on copper, in dyeing, metallurgy, assaying, and medicinal preparations; also, in various chemical processes, on account of the facility with which it dissolves metals, by first parting with a portion of its oxygen to them, and then attacking the oxides. But there are two metals upon which it has no effect—these are gold and platinum; even these, however, may be dissolved by a liquid, of which the nitric acid forms a part.

The salts of this acid are of considerable use; they are termed nitrates.

136. Nitrous Acid.—This is said to be composed of $1\frac{1}{2}$ oxygen to 1 nitrogen, but much uncertainty prevails regarding it. Indeed, its very existence is doubted. The orange-coloured volatile fluid, to which the name has been given, is held by some to be nitric acid, holding a particular sort of air, called nitrous gas in solution. Its salts (if there are such) are *nitrites.*

137. Muriatic Acid.—This, in a gaseous state, consists of chlorine and hydrogen, united in equal volumes. Muriatic acid gas is invisible, has a peculiar pungent odour, and a sour corrosive taste. It is one-fourth heavier than common air. It extinguishes flame, and is destructive of animal life.

Water absorbs 480 times its bulk of this gas, forming liquid muriatic acid. It is generally obtained from common salt, (chloride of sodium,) and hence has been called *spirit of salt.* It is an acid that is much used in the arts, and chemical laboratories. Its salts, (termed *muriates,*) when in a state of dryness, are actually *chlorides,* consisting of chlorine and the metal; but since moisture makes them instantly pass to the state of *muriates,* we shall describe them under that name.

138. Chloric Acid.—This acid, like the muriatic, has for its base chlorine; but its other constituent is not hydrogen, but oxygen. Its solution in water is colourless, has an acrid and astringent taste, and a pungent odour. Its

salts, some of which possess very extraordinary properties, are called *chlorates*.

139. Hydriodic Acid.—This is a gaseous body, which forms a liquid acid, however, by an union with water. It is composed of 124 parts of iodine to 1 of hydrogen. Its density is $4\frac{1}{2}$ to air 1. Its smell is like that of muriatic acid. It is little known. Its salts are termed *hydriodates*.

140. Iodic Acid consists of 15.5 iodine to 5 oxygen. It is a white semi-transparent solid; of a strong acid-astringent taste, without smell, about thrice the density of, and very soluble in, pure water. It destroys vegetable colours. Its salts are called *iodates*.

141. Fluoric Acid.—This acid has bitherto resisted every attempt to decompose it completely, and consequently its real nature is uncertain. It is commonly supposed to consist of a base, called fluorine united to hydrogen; and hence is sometimes called hydrofluoric acid. The gaseous state is that in which it is procured: it is soluable in water. It is intensely sour, corrodes and instantly dissolves glass, and produces very painful wounds when it touches the skin, so that it requires to be examined with great caution.

Its salts are called *fluates*.

142. Prussic Acid.—This is a triple compound; being formed of 1 part of cyanogen, (which is composed of equal parts of carbon and nitrogen,) and 1 part of hydrogen. It is liquid, possessed of a hot, but sweetish taste, and having a very pungent smell, which resembles that of bitter almonds. It is the most violent of all poisons; causing the death of animals, when applied to the skin only. It combines with iron, and forms the well-known pigment—*prussian blue*. Some of its salts (the *prussiates*) are valuable as *re-agents*.

143. Acetic Acid.—The same acid, that, in a very dilute, and somewhat impure state, is called *vinegar*. Its constituent principles are hydrogen, carbon, and oxygen. When pure it is colourless, pungent, acrid, and volatile. It can be concentrated till capable of corroding the skin. Vinegar is generally obtained by fermenting certain vege-

table substances. It may also be obtained by distilling wood. The acetic acid is of great importance, for it is not only extensively used for domestic purposes, but applied to many of the arts. Its salts are called *acetates*.

144. Citric Acid, is the purified juice of limes or lemons. It is obtained in the form of crystals, which have an extremely sharp taste, are fusible by heat, and very soluble in water. Citric acid is of considerable service in domestic economy, and in some of the arts. Some of its saline compounds (termed *citrates*) are also much used.

145. Benzoic Acid, is commonly known by the name of flowers of benjamin, a substance obtained by sublimation from gum benzoin. It appears in white needle-shaped crystals, having a bitter taste, and an aromatic odour. It very readily dissolves in alcohol, but is scarcely at all soluble in water. Its salts are termed *benzoates*.

146. Gallic Acid is obtained from various vegetable substances, particularly from nut-galls. It is a crystallizable acid, soluble in 20 parts of water. It has an astringent acidulous taste, and, when heated, an aromatic, though not pleasant, odour. It is extensively used in dyeing, ink-making, and by the chemist as a re-agent. Its salts are called *gallates*.

147. Oxalic Acid is a deadly poison, which, when in a crystallized state, has much the appearance of Epsom salt,—in place of which compound it has been taken accidentally, and has more than once proved fatal. The best antidote to a dose of it is an emetic, aided by copious draughts of warm water, containing chalk, or common carbonate of magnesia. Oxalic acid has an exceedingly sharp, sour, but not unpleasant taste; it is soluble in water; and is possessed of some bleaching properties. It is obtained by distilling sugar with nitric acid, from the juice of wood-sorrell, and many other vegetables. Its salts are termed *oxalates*.

148. Tartaric Acid.—This is that which, united to potass, forms what is called cream of tartar. It is obtained in crystals, which are soluble in water. It has a very acid and agreeable taste,—so that it may supply the place of lemon-juice. Its salts are called *tartrates*.

149. Alkalies.—These are substances of great impor-

tance. They may be defined, bodies which combine with *acids*, neutralize their powers, and produce *salts*. They are divided into three classes, thus:—

150.—I. Those consisting of a metallic base united to oxygen, which are in number three,—*potass*, *soda*, and *lithia*.

151.—II. That containing no oxygen,—*ammonia*.

152.—III. Those containing oxygen, hydrogen, and carbon;—these are some recently-discovered vegetable alkalies, of which little is known.

153. Besides the already-mentioned properties of alkalies, they possess the following also:

154.—I. They change the purple colour of many vegetables to a green, the red to a purple, the yellow to a brown. They also re-produce the purples which have been reddened by acids.

155.—II. They continue in possession of this property, and retain their solubility in water, when saturated with carbonic acid: these properties distinguish them from the alkaline earths.

156.—III. They have an acrid and urinous taste.

157.—IV. They are powerful corrosives, or solvents of animal matter, with which, as well as with oils in general, they combine, so as to produce neutrality.

158.—V. They are decomposed, or volatilized, by a strong heat.

159.—VI. With water they combine in every proportion; and with alcohol, very largely.

160. Potass, a *fixed alkali*, procured from wood-ashes, and called, on that account, the *vegetable* alkali. It is an oxide of the newly-discovered metal, *potassium*.

Potass, when pure, is solid, white, and extremely caustic. It changes the purple colour of vegetables to a green, and yellow to a brown. When it is exposed to the air, it rapidly attracts humidity from it, and becomes a liquid. In chemistry it is employed very extensively, both in manufactures, and as a re-agent in analysis. It is the basis of all the common soft soaps. The potash of commerce, is this alkali united to carbonic acid, and is, therefore, carbonate of potass. It combines with the other acids also, forming neutral salts.

161. SODA, which, because supposed to be peculiar to the mineral kingdom, was called the *mineral alkali*, is, when pure, of a grey colour, and in its properties bears considerable resemblance to *potass*. Its crystals, however, do not, like those of that substance, liquify, if exposed to the air, but merely fall to powder. The metallic base of this alkali is *sodium*. *Soda* is the basis of common salt, of plate and crown glass, and of all hard soaps.

162. LITHIA, a new fixed alkali, whose metallic base is LITHIUM. It has a very sharp burning taste, is soluble in water, changes vegetable blues to green, and forms neutral salts with the acids. It is scarce.

163. AMMONIA, also called the *volatile alkali*, is composed of nitrogen and hydrogen; and, in its purest form, (the gaseous,) is called ammoniacal gas. Water dissolves 460 times its bulk of this gas, forming with it liquid ammonia. Ammoniacal gas has an exceedingly pungent smell, well known by the name of *spirits of hartshorn*. An animal plunged into it, speedily dies. It extinguishes combustion, has a very acrid taste, and, like *fixed* alkalies, changes the blue colour of vegetables to green. It is a valuable material in manufactures, in medicine, and in chemistry. All the acids are capable of combining with it.

164. The alkalies of the third class,—those containing oxygen, hydrogen, and carbon,—are of so little importance, that in this place no notice need be taken of them.

165. EARTHS.—These are the substances that compose the vast crust of rocks and soils on the surface of the globe, and which, from their very diversified appearance, appear to be innumerable. Analysis, however, has shown, that all these heterogeneous stony masses may be resolved into only *ten* different bodies. The names given to these bodies, are:—

1 *Barytes*, 3 *Lime*, 5 *Alumina*, 7 *Glucina*, 9 *Silica*,
2 *Strontia*, 4 *Magnesia*, 6 *Yttria*, 8 *Zirconia*, 10 *Thorina*.

166. The *earths* are, in *general*, infusible and incombustible, have neither colour nor smell, and are rather less than five times heavier than water. On account of some *particular* properties, they have been divided into two classes:

1. *Alkaline* earths.
2. *Common* earths.

The *alkaline earths* possess *some* properties similar to those possessed by *alkalies*, but, nevertheless, widely differ from those bodies in their *general* properties. The earths of this class, are the first four in the above list.

The *common* earths possess no alkaline properties: they are the latter six in the list.

One of the most important of modern chemical discoveries, is, that the *earths*, instead of being, as was supposed, *simple bodies*, are combinations of *oxygen* with peculiar *metallic bases*.

167. Barytes is an earth of a greyish-white colour, possessed of strong alkaline properties, changing, like them, the vegetable blues to green. Its taste is extremely caustic, and it is a violent poison. It has no smell. When water is poured upon dry *barytes*, it slakes like quicklime, evolving, however, more heat. It is soluble in water, forms an insoluble compound with sulphuric acid, and tinges flame yellow. Under the name of *permanent white*, it is used as a paint. It is employed by the chemist as a re-agent. The metallic base of barytes is *barium*. *Terra ponderosa* is the name formerly given to this oxide, on account of its great specific gravity.

168. Strontia, in its properties, has a considerable affinity to *barytes*. It differs from it chiefly in being infusible, much less soluble, of a different form when crystallized, weaker in its affinities, and not poisonous. Its base is *strontium*. A peculiar characteristic of strontia, is the giving a blood-red colour to flame. Its *salts* are numerous, but not useful.

169. Lime is one of the most abundant substances in nature. It is the chief constituent of vast rocks and mountains, under the names of chalk, marble, limestone, calcareous spar, &c., in the whole of which, it exists in the state of *carbonate*. By exposure to a strong heat, these substances are rendered pure, or form what is commonly called *quicklime*. The recently-discovered metallic base of lime, is named *calcium*.

Lime is a soft white substance, with a caustic, astringent, and alkaline taste. It is fused with great difficulty. It is soluble in water. It renders vegetable blues, green; yellows, brown; and restores to reddened litmus, its usual purple. If a little water only be sprinkled upon dry newly-burnt lime, it is rapidly absorbed, with the evolution of much heat and vapour. It has an immense affinity for carbonic acid, which, when it is exposed to the atmosphere, it rapidly absorbs.

Lime is extensively used in agriculture, and in building; it unites to *chlorine*, forming the very important substance used in bleaching, under the name of *chloride of lime*. It also combines with *sulphur* and *phosphorus*; and with *acids*, forms a very peculiar identifying class of *salts*.

170. Magnesia is a white, soft powder, having a metallic base, called *magnesium*. It renders the infusion of red cabbage, green, and reddens turmeric. By an intense heat, and only by that, it may be fused. It has little taste, and no smell. It is nearly insoluble in water, but absorbs a quantity of that liquid with the production of heat. *Magnesia*, and its combinations, (*Epsom-salt* is its *sulphate*,) are chiefly used in medicine.

171. Alumina is an earth, which, as constituting the plastic principle of all clays and loams, was called *argil*, or the *argillaceous earth*, but now, as being obtained in greater purity from *alum*, is styled *alumina*. It has a metallic base, named *aluminum*.

Pure *alumina* is soft, pulverulent, white; adheres to the tongue, forms with water a smooth paste, produces no change on vegetable colours, is insipid, inodorous, and insoluble in water, but mixes with it in all proportions. It is hardened by fire. It is the basis of some hard gems, and of earthen-ware. It is dissolved by most acids. *Alum* is a *sulphate of alumina* and *potash*.

172. Silica is a compound of a peculiar combustible principle, (the metal *silicium*,) with oxygen. This earth exists nearly pure in flint and rock crystal. It is white, tasteless, infusible, and insoluble in water. It feels gritty. It unites with *alkalies*, and forms *glass*. In the state of gravel, it is, on account of its hardness, much valued for

roads. It is a necessary ingredient in cements, porcelain, and glass. No acids dissolve it, except those containing fluorine.

173. GLUCINA, the oxide of the metal *glucinum*, is exceedingly rare: as yet, it has been obtained only from the emerald, and one or two other precious stones. It is a soft white powder, light, tasteless, and adhering to the tongue. It is infusible, and insoluble in water, but dissolved by the alkalies. Its name is derived from its distinguishing character of forming with acids, salts which are sweet to the taste.

174. ZIRCONIA is, like glucina, procured from gems, consequently it is rare. Its metallic base is *zirconium*. It is a fine white powder, hard to the touch, without taste or smell. Insoluble in water, but uniting with all acids.

175. YTTRIA, whose base is *yttrium*, is white, tasteless, inodorous, infusible, and the heaviest of the earths. Water, and pure alkalies, do not dissolve it, but carbonate of ammonia does. With borax it melts into a glass; and is soluble in most acids, forming with them sweet and coloured salts.

176. THORINA is a lately-discovered earth, resembling *zirconia*. To its supposed metallic base, the name *thorinum* has been applied. Carbonic acid is very readily absorbed by it, and forms with it, (as will almost any other acid,) an astringent-tasted *salt*.

177. OXIDES.—This term denotes, that the bodies to which it is applied, are combinations of various substances with oxygen, in all cases where the oxygen is not in sufficient quantity to make the compound *acid*.

178. Some observations respecting oxidation are to be found at 107, 110, 111. There are many bodies, which are properly oxides, that are not generally known by that name. Atmospheric air, for instance, is an oxide of azote, and water, an oxide of hydrogen. The earths, and alkalies, also, (see 38,) are oxides. Now, under the names here mentioned, and at the paragraphs referred to, the most important oxides have been already described; and there only remain to be noticed in this place, such as cannot properly be placed in any other.

179. Nitric Oxide, or *nitrous gas*, is a compound of oxygen and nitrogen, in equal volumes. It is colourless, but when suffered to mix with air, or oxygen gas, produces reddish fumes, being by its union with oxygen converted into nitrous acid gas. Nitric oxide is fatal to animal life, and extinguishes flame. There are, however, a few bodies that can be burnt in it. Water absorbs about 1.20ths of its bulk of this gas.

180. Nitrous Oxide, a *gas* composed of two parts of nitrogen, and one of oxygen. It supports combustion, but (though it may be respired) is not capable of supporting life. It has a sweet taste, and a faint, but agreeable odour. Water (which has been boiled) absorbs about one-half its bulk of it; but acquires thereby no other property than that of sweetness, and gives out the whole of it again, when boiled or frozen. The most extraordinary property of this gas, is its action on the human body, when respired. The sensations that are produced vary greatly in persons of different constitutions; but, in general, they are highly pleasureable, and resemble those attendant on the pleasant period of intoxication. It has been called *intoxicating gas*. This characteristic of nitrous oxide was discovered by Sir Humphrey Davy.

181. Carbonic Oxide, a gaseous body, composed of half as much oxygen, united to a certain proportion of carbon, as is necessary to form carbonic acid. It is void of taste and smell, and is fatal to animal life. But it is inflammable; its combustion is attended with a blue flame.

182. Chlorous Oxide, and Chloric Oxide, are gaseous compounds of oxygen and chlorine. The preparation of them, and examination of their properties, is attended with much danger, for they are of an exceedingly explosive nature: consequently, they are little known, and they are not at all used.

183. Chlorides.—The most important of the bodies to which this name properly belongs, are described under the name of *muriates*. One of the *chlorides*, (that of *lime*,) commonly called *bleaching-powder*, is much used in bleaching processes.

184. IODIDES.—Bodies of this class are numerous, but very unimportant, being entirely useless.

185. HYDROGEN combines with a great number of bodies:—

With Oxygen,	it forms	Water (118).
... Chlorine,	...	Muriatic Acid (137).
... Iodine,	...	Hydriodic Acid (139).
... Nitrogen,	...	Ammonia (163).
... Carbon,	...	Carburetted Hydrogen (186).
... Prussine,	...	Prussic Acid (142).
... Phosphorus,	...	Phosphuretted Hydrogen (187).
... Sulphur,	...	Sulphuretted Hydrogen (188).
... Arsenic,	...	Arsenuretted Hydrogen (189).
... Tellurium,	...	Telluretted Hydrogen (190).
... Potassium,	...	Potassuretted Hydrogen (191).

Some of these compounds have been described already, and others we proceed to describe now.

186. CARBURETTED HYDROGEN is a *gas* composed of equal parts of carbon and hydrogen; sometimes, however, the gas is obtained with a less proportion of carbon, in which case it is called sub-carburetted hydrogen. Carburetted hydrogen gas is heavy, invisible, and, when pure, void of taste and smell: it generally, however, has a sulphurous smell, owing to its holding a portion of sulphur in solution. The effects of heat upon this gas are curious: when made very hot, it deposits nearly the whole of its carbon, and enlarges its bulk, till it assumes a volume $3\frac{1}{2}$ times greater than it had at first. By the combustion of carburetted hydrogen, we obtain a splendid white flame, which is now much employed in domestic economy, in preference to the light of candles. The much-dreaded *fire-damp* of the coal mines, is identical with the gas under consideration.

187. PHOSPHURETTED HYDROGEN, is a gaseous compound of phosphorus and hydrogen. Its characteristic property is extreme combustibility: it inflames by merely coming into contact with the atmosphere. A very brilliant white light attends its inflammation in oxygen.

When brought into contact with chlorine, it detonates with a brilliant green light. It has a very disagreeable smell, resembling that of putrid fish. It combines in a very slight degree with water. Those flashes of light, called by the vulgar *will-of-the-wisp*, and by some *ignes-fatui*, which are often seen in church-yards, and other places where vapours are exhaled from putrifying animal matter, are produced by the formation and inflammation of this gas.

188. Sulphuretted Hydrogen is a *gas*, whose component principles are hydrogen and sulphur. It is twice the weight of common air, and is slightly absorbed by water. It burns (when lighted) with a pale blue flame, depositing sulphur. It does not support combustion. Its smell is extremely fetid, resembling that of rotten eggs. Its taste is sour. It reddens vegetable blue. Hence, by some, it has been reckoned an acid, but is not fully (though nearly) entitled to that appellation. Of all the gases, sulphuretted hydrogen is perhaps the most deleterious to animal life. A dog of middle size is destroyed in air, containing only 1.800ths of its bulk of it. Indeed, it has been proved, that to kill an animal, it is sufficient to make the sulphuretted hydrogen act on the surface of its body, when it is absorbed by the inhalents. Yet, to the presence of this gas, is chiefly owing the beneficial medicinal properties of Harrowgate, Aix-la-Chapelle, and some other mineral waters. Sulphuretted hydrogen is employed by the chemist as a re-agent. It unites with several bodies, forming hydro-sulphurets.

189. Arsenuretted Hydrogen is a gaseous compound of arsenic and hydrogen. It is inflammable, extinguishes flame, and destroys animal life instantaneously.

190. Telluretted Hydrogen, a *gas* composed of tellurium and hydrogen, is soluble in water, and gives a claret-coloured solution. It combines with the alkalies. It burns with a blue flame. It smells like rotten eggs.

191. Potassuretted Hydrogen.—When hydrogen and potassium are poured through a tube heated to whiteness, the gas dissolves the metal, and potassuretted hydrogen gas is formed, and inflames spontaneously.

192. Carburet of Sulphur—Sulphuret of Carbon—

Alcohol of Sulphur.—(It is differently named) an interesting compound of carbon and sulphur,—prepared with difficulty,—possessed of the following properties: it is an oily liquid, eminently transparent, and perfectly colourless. It has a pungent aromatic taste, and a nauseous fetid smell. It boils briskly at about half the heat of boiling water, and at 600° inflames, burning with a blue flame. Mixed with oxygen, and having the elective spark passed through it, it detonates.

193. Carburet of Iron—Steel.—This is a compound of iron and carhon. It may be made, by keeping iron mixed with charcoal in a crucible, for a number of hours, in a strong heat. It is hardened by being thrown, when red-hot, into cold water. Steel contains scarcely 1.200ths of its weight of carbon, and yet its properties differ very greatly from those of pure iron. The uses of this compound are well-known.

Plumbago is another carburet of iron. This substance is generally called *black-lead*, which, as it contains not an atom of lead, is exceedingly absurd. The only thing in which plumbago and lead agree, and from which the name must have originated, is the making a black mark on paper. Plumbago is composed of 90 carbon + 10 iron. Large quantities of it, in a very pure state, are found at Keswick, in Cumberland.

194. *Carbon* and *Nitrogen* unite, and form a substance, termed *prussine* (by others *cyanogen*). It is a gas. It has a peculiar penetrating smell, burns with a blue flame, and reddens vegetable blues. It forms, with hydrogen, prussic acid (142).

195. Sulphurets.—Bodies of this class are very numerous, and some of them very important. All the metals appear capable of forming sulphurets. Copper pyrites, and iron pyrites, are two native compounds of metals with sulphur. Copperas (sulphate of iron) is obtained for commercial purposes, by exposing the sulphuret of iron to air: the sulphur absorbs oxygen, and becomes changed into sulphuric acid, which dissolves the metal, and produces a sulphate. Alkalies and earths, likewise, form sulphurets.

196. Phosphurets.—Compounds of phosphorus with

metallic, and other bases. Phosphuret of sulphur is employed to form matches for the instantaneous production of light. Phosphuret of lime is remarkable for having the property of decomposing water, at the common temperature of the atmosphere: when a piece of it is thrown into water, the hydrogen that is liberated, unites with a portion of phosphorus, and forms phosphuretted hydrogen gas, which takes fire spontaneously.

197. Salts.—These are compounds of acids, in definite proportions, with alkalies, earths, and metallic oxides. They form a very numerous, and very important class of chemical bodies; and the study of their composition and properties, must occupy a large share of the learner's attention. Nothing can give such clear ideas concerning the nature of chemical changes, so well explain the laws of affinity, and exhibit to advantage the doctrine of definite proportions, as the synthesis and analysis of salts. There is another thing also which may be mentioned here, as it serves to show with what facility some parts of chemical knowledge may be acquired. The student, upon being told, that the number of salts amounts to several thousands, might be terrified into the opinion, that it would be scarcely possible to remember even the *names* of so many bodies. But when he is shown how philosophically these bodies have been arranged, and how excellently named, he will perceive, that the learning and remembering—not only their names, but their constituent principles also, is a task of but little difficulty. To illustrate this,

198. Let the student be told, that every salt has a double name: one part of it intimating the acid of the compound, and the other, the particular base. Let him also be told, that the terminations of the names of the salts invariably agree with the terminations of the names of their components; and then the nomenclature of salts will be perfectly intelligible. Thus, if an acid, whose name ends in IC, as sulphur*ic* acid, combines with a base, as soda, and forms a salt, the part of the name of that salt which intimates its acid constituent, will end in ATE; the compound being a *sulph*ATE. But, on the contrary, if the salt be formed by an acid ending in OUS, as sulphur*ous* acid, then the name

of the salt ends in ITE, as *sulphite of soda.*—A few more examples may render this familiar:—

Acids.	*Bases.*	*Salts Produced.*
Sulphuric.	Lime.	Sulphate of Lime.
Sulphurous.	Lime.	Sulphite of Lime.
Nitric.	Potass.	Nitrate of Potass.
Nitrous.	Potass.	Nitrite of Potass.

The salts which end in *ite*, like the acids they are formed from, are generally of very little value.

199. When the proportions of the constituents of a salt are so adjusted, that the resulting substance does not affect vegetable colours, it is called a *neutral* salt. When an alteration of colour evinces a predominance of acid, the salt is said to be acidulous, and the prefix *super*, or *bi*, is used to denote the excess of acid. If, on the contrary, the acid matter appears to be in defect, or short of the quantity necessary for neutralizing the properties of the base, the salt is then said to be with excess of base, and the prefix *sub*, is attached to its name.

200. It is to be remembered, that all salts are combinations of metals with acids, and that the bond of union between the two bodies is oxygen. If a piece of pure metal is put into an acid, it remains unacted upon, until, by some means, it acquires oxygen, and is converted into a metallic oxide: *then* its dissolution immediately commences. But whence does pure metal, when put into an acid, obtain the oxygen necessary for its conversion into an oxide?—To this question must be given the following answer. A metal, previous to its dissolution in an acid, decomposes either part of the acid itself, or else the water with which the acid is diluted. It then attracts to itself the oxygen of the decomposed liquid, and sets the other constituent of it at liberty. It will be worth while to consider the chief phenomena of metallic dissolution more closely, in order to show, that this is a right explanation of what takes place.

201. The first and most striking of these phenomena, is

the effervescence which takes place: what is this occasioned by?—The effervescence itself is a disengagement of gas, but what is this gas disengaged from? Let us consider. We may suppose that the dissolution is taking place in nitric acid. Now, we know, that the constituent principles of nitric acid (oxygen and nitrogen) can only exist, when separated from each other, or when united in other proportions, in the state of gas; we also know, that nitric acid imparts its oxygen to other bodies with great readiness. Hence it is easy to infer what takes place when this acid has a metal put into it: a portion of the acid is decomposed; part of the oxygen of this decomposed portion of acid combines with the metal, another part combines with the other element of the acid, (nitrogen,) and constitutes a body *not* soluble in water. This newly-formed body is *nitrous gas*, and this it is, which, by its sudden conversion from the liquid to the gaseous state, produce, by its disengagement, the noise and frothing which is termed effervescence.

202. The same decomposition, and consequent formation of gas, takes place when solutions of metals are made in other acids, whether they be diluted or concentrated. In solutions with sulphuric acid, the disengaged aëriform body is either sulphurous acid gas, or hydrogen gas, according as the oxidation of the metal happens to be made at the expense of the sulphuric acid, or of the water.

203. The second observable phenomenon is, that when the metal has been previously oxidised, its dissolution takes place *without effervescence*—and why?—because, not needing oxygen, the metal does not decompose the acid, or water, to obtain it, and no gas, therefore, is set at liberty. The earths, and alkalies, dissolve without effervescence, for this reason.

204. Another phenomenon worthy of notice, is, that all metals which have a weaker affinity for oxygen, than the bases of certain acids, are absolutely insoluble in those acids. Hence iron, and some other metals, are, in their metallic state, insoluble in sulphuric acid; but, if those metals are put into the acid in an oxidised state, they become readily dissolved, without effervesence; or, if the

acid be diluted with water, to oxidise the metals by its decomposition, they are then dissolved *with* effervescence.

205. The solubility of salts in water, is their most important general habitude. In this menstruum they are usually crystallized; and, by its agency, they are purified and separated from each other, in the inverse order of their solubility. It is not very difficult to determine the quantity of a salt, which water can dissolve. Water, at a determinate temperature, must be saturated exactly with the salt whose solubility we wish to know; a certain quantity of this solution must be weighed out and evaporated, and the saline residue, upon being weighed, gives the amount. If, for example, 3 parts of the saturated solution, upon being evaporated, leave 1 part of salt; then, that salt is said to be soluble in 2 parts of water, at the given temperature.

206. To obtain a perfectly saturated saline solution, we heat the water with the salt, and then allow it to cool to the temperature required. In very particular cases, it is necessary to keep the final temperature constant for at least two hours, and to stir the solution frequently, to be sure of its saturation.

207. The following pages contain descriptions of some of the most important salts. They will be found very interesting, and will repay the student for the closest attention.

208. Nitrate of Potass—Saltpetre.—This well-known salt is a compound of nitric acid and potass. It is found native in many parts of the world, and is brought to this country, as an article of commerce, chiefly from the East Indies. A method of forming it artificially, will be detailed in a succeeding division of this work. Nitrate of potass possesses the following properties:—1. It crystallizes, and its crystals contain very little water of crystallization. 2. Its component parts are 47 base, and 53 acid. 3. Its solution requires 4 times its weight of cold, but only an equal weight of boiling, water. 4. By the application of a moderate heat, it fuses, and, being cast into moulds, forms a medicinal preparation, called sal prunelle. 5. If a red heat be applied, it is decomposed, in consequence of the destruction of its acid. By distilling in an earthen

retort, or in a gun barrel, oxygen gas may be obtained in great abundance, one pound of nitrate of potass yielding about 12,000 cubic inches, sufficiently pure for common experiments. 6. This salt powerfully promotes the combustion of inflammable substances: it is the principal ingredient in the composition of gunpowder. 7. Besides the uses already mentioned, nitre enters into the composition of fluxes, and is extensively employed in metallurgy; it serves to promote the combustion of sulphur in fabricating its acid; it is used in the art of dyeing; it is added to common salt for preserving meat, to which it gives a red hue; it is an ingredient in some frigorific mixtures; and is frequently prescribed in medicine. It is also from this body, that the nitric acid of commerce is generally obtained.

209. Chlorate of Potass, a salt of a very singular nature, composed of chloric acid and potass, or, according to some, of chlorine 1 part, potassium 1 part, and oxygen 6 parts. Its properties are the following:—It crystallizes in shining scales. One part requires for solution 17 of cold water, or $2\frac{1}{2}$ of hot. Its taste is cooling and unpleasant. When one hundred grains of this salt are exposed to a gentle red heat, they yield 115 cubic inches of very pure oxygen gas. It is incapable of discharging vegetable colours; but the addition of a little sulphuric acid, by setting chlorine at liberty, developes this property. It is decomposed by all the strong acids. It exerts very powerful effects on inflammable bodies. The mode of preparing and performing experiments with this body, will be found described among the other experiments. *It must not be forgotten for a moment, that, on account of its explosive nature, the employment of this salt must be conducted with the greatest caution.*

210. Carbonate of Potass.—This salt has been long known. There are two varieties of it. The first is when the alkali is fully saturated with carbonic acid; the second is the potass of commerce, which is in the state of a sub-carbonate—the alkali being in excess. The mode of transforming the sub-carbonate into the carbonate, will be found described hereafter. The sub-carbonate is

composed of 1 part of carbonic acid to 2 of potass: the carbonate, of equal portions of the two bodies. The sub-carbonate has a taste far less penetrating and corrosive than pure alkali; but it still turns to green, the blue infusion of vegetables. Upon the addition of an acid, carbonic acid is given out with effervescence. It dissolves very readily in water, which, at the ordinary temperature, takes up more than its own bulk. When exposed to the atmosphere, it attracts so much moisture, as to pass rapidly to a liquid state. This change is termed deliquescence. The carbonate of potass differs from the sub-carbonate, in the following particulars:—In the greater mildness of its taste. Though still alkaline, it is but slightly so. It is unchanged by exposure to the air. It assumes the shape of regular crystals. It requires, for solution, four times its weight of water at 60°; but boiling water dissolves nearly an equal weight; the heat, however, in this case, drives off a portion of carbonic acid gas.

211. Prussiate of Potass.—This salt is composed of prussic acid and potass. It is one of the most valuable re-agents, which the chemist possesses, in metallic analysis. The crystals of this salt are transparent, and of a beautiful lemon, or topaz yellow colour. It has a saline, cooling, but not unpleasant taste. In large crystals, it possesses a kind of toughness, and, in thin scales, of elasticity. When moderately heated, the crystals lose 13 per cent. of water, and become of a white colour. Water, when cold, dissolves one-third of its weight, and an equal weight at the boiling point. It is not soluble in alcohol. It is not altered by air. Its solution is not affected by alkalies; but it is decomposed by almost all the salts of the permanent metals,—the alkali combines with the acid of the metallic salt, and the prussic acid with the precipitated metallic oxide, to which, according to the nature of the metal, it communicates a peculiar colour. Hence the use of prussiate of potass as a test. The following table presents a view of the colours of some of the metallic precipitates thus obtained:—

Solutions of	*Give a*
Manganese,	White precipitate.
Protoxide of iron,	Copious white.
Deutoxide of iron,	Copious clear blue.
Tritoxide of iron,	Copious dark blue.
Tin,	White.
Zinc,	White.
Cobalt,	Grass green.
Bismuth,	White.
Protoxide of copper,	White.
Deutoxide of copper,	Crimson brown.
Lead,	White.
Silver,	White, passing to blue, [in the air.
Gold,	None.

212. Oxalate of Potass, sometimes called *essential salt of lemons*, exists in two states: one, the super-oxalate, is obtained from the leaves of wood-sorrell; the other, the oxalate, may be obtained by adding more potass to the super-oxalate. Both may be formed by the direct union of potass with oxalic acid, certain cautions being observed. Oxalate of potass is a crystallizable salt; but it does not readily crystallize, unless one of the ingredients be in excess. The crystals are nearly insoluble in cold water, but will dissolve in 10 parts of boiling water. The taste of this salt is sharp, acrid, and bitter. It is used for removing stains from linen, and for various purposes of the arts.

213. Tartrate of Potass.—There are two varieties of this salt, the tartrate, commonly called *soluble tartar;* and the super-tartrate, well known by the name of *cream of tartar*. 1. The super-tartrate of potass contains tartaric acid in excess. It is found encrusted on the bottoms and sides of casks in which wine has been kept. The crust is purified, and the salt is procured from it in crystals. This dissolves in 60 parts of cold water, or 14 of boiling. It is much used in chemical and medicinal preparations. 2. The tartrate of potass is formed by adding the super-tartrate, in powder, to carbonate of potass, until effervescence ceases. The solution must be boiled sometime, filtered, and evaporated, until a pellicle appears on

the surface; when, by slow cooling, it deposits crystals. This salt has a bitter taste. It is used in medicine as a mild purgative. It is dissolved by its own weight of cold water, and by a still smaller quantity of hot water. It is decomposed by heat.

214. Muriate of Soda—Culinary Salt.—This abounds in the waters of the ocean, and chiefly occasions their peculiar taste. It is likewise found, in great abundance, in various parts of the globe, in a dry state. At Northwich, in England, is a salt mine, which yields 4,000 tons of rock-salt a-year; and in Spain, there is a remarkable solid mountain of salt, 500 feet high, and a league in circuit; its depth below the surface of the earth is unknown. This mountain is composed of salt, in a state of perfect purity. In short, salt is one of the most abundant bodies in nature. And it is a very useful body. The shape of its crystals is a regular cube. Its taste is well known. It dissolves in $2\frac{1}{2}$ parts of water, whether it be cold or boiling. It is not affected by exposure to the atmosphere. When heated, it breaks with a crackling noise, which phenomenon is termed *decrepitation*. By a greater heat it may be fused, and by a still greater volatilized; but heat cannot decompose it, for, after volatilization, it remains muriate of soda. The muriatic acid of the shops is obtained from this salt.

215. Sulphate of Soda—Glauber's Salt.—A compound of sulphuric acid and soda. It is found native in various saline springs, and sometimes efflorescent on the walls of old houses. It may be formed artificially by the combination of its constituent parts. The taste of this salt is cooling and bitter. Its crystals, when in contact with the atmosphere, lose their water of crystallization, and become pulverulent. It is soluble in three parts of cold water, and less than its own weight of boiling water; a saturated hot solution, when cooled, readily shoots into beautiful crystals. The crystals, on exposure to the fire, liquify in a short time; but, when their water of crystallization is expelled, an intense heat is required to fuse them. Sulphate of soda is decomposed by barytes, strontia, and potass; the first two take its acid from it entirely, the last

only partially. The salt in crystals is composed of 5 acid + 4 base + 11 water: in a dry state, the last is not a constituent. It is generally used in medicine, as a purgative.

216. Borate of Soda—Borax.—Neutral borate of soda is an artificial production, not much known; but the sub-borate of soda, or common borax, is a body that is well known, and very useful. It is brought from the East Indies in an impure state, and called *tincal*. It is purified by being boiled very strongly, and for a long time. It is white, transparent, has a greasy feel, and a styptic alkaline taste; it converts vegetable blues to green; it is soluble in 6 parts of boiling water, and 18 of cold water; it slowly and slightly effloresces in the air. When exposed to heat, it swells, boils, loses its water of crystallization, and becomes converted into a porous, white, opaque mass, termed calcined borax. With a stronger heat it melts into a transparent glass, but remains soluble in water. The component parts of sub-borate of soda, are boracic acid 36, soda 17, water 47. It is much used as a flux for metals, and is therefore of great importance in analysis by the blow-pipe. It is employed in soldering also: it assists the fusion of the solder, and facilitates the operation very considerably, by keeping the surface of the metals soft and clear.

217. Phosphate of Soda.—*Microcosmic Salt.*—The taste of this salt is very similar to that of common salt. Its crystals are soluble in 2 parts of boiling water, or four of cold water: they effloresce in the air, and, when heated, undergo the watery fusion. At a red heat they melt into a white enamel, and before the blow-pipe into a transparent globule, which, on cooling, becomes opaque. It is much used by mineralogists in the fusion of minerals.

218. Carbonate of Soda.—This compound of carbonic acid and soda, is known in commerce by the names of *kelp*, *barilla*, and *soda*, and is obtained either from the de-composition of common salt, or from the combustion of marine plants. This salt, like the carbonate of potass, exists in two states—1. The *carbonate*, properly so called, in which the soda is fully saturated with carbonic acid.

2. The *sub-carbonate*, in which the soda is in excess. The latter sort is the one generally found in commerce, and known by the above-mentioned names.

219. Carbonate of soda is found native, and may be formed artificially. It is not a crystallizable salt, but is obtained in the form of a white solid mass, which is so little liable to change by exposure to air, that it has been used in the construction of walls of edifices, instead of stone.

220. Sub-carbonate of soda, crystallizes. Its taste is urinous, and slightly acrid, without being caustic. It changes blue vegetable colours to a green. It is soluble in twice its weight of cold water, and less than its weight of boiling: hence a saturated hot solution crystallizes on cooling; the crystals, are, however, more beautiful, when the evaporation is carried on slowly. It is one of the most efflorescent salts known, falling completely to powder, in a very little time after its exposure to the atmosphere. On the application of heat, it is soon rendered fluid, on account of the great quantity of its water of crystallization; but it is dried by the continuance of the heat, and then melted. The heat drives off a part of the carbonic acid, but the remainder adheres to the base with great obstinacy. As it is more fusible than the carbonate of potass, it is preferred to that salt in the manufacture of glass; because it promotes the fusion of the earth in a greater degree, and produces a glass of better quality. It consists, in its dry state, of 4 soda, $2\frac{3}{4}$ carbonic acid. But the crystals are composed of 4 soda, $2\frac{3}{4}$ carbonic acid, 10 water.

221. Nitrate of Ammonia—*Inflammable Nitre.*—This is a combination of nitric acid and the volatile alkali. It is obtained in crystals, (though its components cannot be crystallized,) which differ in their appearance, according to the degree of heat employed to evaporate the water of solution. The taste is extremely cold and acrid. It dissolves in 2 parts of cold water, and in half its weight of boiling water. It deliquesces. The most remarkable property of this salt, is, that, when thrown on a red hot iron, it explodes, with a loud noise, accompanied by a

white flame. By this it is decomposed: the oxygen of the acid forms water, by combining with the hydrogen of the alkali; and the nitrogen of both bodies is dissipated in the shape of gas. The chief use of nitrate of ammonia, is for affording nitrous oxide gas, by a certain mode of decomposition. When dry, it consists of 6.75 acid, 2.13 ammonia, 1.125 water.

222. Muriate of Ammonia—*Sal Ammoniac.*—This salt was brought to this country for a long time from Egypt; but it is now economically prepared at home. This salt is purified by sublimation: hence, heat does not decompose it. When sublimed, it is in cakes, which are remarkable for possessing a certain degree of ductility, so as not to be easily pulverable. But it may be obtained from its solution, (which requires $3\frac{1}{2}$ parts of cold, or little more than 1 of boiling, water,) in regular quadrangular crystals. The compact salt is not affected by air, but the crystals deliquesce. It has a pungent, acrid, cooling taste, and the white smoke in which it sublimes has a very peculiar smell. Great cold is produced, both by its solution in water, and its mixture with pounded ice: hence, here, it is useful for frigorific mixtures, and in warm countries, for cooling wines. It is composed of 48 acid, 16 base, 37 water. Few salts are of more extensive use than this. In chemistry, medicine, metallurgy, dyeing, and many other arts, it is much employed; and it is indispensable in operations whereby the surfaces of some metals are coated with others—for example, in the tinning of copper.

223. Carbonate of Ammonia, vulgarly called *smelling salts*, when very pure, is in small crystals. The taste and smell of this salt are the same with those of pure ammonia, but much weaker. It turns the colour of violets green, and that of turmeric brown. It is soluble in rather more than twice its weight of cold water; and in its own weight of hot water; but a boiling heat volatilizes it. It is not decomposed, however, by heat, though so readily sublimed. It is soluble in the atmosphere: if left in a state of exposure, it diffuses its smell, and diminishes in weight. It is prepared in different ways, and as these vary, so docs its component parts.

The salt of the shops consists of 55 acid, 30 base, 15 water. The solid precipitate produced by the union of its constituents in the state of gas, is composed by $56\frac{1}{3}$ acid + $43\frac{2}{3}$ alkali.

224. Sulphate of Barytes.—This salt may easily be, though it seldom is, formed by art; because it abounds in nature, especially in veins of metals. It is generally obtained in crystals, differently shaped. It is the heaviest of all salts, and is insoluble in water. It is tasteless, and inodorous, but poisonous. When formed into a thin cake with flour and water, and heated to redness, it shines afterwards in the dark. This property was discovered in Bologna, and hence the salt has been termed *Bolognian phosphorus*. It is composed of 5 parts acid to 9 base.

225. Carbonate of Barytes.—This is found native, but not so abundantly as the sulphate of barytes. It crystallizes, is very heavy, tasteless, inodorous, extremely poisonous, and nearly insoluble in water. It is not altered by air, but is decomposed by heat. Its constituents are $2\frac{3}{4}$ acid + $9\frac{3}{4}$ base.

226. Nitrate of Barytes.—This is obtained, by processes which will be hereafter described, either from the native carbonate, or sulphate of the earth. Its taste is hot, and acrid. It is soluble in 12 parts cold, and in 4 parts boiling water. It crystallizes, sometimes in stars, sometimes in small brilliant plates. When heated, it decrepitates: if the heat is continued, the acid is expelled, and the barytes remains pure. This salt is composed of 6.75 acid + 9.75 base. It is chiefly used as a *test* for sulphuric acid, for which purpose it is exceedingly well suited, as will by and by be shown.

227. Muriate of Barytes.—The observation prefixed to nitrate of barytes, respecting the mode of obtaining that salt, applies to this also. Muriate of barytes crystallizes. It is soluble in 5 parts of cold water, in still less of hot water, and also in alcohol. It is not altered by air, and only partially decomposed by heat. It has a nauseous burning taste, and is poisonous; but is sometimes given medicinally in small doses. It consists of 6 acid + 19 base, in a dry state: and 5 acid, 16 base, 4 water, when

crystallized. The muriate, like the nitrate of barytes, is of great use as a *test* for sulphuric acid.

228. Sulphate of Strontia bears, in many of its properties, considerable resemblance to sulphate of barytes. It occurs native, in great abundance, in various parts of the world, usually in a crystallized form. It is only soluble in 3840 parts of boiling water. Its composition is 5 acid + $6\frac{1}{2}$ base.

229. Carbonate of Strontia is formed native, but, as well as the preceding salt, may be formed artificially. The native substance appears in semi-transparent crystals, of a white colour, tinged with green. It is insipid; requires 1536 parts of boiling water to dissolve it; is not altered by exposure to the air; but is decomposed by heat. If thrown in powder on well kindled coals, it exhibits red sparks. It is much lighter than carbonate of barytes, (with which body it was long thought identical,) and is not poisonous. It consists of 2.75 acid + 6.5 strontia.

230. Nitrate of Strontia may be obtained in the same manner as that of barytes, with which it agrees in the shape of its crystals, and most of its properties. It is much more soluble, however; requiring but an equal weight of water at 60°, and half its weight of boiling water. In dry air, it effloresces; in moist air, deliquesces. By heat it is decomposed. Applied to the wick of a candle, or added to burning alcohol, it gives a deep red, or purple colour to the flame. This is the characteristic property of strontia. It consists of 6.75 acid + 6.5 strontia.

231. Muriate of Strontia, formed artificially; taste cold and sharp; soluble in less than its own weight of cold water, and in any quantity of boiling water: soluble also in 24 parts of cold alcohol, or 19 of boiling, It deliquesces in moist air. Its constituents are 24 acid + 36 base + 40 water.

232. Carbonate of Lime forms a considerable part of the solid strata of the globe. It is sometimes obtained pure; but generally mixed with other earths, with metals, coal, &c. It is occasionally obtained in transparent crystals. In these various states it is known by the names of chalk, marble, limestone, staclactites, &c. With the ex-

ception of muriate of soda, it is of more importance than any other of the salts. Carbonate of lime has no taste, is insoluble in water, but slightly soluble (like the other carbonates) in water impregnated with carbonic acid. But, by exposure to the air, the extra dose of carbonic acid flies off, and the salt reverts to its state of insolubility. No alteration is effected in it, on exposure to the air. When heated, it decrepitates, its water flies off, and lastly its acid; but this requires a pretty strong heat. By this process it is burned into lime. It is composed of 3.56 lime + 2.75 carbonic acid. The specific gravity of this body varies, as does its state of aggregation: chalk and marble are essentially the same in constitution, but very different in their relative weights. Perhaps it may be stated at 2.7.

233. Sulphate of Lime.—This is known also by the names of alabaster, gypsum, plaster of Paris, and various others. It is found native in great abundance; sometimes in a crystallized state, sometimes otherwise. It requires for its solution 500 parts of cold water, and 400 of hot. At a red heat it loses its water of crystallization, and falls into a white powder. When this powder is mixed with water, heat is disengaged, and the product is a solid mass. In this case, the water loses its heat of liquidity, by entering into a state of solidity with the calcined salt. A hasty crystallization takes place, with an enlargement of bulk. Owing to this property, calcined sulphate of lime has been much employed in making casts from anatomical and ornamental figures. It also forms one of the bases of stucco, is used as a cement, and for making various mouldings and other ornaments in building. By the heat of a blow-pipe, it is converted into a white glass. Its constituents (when deprived of its water of crystallization) are 56.3 lime + 46.3 sulphuric acid.

234. Fluate of Lime.—This body is very abundant in the native state, and is called fluor spar, Derbyshire spar, phosphoric spar, &c. The substance found in Derbyshire is a very beautiful variety, and is much employed in the formation of various ornaments for cabinets, and of cups, candlesticks, &c. It is insoluble in water, and unalterable by air. When heated, it decrepitates, loses its

water of crystallization, and afterwards shines in the dark. At a strong heat, it melts into a glass. Several acids, when assisted by heat, decompose it, and expel the fluoric acid in white fumes. The constituents of fluate of lime are acid 16 + base 57 + water of crystallization 27.

235. Nitrate of Lime.—This salt is formed in the operations attending the crystallization of nitrate of potass. Its crystals resemble bundles of needles, diverging from a centre. Its taste is hot and bitter. It deliquesces in the air, and is so extremely soluble, that it can only be kept in the dry state with great difficulty. It is soluble in an equal weight of alcohol. It is decomposed by heat, and thus is obtained a substance called *Baldwin's phosphorus*, which has the property of shining in the dark. Nitrate of lime is of very little use. Its constituents are 45 acid + 22 lime + 35 water of crystallization.

236. Muriate of Lime.—This salt exists in nature, but neither very abundantly, nor very pure. It is easily formed artificially, but very difficultly crystallized: it being one of the most deliquescent salts known. It has on this account acquired the name of *oil of lime*, which is applied to it when deliquesced. Its taste is acrid, bitter, and very disagreeable. It is soluble by heat in its own water of crystallization, and in half its weight of cold water. It dissolves in alcohol; during the solution, so much heat is generated, that the alcohol boils. It acquires by heat a phosphorescent property, and, when possessed of that property, is called Homberg's phosphorus, from the name of the discoverer. Muriate of lime is chiefly used in frigorific mixtures; and with snow it produces a very great degree of cold. Its constituents are 31 acid, 44 lime, 25 water.

237. Phosphate of Lime.—This is the basis of the bones of animals, and the principle which gives to them their hardness and strength: hence it is a body of great importance. It is not only found in bones, however, but in considerable abundance in a native mineral state, and it may be formed artificially. It is sometimes obtained crystallized, but is generally in the form of a white powder, which is insoluble in water. By a violent heat, it may be fused into an enamel. It is used for making cupels, for

polishing gems and metals, to absorb grease from linen, paper, and silk, and as a medicine. It is identical with the burnt hartshorn of the shops. Its constituents are 30.5 acid, 69.5 base.

238. Oxalate of Lime is a white powder, which is insoluble in water, not decomposable, except by fire, and turning vegetable blues green. It is composed of 48 acid + 46 lime + 6 water.

239. Sulphate of Magnesia—*Epsom-Salt.*—This salt obtained the latter name, from having been obtained for a long time by evaporating the water of the saline springs at Epsom, in England. It is now generally obtained from sea-water, in which it exists in large quantities, mixed with muriate of soda. It may be formed artificially. When pure, it crystallizes. Its taste is cool and bitter. It is very soluble, requiring only an equal weight of cold water, and three-fourths its weight of hot. It effloresces in the air, though but slowly. When heated, it dissolves in its water of crystallization, but is not decomposed. It is chiefly used as a purgative in medicine, and to furnish magnesia by its decomposition. It is composed of 5 acid + 2.5 magnesia + 7.9 water of crystallization.

240. Muriate of Magnesia.—This salt forms about 27 per cent. of the saline matters dissolved in sea-water. It is also found in rock-salt, and is the most pernicious body with which common salt is contaminated. It is very deliquescent, and difficultly crystallizable. Its taste is intensely bitter. Heat decomposes it. The proportions of the constituents of this salt are, 34 acid + 41 magnesia + 25 water.

241. Carbonate of Magnesia, like the carbonate of lime, exists in two states: one in which the constituents are neutral, the carbonate; another, in which the acid is in defect, the sub-carbonate. This latter kind is the same as the *magnesia* of the shops; what is really simple magnesia, is commonly termed *calcined* magnesia. The methods of preparing both kinds of the salt will be described hereafter. The carbonate crystallizes, and its crystals are soluble in 48 times their weight of cold water;

the sub-carbonate is a white powder, and requires for its solution ten times that quantity of water. The crystals slightly effloresce, and, upon exposure to the fire, decrepitate, lose their water and acid, fall to powder, and are reduced to one-fourth of their original weight. The powder, upon being heated, boils, its acid flies off, it loses half its weight, and the magnesia remains quite pure.

242. Sulphate of Alumina and Potass—Alum.—This salt is sometimes found in a native state, but is generally formed from various minerals, called alum ores. It crystallizes, has a sweetish, but very astringent taste, and reddens vegetable blues, showing the acid to be in excess. It is soluble in from 15 to 20 parts of cold water, and in three-fourths its weight of hot. Its crystals effloresce, and, when heated, melt in their water of crystallization: at a strong heat, they lose 44 per cent. (chiefly water) of their weight, and are reduced to a white porous mass, called *burnt* alum. This salt is a very important one: it is extensively used in medicine, bleaching, dyeing, calico-printing, tanning, paper-making, and various other arts. Bodies which have been steeped in a solution of alum, are not apt to take fire. Its composition is stated thus: acid 10, alumina 3, potass 3, water of crystallization 16.

243. Metallic Salts.—This term is applied to the bodies which are formed by the combination of acids with those metals, that are better known in their metallic state, than in their oxidised. It might certainly, with strict propriety, include the alkaline and earthy salts, for *they* are as much metallic salts as any others are; but the term is, however, generally prescribed to what we have stated. The following are among the most curious and useful of the metallic salts.

244. Nitro-Muriate of Gold.—No simple acid, however strong it may be, has the power of dissolving gold; but a compound, made by mixing one part of nitric acid with two of muriatic, *does* possess this property. This menstruum was formerly called *aqua regia*, but is now more properly named nitro-muriatic acid. On mixing the two acids, heat is given out, an effervescence takes place, and the mixture acquires an orange colour.

245. A saturated solution of nitro-muriate of gold, is of a deep yellow colour, very caustic, and of an astringent metallic taste. It tinges the skin, and almost all animal and vegetable bodies, and even marble, of a deep and indelible purple. It crystallizes, its beautiful golden colour being preserved. The crystals are very soluble in water, and still more so in ether. Decomposition of this salt is effected by light, heat, earths, alkalies, and several metals; as in another part of this work will be proven.

246. Nitrate of Silver.—Nitric acid dissolves half its weight of silver. The solution is limpid, colourless, heavy, and caustic. It conveys to hair, the skin, and most animal substances, an indelible black colour. It forms brilliant transparent crystals, possessed of a very bitter metallic taste, and being very soluble in water; not deliquescent, but decomposed by light; converted by heat into a preparation, used in medicine, under the name of *lunar caustic*, which is a sub-nitrate. It enters into the composition of several detonating or fulminating compounds. It is decomposed by nearly the same bodies, and in the same manner, that nitro-muriate of gold is.

247. Muriate of Silver is an insoluble salt, formed by adding muriatic acid, or compounds containing it, to nitrate of silver. It cannot be decomposed by heat, for, after melting, it rises in vapour; but the silver may be reduced by a process, which will be hereafter described. On account of the immense affinity which muriatic acid has for silver, these two bodies serve as excellent tests for each other. The composition of muriate of silver is acid 17 + silver 83.

248. Nitrate of Mercury is colourless, heavy, and very caustic: it tinges the skin of an indelible black colour, and yields transparent crystals, which are soluble in hot water. It is decomposed by sulphuretted hydrogen gas, by alkalies, and by muriate of tin. It is the bases of a fulminating compound.

249. Nitrate of Copper is very caustic. Its crystals are of a beautiful blue colour; deliquescent, soluble, and decomposed by heat. This salt, from the facility with which it parts with oxygen, is capable of acting on several

substances with much energy; this will be shown by some experiments. Nitrate of copper is decomposed by the alkalies, by iron, and by several other bodies.

250. Sulphate of Copper is a regularly crystallized salt, easily dissolved by water. It is of a beautiful deep blue colour, and hence obtained the name of *blue vitriol.* It is a salt that is of great use in several of the arts. It is caustic, reddens vegetable blues, and effloresces, when exposed to the air. It is decomposed by heat, by pure and carbonated earths and alkalies, and by several metals. It is composed of acid 33 + oxide of copper 32 + water 35.

251. Muriate of Copper is of a deep green colour, and very acrid. Its crystals are deliquescent, soluble in water, and decomposed by the same bodies as the other salts of copper are. Its constituents are 40 black oxide of copper +24 acid + 36 water. Muriate of copper, when deprived of its water, is a chloride of copper, (see 137.)

252. Acetate of Copper.—When plates of copper are exposed to the vapour of vinegar, a substance is formed, of a blueish green colour, used in dyeing and painting, and called *verdigris.* This substance, when dissolved in acetic acid, forms acetate of copper. This salt, like the sub-acetate, *(verdigris,)* is blueish-green; its crystals are soluble in 5 parts of hot water, but scarcely at all in cold. They effloresce in the air, and are decomposed by heat, yielding pure acetic acid. Acetate of copper is a violent poison, like all other bodies of wbich this metal forms a part. But we possess an antidote of undoubted efficacy to this poison—this is *sugar.* The chief use of this salt is in dyeing.

253. Sulphate of Iron, the body so well known by the names of *green vitriol* and *copperas.* It forms beautiful transparent green crystals. Its taste is harsh and styptic. It reddens vegetable blues, the acid being always in excess. Two parts of cold, and three-fourths of boiling water, dissolve it. It does not dissolve in alcohol. It is efflorescent. A moderate heat drives off its water of crystallization, and a strong heat its acid. Sulphate of iron

is of extensive use in the arts. Its constituents are 29 acid + 28 oxide of iron + 45 water.

254. Nitrate of Iron is of a colour varying from yellowish brown to green. It cannot be crystallized. It is decomposed by heat: the acid flies off, and the metal remains in a highly oxidised state, in the form of a bright red powder.

255. Muriate of Iron.—The iron in this salt is sometimes in the state of a protoxide, at others, of a peroxide; and the salts are thence called promuriate, and permuriate. The former is of a green colour, crystallizable, and very soluble. It absorbs nitrous gas. From it, alkalies throw down a green precipitate; prussiate of potass, a white one; and gallic acid, none at all. The permuriate has a brown colour, is uncrystallizable, very soluble, and readily decomposed by heat: the addition of sulphuric acid expels chlorine; and alkalies throw down a yellowish brown precipitate.

256. Carbonate of Iron is the chief ingredient in *Chalybeate,* mineral waters. It has a green colour, is brittle, somewhat transparent, and soluble in water. It possesses the singular property of becoming a permanent magnet, when heated red hot. Common *rust* of iron is a compound of carbonic acid, and peroxide of copper. It is not soluble in water.

257. Acetate of Iron crystallizes, has a green colour, and a sweetish styptic taste. A solution of it is much used by calico-printers, and called by them *iron liquor.* By the aid of this salt, they can easily produce any shade of colour, from a faint grey to a deep black.

258. Gallate of Iron.—This salt constitutes black dyes and ink. It is formed by the union of gallic acid with peroxide of iron. It is decomposed by the stronger acids; hence ink-spots are taken from paper or linen by their application.

259. Prussiate of Iron, the bases of the beautiful pigment called *prussian blue.* The combined iron in this substance is in the state of a peroxide.

260. Nitrate of Tin is a salt that is not permanent (though the acid acts upon the metal with amazing vio-

lence): the tin continues to attract oxygen from the nitric acid, until it becomes too highly oxidised to remain soluble. It is accordingly precipitated in the form of a grey powder. The same change is produced, by heating the solution.

261. MURIATE OF TIN is of a yellow colour, and may be crystallized. The crystals are deliquescent and soluble. This salt is a test for several metals; especially for mercury and gold.

262. NITRO-MURIATE OF TIN is transparent, and of a brown colour: a short time after it is made, it becomes of the consistence of jelly, and may be cut with a knife. This salt is of great importance in the art of dyeing; being used as a mordant, and to brighten the colours of several tinctures, chiefly crimson and scarlet.

263. CARBONATE OF LEAD, commonly known by the name of *white lead*, is formed by exposing thin plates of lead, coiled up, to the vapour of vinegar. The metal is oxidised by the decomposition of the vapour of the acetic acid; and the salt is formed by the abstraction of carbonic acid, partly from the atmosphere, and partly from the acetic acid vapour. It is used as a white paint.

264. ACETATE of LEAD.—*Sugar of Lead.*—This salt obtained the latter name, from its sweet taste. It is a deadly poison, like all other preparations of lead. It crystallizes in needles, which have a silky appearance. These are soluble in $3\frac{1}{2}$ parts of cold water, and something less of hot. Acetate of lead is of great utility. The constituents of this salt are 26.96 acid + 58.70 base + 14.32 water.

265. SULPHATE OF ZINC—the *White Vitriol* of commerce —a compound of some importance. It crystallizes. Its crystals are soluble in $2\frac{1}{4}$ parts of cold water, and less of boiling. Heated, they melt, lose their water of crystallization, and then their acid. Heated with charcoal, the zinc is reduced, it then rises in vapour, and inflames. This salt is used in dyeing, to deepen several red colours. It is decomposed by alkalies. Its constituents are 40 acid + 20 base + 40 water; or, in a *dry* state, 50 acid + 50 oxide of zinc.

266. Nitrate of Bismuth is colourless, yields white crystals, which effloresce and detonate weakly. When the crystals are put into water, they are decomposed; the oxide of bismuth falling down in a white powder, called magistry of bismuth, which is used as a paint for the complexion, though it is liable to turn black, by exposure to sulphuretted hydrogen gas. The *pearl powder* of the perfumers is an oxide of bismuth precipitated by cold water, from the nitro-muriate of the metal.

267. Nitro-Muriate of Cobalt.—The solution of this salt is red, in the neutral state; but green, when the acid is in excess. The neutral salt forms one of the most curious sympathetic inks; letters written with a diluted solution are colourless, but become of a fine green colour, when heated. Many theories have been adopted to account for this, but as none of them appear to be satisfactory, we shall not enter into them.

268. Minerals.—The inorganic and inanimate substances, both simple and compound, and of whatever nature, that are found native, either on the surface, or in the bowels, of the earth. The totality of these bodies has received the name of the mineral kingdom.

269. The following arrangement of minerals is the one generally adopted:—

Class 1. Metallic minerals, or ores.
2. Earths and stones.
3. Saline minerals, or native salts.
4. Inflammable fossils.

270. From bodies of the first class, we obtain, by certain processes, *pure metals,* from those of class 2, *pure earths;* from those of class 3, various *salts*, but chiefly nitrates, muriates, sulphates, and carbonates; and from bodies of the 4th class, such substances as *sulphur* and *bitumens*.

271. The study of what relates to mineral bodies, properly constitutes the science of *mineralogy*. The subject, though interesting, is one which we are not able to do more than just touch upon. From what is said above, and from the *analysis of ores, stones, marls, soils, salts,* &c. to be found among the experiments described hereafter, the student will obtain as much knowledge of mineralogy as

will be sufficient for him, till he advances farther in other divisions of chemistry.

272. MINERAL WATERS.—This is the term applied to the waters of certain springs, which, because they possess peculiar tastes, smells, colours, and other singular properties, cannot be applied to purposes of domestic economy. But, though these waters cannot be used for what water in general is used, yet they are not altogether unserviceable. Mineral springs have been resorted to in all ages for the cure of various diseases; and some of them have effected wonderful cures, in several obstinate disorders.

273. The examination of mineral waters with a view to ascertain their ingredients, and thence their medical properties, and the means of compounding them artificially, is an object of considerable importance to society. In the analysis of mineral waters, we, in the first place, by means of certain tests, ascertain what are the *ingredients*; and then, by a more minute process, determine the *proportions*. But the quantity of mineral substance which gives to water those peculiar properties, is sometimes so very small, and the ingredients so various, that few problems in chemistry are attended with more difficulty than the correct analysis of mineral waters. On this account, we shall be excused from going into the subject very deeply, and, therefore, instead of giving a formal account of *all* the substances that have *ever* been found in mineral waters, we shall mention merely those which are *generally* found in them; and furnish some pleasing experiments, to show the mode of detecting the presence of these substances. We shall also give directions for composing several mineral waters, of which the ingredients and proportions have been correctly ascertained.

274. BITUMEN.—This term includes a considerable range of inflammable mineral substances, burning with flame in the open air. Some of them are solid, some fluid. The following are those of greatest importance. *Naphtha*; a fine light, white, thin, fragrant, very inflammable oil. *Petroleum*, or mineral oil, a kind of naphtha, darkened, and thickened by exposure to air. *Asphaltum*, a solid substance, easily melted and inflamed. Besides these, there are other

bituminous substances, as *jet*, *amber*, and *sea-coal*, respecting the properties of which, we shall perhaps have occasion to speak hereafter.

275. NATURAL CHEMISTRY.—Having now considered the properties of the elementary substances, and such of their compounds as can be formed artificially, or are found in the mineral world, we proceed to examine the states of combination in which they occur in organic substances.

276. By *organic substances*, we mean those which constitute the vegetable and animal kingdoms: and which essentially differ from those composing the mineral kingdom, inasmuch as, while the latter seem to be composed by the accidental combinations of their constituents, *their* constitution bears the most striking and impressive marks of design, and they are in possession of, and are governed by, the unknown, but vastly important, principle called *life*. With the real nature of life, we are perfectly unacquainted; all we know of it regards its operations.

277. ON VEGETABLE SUBSTANCES.—The elementary bodies which enter into this class of compounds, are very few. Plants are found by analysis to consist principally of aëriform matter, and charcoal. They give out, by distillation, volatile compounds, which are composed of oxygen, hydrogen, nitrogen, and coally matter, or charcoal. Yet, although these elements are few, the principle of life enables plants to form from them a great variety of new chemical arrangements, by means of appropriate organs. The various solid parts and juices of vegetables, thus composed, and existing ready-made in them, may, therefore, be regarded, as their immediate materials, or *proximate* constituents. The following are the most important of these substances:—

278. GUM.—Colourless, tasteless, and inodorous. Does not crystallize. Dissolves in water, forming mucilage. Insoluble in alcohol. There are several kinds of gum; the one most used in the arts is *gum arabic*. Gum exudes from growing trees.

279. SUGAR.—To be found in every vegetable. Is very abundant in, and easily obtained from, the plant called the sugar-cane. Taste sweet. Crystallizes. Solu-

ble in water, alcohol, and nitric acid. When distilled with the latter, yields oxalic acid.

280. Fecula, or *Starch.*—Obtained from seeds and roots, particularly wheat and potatoes. An insipid white powder. Insoluble in cold water. Forms an opaque glutinous solution in hot water. Insoluble in alcohol.

281. Gluten.—Obtained from wheat flour. Forms a ductile elastic mass with water. Partially soluble in water, but insoluble in alcohol. It is this substance that gives to flour the property of forming good paste with water.

282. Oils are of two kinds, fixed and volatile; and both are obtained from plants. *Fixed* oils exist chiefly in seeds, and each oil bears the name of the plant from whose seed it is extracted; thus lintseed, rapeseed, almond oil. Sometimes a fixed oil is obtained from the pulp of fruit; olive oil is one that is. They are extracted by pressure and boiling, have no smell, are insoluble in water and alcohol, form soaps with alkalies, and are coagulated by salts.

283. *Volatile* oils are obtained from all parts of plants, *excepting* the seeds. Extracted by distillation and pressure. Strong peculiar smell to each individual oil. Insoluble in water. Soluble in alcohol. Volatilized by heat.

284. Camphor.—Obtained from a species of laurel tree. Analogous in its nature to volatile oils. Strong smell. Extremely volatile and inflammable. Insoluble in water and alkalies. Soluble in alcohol, oils, acids. Used in medicine.

285. Resins.—These are volatile oils, peculiarly modified by the action of oxygen. Solid. Melt, when heated. Insoluble in water. Soluble in alcohol, ether, and alkalies. By nitric acid converted into artificial tannin. Pitch, tar, and turpentine, are the most common resins: they exude from trees. Copal, mastic, and frankincense, are also of this class of compounds.

286. Gum Resins are precisely what their name denotes, —resins combined with mucilage. Strong smell. Brittle, opaque, infusible. Form milky solutions with water; transparent with alcohol. Myrrh and assafœtida are of this class.

287. Balsams.—Peculiar resinous juices, combined with benzoic acid, which body sublimes, when they are heated. Strong smell.

288. Caoutchouc.—A milky glutinous fluid, which exudes from certain trees, and in drying turns black and acquires consistence; in this state it is called Indian-rubber. Very elastic. Insoluble in water and alcohol. Very combustible.

289. Colouring Matter.—The colours of vegetables are owing to certain matters, which may be extracted, and converted into dyes and pigments. The art of dyeing consists in extracting colours from vegetables, and fixing them on cloth.

290. Tannin.—Taste astringent. Soluble in water. Forms a precipitate with gelatin, which is insoluble in water. This precipitate is formed when skins are *tanned* and made into leather. It is found abundantly in oak-bark and nut-galls, and may be formed (though not economically) artificially.

291. Wax.—Insoluble in water. Fusible. Soluble in alcohol, ether, and oils. Forms soap with alkalies.

292. Wood.—Composed of fibres. Tasteless. Insoluble in water and alcohol. Yields much charcoal, (giving out impure acetic acid,) when distilled in a red-heat.

293. Vegetable Acids.—The most important of these are the mucous, obtained from gum; the suberic, from cork; the camphoric, from camphor; the benzoic, from balsams; the gallic, from galls, &c.; the malic, from ripe fruit; the citric, from lemon and lime juice; the oxalic, from sorrell, and from bodies distilled with nitric acid; the succinic, from amber; the tartaric, from cream of tartar; the acetic, from vinegar. They are all decomposable by heat, and soluble in water. The other properties of the most useful amongst them, have been stated already (see 143, to 148).

294. The *Decomposition of Plants* begins as soon as they are dead. The reduction of the various matters composing them to their simple elements, is a process of very considerable length; during which many new com-

binations are successively established, and successively destroyed. The process here spoken of is *fermentation*.

305. The *Vinious Fermentation* derives its name from its product, which is *wine*.—When saccharine vegetable matter, accompanied by some other bodies, as fecula, mucilage, &c., are exposed to water and heat, they shortly experience a very striking alteration. An internal commotion takes place; the mass grows turbid; carbonic acid gas is disengaged, in considerable quantity, and, being enclosed in viscid matter, forms, on the surface of the liquor, a stratum of *yeast*. After a time these appearances cease, and the fermented liquor becomes clear and transparent. It will now have lost its sweetness and vaiscidity, and have acquired the vinious taste, and intoxicating quality. Thus *wine* is made from the juice of the grape, and thus *beer* (which may be chemically regarded as the wine of grain) is made from malt.

306. If the fermentation be stopped, by the exclusion of air, before the whole of the carbonic acid gas is evolved, the wine is brisk and sparkling, like Champaigne, from the carbonic acid gas imprisoned in it; it is also sweet, like cyder, from the sugar not being completely decomposed.

307. Sugar alone does not furnish wine, by undergoing fermentation; for, when *it* is decomposed, its constituents are recombined into two new substances; the one a peculiar liquid substance, called *alcohol*, or *spirit of wine;* the other, carbonic acid gas.

306. It is to *alcohol* that fermented liquors owe their intoxicating qualities, and from those bodies it may readily be separated by distillation. Alcohol, when pure, is of a strong heating nature, very light, inflammable, volatile, and possesses a peculiar odour. It dissolves resins, volatile oils, camphor, and many other substances. It is composed of small quantities of carbon and oxygen, united to a considerable proportion of hydrogen. Of these elements, (in different proportions though,) sugar too must be composed, of course. But, though sugar may be decomposed into alcohol and carbonic acid, it is not possible to compose sugar, by uniting carbonic acid and alcohol.

299. *Ether*, the lightest of all liquids, highly volatile, inflammable, and odorous, is alcohol, deprived of a portion of its carbon. The decarbonization of alcohol is effected by the action of strong acids on it; and the ether differs in its nature, and is differently named, according to the particular acid that is made use of. Thus nitric acid with alcohol, produces *nitric ether*, and sulphuric acid, *sulphuric ether*.

300. The *Acetous Fermentation*, is that which produces *vinegar*. It is generally said, that, in this species of fermentation, the product is obtained from liquors which have already undergone the *vinous* fermentation; indeed, vinegar *is* chiefly prepared from wines, but the vinous fermentation is not necessarily preliminary, for vinegar may be obtained from simple mucilage. Common vinegar may be purified and concentrated by distillation, and it is then called distilled vinegar, or acetic acid (143).

301. The phenomena of *putrefaction* is occasioned by the last change, or final decomposition, which vegetables undergo. The putrefactive fermentation is a complete analysis of vegetable substance, during which the constituent elements are all disengaged in the form of *gas*, with the exception of some fixed earthy products, which remain in the state of mould, and are used as a manure.

302. But the element *nitrogen* is one that is exceedingly favourable to putrefaction; and substances which contain it, or to which it has been added, and decomposed very rapidly. Among the gaseous bodies which are evolved during this process, are those described in paragraphs 163, 186, 187, 188. These have all peculiar and disagreeable smells; and from the mixture of these different odours proceeds the fetor that accompanies putrefaction.

303. No substance can enter into the putrefactive fermentation, if unaccessible by moisture and air; we can, therefore, by keeping bodies in a state of dryness, and where air has no access, hinder their putrifying.

304. Animal Kingdom.—The principal primary constituents of animal substances are nearly the same as those of vegetables; but they have less carbon and hydrogen, and a far greater quantity of nitrogen and phosphorus.

The immediate materials of animals, which are formed by the combinations of these substances, are *gelatin*, *albumen*, and *fibrin*. These three kinds of animal matter form the bases of all the various parts of the animal system: *viz.* solid, as the *skin*, *flesh*, *nerves*, *membranes*, *cartilages*, and *bones*; and fluids, as *blood*, *chyle*, *milk*, the *gastric juice*, *saliva*, *tears*, &c.

305. *Gelatin*, or *jelly*, the chief ingredient in skin. It is obtained under the forms of glue, size, isinglass, jelly, &c. It is a viscid substance, very soluble in water, but not in alcohol; insipid, and without smell; when cold, it congeals into a cohesive tremulous substance. It forms the bases of soups, &c. The union of gelatin with tannin in a skin, constitutes leather.

306. *Albumen* is the principal ingredient in the serum of blood, and the white of eggs. It is miscible with cold water, but is coagulated by heat, which forms the best test of its presence. It is also coagulated by acids and alcohol.

307. *Fibrin* forms the basis of the muscular part of animals. It is an insipid and inodorous substance, having somewhat the appearance of fine white threads adhering together. It is insoluble both in water and alcohol.

308. Animal matter, although the most complicated of all natural substances, returns to its elementary state by one single spontaneous process, the *putrefactive fermentation*. By this, the substances forming its different parts are slowly reduced to the state of oxygen, hydrogen, nitrogen, and carbon; and thus the circle of changes through which these principles have passed, is finally completed. Quitting their elementary forms, they entered the vegetable system, thence passed, to the animal kingdom, and from that return again to their original simplicity; soon to re-enter the sphere of organized existence.

ON

CHEMICAL OPERATIONS,

AND

APPARATUS.

309. The very prevalent notion, that "a laboratory, fitted up with furnaces, and expensive and complicated instruments, &c. &c. &c., is absolutely necessary for the performance of chemical experiments," is exceedingly erroneous. In fact, the truth of the matter is diametrically opposite to this opinion. "For general and ordinary chemical purposes, (says Dr. Henry,) and even for the prosecution of new and important inquiries, very simple means are sufficient: some of the most interesting facts of the science may be exhibited and ascertained, with the aid merely of Florence flasks, of common phials, and of wine glasses. In converting these to the purposes of apparatus, a considerable saving of expense will accrue to the experimentalist; and he will avoid the encumbrance of various instruments, the value of which consists in show, rather than real utility." It is a curious and instructive fact, that some of the most important discoveries in chemistry, were made by persons who, either from choice, or motives of economy, used utensils of the very simplest character. The laboratory of the great Priestley cost a mere trifle.

310. We intend, in this section of our work, to give an account of the chemical processes of most frequent recurrence, and to describe with minuteness the instruments whose real utility, simplicity, and cheapness, entitle them to be so distinguished. We shall also inform the student where

the different utensils may be obtained, and how much they will cost him. We shall point out the best mode of obtaining and preserving chemical preparations; and notice the precautions necessary to be observed in conducting processes, or handling substances, that are in the least degree dangerous. In short, as we proceed with our instructions, we shall continually bear in mind, that the persons we are addressing have need and inclination for information; that they have neither time to be lost, nor money to be wasted, and thus understanding the situation of our readers, we shall suitably model our discourse. We are not unaware, however, that while we proceed thus, we are laying ourselves open to the charge of puerility. We shall probably be told, that the mention of such trifling things is not befitting the pages of a philosophical treatise. But, being of opinion that elementary writers in general are by far too concise in their practical instructions—that they presume the student knows many things which he really does not know,—we do humbly conceive, that we shall be serviceably employed, in giving precise directions for the performance of the most curious and instructive chemical experiments.

311. The following observations, by a writer of celebrity, on the conducting of chemical processes in general, are truly valuable and judicious. Method, order, and cleanliness, are essentially necessary in a chemical laboratory. Every vessel and utensil ought to be well cleansed as often as it is used, and put again into its place: labels ought to be put upon all the substances. These cares, which seem to be trifling, are however very fatiguing and tedious; but they are also very important, though frequently little observed. When a person is keenly engaged, experiments succeed each other quickly; some seem nearly to decide the matter, and others suggest new ideas: he cannot but proceed to them immediately, and he is led from one to another: he thinks he shall easily know again the products of the first experiments, and therefore he does not take time to put them in order: he prosecutes with eagerness the experiments which he has ast thought of; and, in the mean time, the vessels employed, the glasses and

bottles filled, so accumulate, that he cannot any longer distinguish them; or at least, he is uncertain concerning many of his former products. This evil is increased, if a new series of operations succeed, and occupy all the laboratory; or if he be obliged to quit it for some time, every thing then goes into confusion. Thence it frequently happens, that he loses the fruits of much labour, and that he must throw away almost all the products of his experiments.

312. When new researches and inquiries are made, the mixtures, results, and products of all the operations ought to be kept a long time, distinctly labelled and registered; for these things, when kept some time, frequently present phenomena, that were not at all suspected. Many fine discoveries in chemistry have been made in this manner; and many have certainly been lost, by throwing away too hastily, or neglecting the products.

313. The great agents whose aid the chemical analyst most frequently needs, are *fire* and *water*. When a process requires the first chiefly, it is said to be executed in the *dry* way; but when the latter is employed, the operation is performed in the *humid* way.

314. But, besides modes of proceeding which are purely chemical, and independent of the employment of chemical agents, the operator is frequently obliged to resort to practices entirely mechanical. The operations of chemistry might be naturally divided, therefore, into different classes, according to the several objects they have in view, and to the ways and means employed to accomplish those objects. All the operations which tend to change the form, without changing the nature, of a substance; those, for example, performed by the hammer, the knife, the pestle, and instruments of a like nature; and all those which determine the quantities of bodies, are mechanical operations. But the operations performed by the aid of chemical powers and agents, and which separate the constituents of bodies, are purely chemical operations. We know that chemical action can only take place between bodies of different kinds, and that at least one of the bodies must be in a fluid state; we also know that chemical action is accelerated, when the solid that is put into the fluid is divided into small particles.

Now the division of a solid body into small particles is accomplished by pounding, grinding, rasping, cutting, and other operations of a like nature: hence the adoption and employment of mechanical agents by the practical chemist.

315. It would be of little account to draw a line of distinction between these different kinds of processes: we shall therefore, instead of classifying them, proceed to give directions for conducting them.

316. Weighing.—The beginning and end of every exact chemical process consists in *weighing*; and the best means of ascertaining measures of weight is by means of *scales*. Accurate balances are therefore indispensable. What are termed *apothecaries' scales*, are very convenient for students who operate on small quantities of the different substances. These may be bought at the Apothecaries' Hall (and perhaps at Druggist's shops). They are put up in a little box, which, besides the scales, contains a series of weights, from half a grain to two drachms, in all about 20. These scales are sufficiently accurate for all common purposes. The charge made for the box complete is about 4*s*. 6*d*. The student must be careful not to use scales, or any other delicate metallic apparatus, in any place where acid vapours are flying about; for if he does, they will be seriously injured. It is not absolutely necessary, but it would be found very convenient, to have, besides these scales, others to weigh quantities as high as a pound.

317. We here annex the table by which, in chemistry, the weights of bodies are calculated. It may be mentioned, that ambiguity is most easily avoided by reckoning by grains.

TROY WEIGHT.

Pound.	*Ounces.*	*Drachms.*	*Scruples.*	*Grains.*
1 —	12 —	96 —	288 —	5760.
	1 —	8 —	24 —	480.
		1 —	3 —	60.
			1 —	20.

318. In order to estimate the quantities of fluid bodies recourse is had to measures of capacity. In chemistry the *wine pint* is usually employed. This measure corresponds

to 28.875 cubical inches of water, at the temperature of 60°. For chemical use, the graduated test-tube, fig. 12, is a measure of great convenience. It holds two troy ounces of water, equal to the $\frac{1}{8}$ of the pint, to 960 troy grains, and to 3.6096 cubical inches. The following is a table of this measure:—

LIQUID MEASURE.

Gal.	*Pints.*	*Troy Ounces.*	*Drach.*	*Cubical Inches.*
1 —	8 —	128 —	1024 —	231.
	1 —	16 —	128 —	28.875.
		1 —	8 —	1.8048.
			1 —	0.2256.

319. Specific Gravity.—By this term, is understood, the density (or quantity of matter under a certain bulk) of one body, compared to the density of another. This latter body is assumed as the standard, and is generally pure water, at the temperature of 60°. In other words, specific gravity is the comparative weight of different sorts of matter. Having found, by a certain process, that a given quantity of water weighs 1000, we employ the same method to ascertain the weight of the same quantity of the metal mercury; we find it to be 13000: thus we have the comparative weights of the same bulk of these two bodies, and we say that the specific gravity of mercury, is to that of water, as 13 to 1. If water at 1000 is assumed as a standard of specific gravities, which, as it has been said, it generally is, then the specific gravity of mercury (given with a reference to the standard) is 13000. The object of finding the specific gravity of bodies, to distinguish them from each other, is one of their most obvious qualities—namely, weight of matter contained in a given space. We shall describe the methods by which the specific gravity of different kinds of bodies are obtained, and shall give a *table* of the specific gravities of the most important known bodies.

320. *To determine the specific gravity of a solid*, it is weighed, first in air, and then in water. To do this, it is necessary to be provided with very accurate balances; to the bottom of one of the scales is affixed a small hook, to

which the substance is fastened by a fine thread, or hair. When the solid, after being weighed in air, is lowered into the water, it loses of its weight, a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with its total weight, we find its specific gravity. The rule therefore is, divide the total weight by the *loss* of weight in water, the quotient is the specific gravity. Thus, if a mineral weighs 3 ounces in air, and 2 ounces in water, and the *total* weight be divided by the *loss*, which is 1, the quotient, or specific gravity of that mineral, will be 3.

321. *A very ready way to determine the specific gravity of solids*, is to fill a phial with water, and note the weight of the whole accurately in grains. Then weigh 100 grains of the mineral or other substance to be examined, and drop it gradually into the phial of water. The difference of weight of the phial with its contents now, and when it was filled with water only, will give the specific gravity of the matter under consideration. For example, if the bottle weighs 50 grains more than it did when filled with water only, it shows that 100 grains of the mineral displace only 50 grains of water, and consequently that its specific gravity is 2000, or twice that of water. The kind of phial which may be advantageously used for experiments of this kind, is represented by fig. 41, plate 3.

322. *To determine with readiness the specific gravity of a liquid.* We use for this, the *specific-gravity bottle* (fig. 41). This when filled with water, contains 500, 1000, or any even number of grains. This bottle is filled with the liquid, the specific gravity of which is required, and then weighed with its contents: the result, deducting the weight of the bottle, is the weight of the liquid under examination, compared to the weight of water. If, for instance the bottle holds 1000 grains of water, and 1850 grains of sulphuric acid, then the specific gravity of the latter, is to that of the former, as 1850 is to 1000.

323. In taking the specific gravities of bodies, attention should always be paid to their temperature; because the specific gravity of a body when heated, is much less than the specific gravity of the same body, in a cold state.

324. PULVERIZATION,—LEVIGATION,—TRITURATION.— These, strictly speaking, are merely mechanical operations, by which bodies are reduced into fine powder, and rendered more fitting to undergo chemical action than they were in their compact form. This kind of process never separates from each other the elementary principles of bodies; for every particle of an impalpable powder, is a small whole, perfectly similar in its composition to the original mass from which it was divided. But, on the contrary, chemical action separates the constituents of a body. The one class of processes is employed to overcome the attraction of aggregation, the other, to overcome the attraction of composition (85).—Brittle substances are reduced to powder by means of *the pestle and mortar*. Fig. 5, represents one formed of Wedgewood's-ware. This is a very excellent kind for most purposes; for it is very strong, and is not acted upon by acids. A strong iron mortar is useful, in the large way, for reducing very hard bodies to powder; but for this a good hammer answers very well in the small way. Substances are reduced to powder in the Wedgewood's-ware mortar by a dexterous use of the pestle round the sides of it; in fact, by *rubbing*, and this is that which is termed *trituration*. Reiterated blows of the pestle (which constitutes *pulverization*) might break mortars of this kind. Only a small quantity of the substance to be powdered should be put into the mortar at one time. *Levigation* is generally performed by rubbing a body (sometimes with the addition of water) on a flat stone, with another stone, round on one side, to suit the hand, and flat on the other. This is called a *muller*. A thin flexible knife, either of iron or bone, is employed to collect the substance under operation, from the sides to the centre of the flat stone or mortar. Bodies that are not brittle are reduced to small particles by means of *files*, *rasps*, *knives*, and *graters*.

325. SIFTING and WASHING are performed to separate the finer particles of bodies from the coarser, which may want further pulverization. For the operation of sifting, the well-known instrument called a *sieve* is employed. They should, for nice cases, be kept of different degrees of fineness. *Washing* is used for procuring powders of a more

uniform degree of fineness, than can be done by means of the sieve; but it can only be used for such substances as are not acted upon by the fluid which is used. The powdered substance is mixed with water, or other convenient fluid; the liquid is allowed to settle for a few moments, and is then decanted off; the coarser powder remains at the bottom of the vessel, and the finer passes over with the liquid. By repeated decantations in this manner, various sediments are obtained, of different degrees of fineness; the last, or that which remains longest suspended in the liquor, being the finest. Any of the glasses, fig. 6, 7, 8, 9, 14, 16, 17, may be used for this purpose: those with lips, fig. 7, 8, 9, 14, are most convenient.

326. Filtration is employed to separate solids from fluids. Filters are of different materials; for ordinary purposes, paper is used. The paper must be of a porous nature; and unsized *blotting paper*, without colour, which may be had at the stationers, answers very well. The filtering paper is folded into a conical form, and placed in a glass funnel, in order that, when wetted, it may not break. *Fig.* 13, is a ribbed funnel, which is the best that can be used for this purpose. The substance to be filtered must be poured into the filter gradually. The portion of liquid that passes through first, must be re-filtered, as it is seldom clear. But in a short time, the fibres of the paper swell, by accumulating moisture, and then the liquid that runs through, is perfectly transparent. Acids, alkalies, and other corrosive fluids, are best filtered, by means of a glass funnel filled with pounded glass, a few large pieces being first put into the neck of the funnel, smaller pieces over these, and the finer powder at the top. The porosity of this filter retains much of the fluid, which may, however, be recovered (though at the inconvenience of dilution) by gently pouring on it, a portion of water. The fluid will then be displaced, and pass through, and part of the water be retained in its stead. The funnel should be placed on one of the tall glasses, figs. 7, 8, 9, which may serve as a recipient for the filtered liquid.

327. Decantation, as well as filtration, is an expedient by which fluids are separated from solids that are diffused

in them. The operation consists in allowing the liquid to settle till the solid matter have subsided, when the clear supernatant fluid is gently poured off. It is best performed with tall cylindrical glasses, furnished with spouts—such as figs. 7, 8, 9. If the sediment be so light as to mix again with the fluid when gently moved, the clear fluid must be drawn off by means of a syphon.

328. SOLUTION is when a solid put into a fluid entirely disappears in it, leaving the liquor clear. The body which thus disappears, is said to be *soluble*, and the liquid it dissolves in, is called the *solvent*, or *menstruum*. Sugar, and salt are soluble bodies; for when they are put into water, they disappear entirely; but chalk is an insoluble body; for when that is put into water, it makes the fluid *turbid*, or muddy, for a short time (being merely *diffused* through it) and then sinks to the bottom. Some bodies are capable of being dissolved in one kind of liquid, though not in another kind. Camphor, for instance, is soluble in alcohol, but insoluble in water. Metals are soluble, but their *dissolution* only takes place when they are put into acids. For some observations regarding metallic dissolution, see 200 to 206.

329. The operation of *solution* is more speedy in proportion as the substance to be dissolved presents a greater surface: on this principle is founded the practice of pounding, cutting, and otherwise dividing the bodies intended to be dissolved.

330. The solution of a body invariably produces cold; and advantage has been taken of this phenomenon, to procure artificial cold, much greater than the most rigorous temperature ever observed in any climate. A *table* showing the different degrees of cold produced by different mixtures, will be found at the end of the book.

331. Solution is much accelerated by heat and agitation. Whether a cold liquid, or heat, or agitation should be employed in a particular case, must be determined by the nature of the substance operated upon. In making solutions, it is necessary to use a vessel of such materials as shall not be acted upon by its contents, and of sufficient capacity to admit of any sudden expansion, or frothing, to which chemical

action may give rise. The glasses, fig. 6, 7, 8, 9, 14, 16, 17, may be employed when heat is *not* required, and those, fig. 53, 54, when heat *is* required. The vessel employed should not be above $\frac{1}{3}$ full. It should be tied over with a piece of wet bladder, so that none of the fluid may be thrown out by the agitation of the contents. A few pin-holes must be made in the bladder to admit of the escape of any gas which may be generated. Heat is applied by putting the flask, fig. 54, or mattrass, fig. 53, upon one of the rings of the lamp furnace, fig. 23, and placing a lighted lamp, figs. 21, or 24, beneath it.

332. Lixiviation is used for separating substances which are soluble in water from such as are insoluble. Suppose, for example, it is required to separate the *sand* from a mixture of sand and salt: the compound body is placed in water; the salt is dissolved by the water; the sand is diffused through it. The mixture is filtered; the salt passes through with the water; the sand remains on the filter. The apparatus for filtration, with the addition of a jug, is all that is required for this operation.

333. Infusion is performed when we pour a hot liquor upon a substance that is partly soluble and partly insoluble, in order to extract something from it. The making of *tea* is an instance of the performance of this operation.

334. Digestion.—This operation consists in soaking, for a long time, a solid substance in a liquid kept constantly hot.

335. Maceration.—The continued steeping of a solid body in a cold liquid. Ink is produced by macerating the materials of which it is composed.

336. Evaporation is a process employed to separate a fluid from a solid, or a more volatile fluid from another, which is less volatile, by means of heat. It is performed in sections of glass globes, such as watch glasses, or in shallow basins of Wedgewood's-ware, fig. 4, supported over a flame, by the rings of the lamp-furnace, fig. 23. The vessels used for evaporation should always be thin at the bottom, in order that they may bear, without breaking, the sudden application of heat.

337. As during evaporation, the fluid carried off in the

state of vapour is entirely lost, being sacrificed for the sake of the fixed substances, with which it was combined, and which remain behind, this process is only employed when the fluid is of small value, as water, for instance. But, when the fluid is of sufficient consequence to be preserved, we have recourse to a process termed *distillation*.

338. DISTILLATION is evaporation performed in close vessels, composed of different materials, and varying in their forms. The vessel usually employed, in the large way, is called a *still*, and is represented by fig. 56. It consists of a copper vessel, of the shape of a tea-kettle, but without its spout and handle, (*a*,) enclosed in the brick-work of a furnace. Into the opening of this vessel, instead of a common lid, a moveable head (*b*) is affixed, which ends in a narrow open pipe. This pipe is received into a tube of lead, which is twisted spirally, and fixed in a wooden tub, (*c*,) so that it may be surrounded by cold water. When the apparatus is to be used, the liquid intended to be distilled, is put into the body of the still, and the head is fixed in its place, the pipe, which terminates it, being received into the leaden worm. A fire is then kindled in the furnace, the door of which is seen at *f*, and the liquid is raised into vapour, which passes into the worm, is there condensed by the surrounding cold water, and flows out of the extremity of the pipe, by the cock *d*, into the vessel *e*, placed to receive it.

339. The common still, however, can only be employed for volatilizing substances, that do not act on the copper (or other metal) of which it is made; and it is, therefore, limited to a few operations. The vessel, fig. 26, is of glass, and is also used for distillation. It is termed an *alembic*, and consists of two parts; the body *a*, for containing the materials, and the head *b*, in which the vapour is condensed, by the application of wet cloths. The condensed fluid is conveyed, by the pipe *c*, into the receiver *d*. At *e*, is represented one of the rings of the lamp-furnace, (fig. 25,) into which the alembic is placed, in order to be held over the flame of a lamp. Besides the alembic and still, there is another utensil, which is employed perhaps more than either of those, in the operation of distilling. This is the

retort. It is a glass vessel, represented by fig. 18; *a* is the body of it, *b* the neck. In the top of the body is an opening, through which the materials to be distilled, are inserted. To this opening a glass stopple is fitted, by grinding, so as to be air-tight. Retorts are sometimes made without the opening at the top, they are then cheaper and are called *plain* retorts; but those with the opening, (called *tubulated* retorts,) are by far the most convenient. Retorts are also made of earthen-ware, and of metal.

340. A necessary appendage to the retort, is a *receiver*. This also is a vessel of glass, and, like the retort, is either tubulated or plain. Fig. 19, represents a tubulated one; *a* represents the body of the receiver, *b* the neck which receives into it the neck *b* of the retort. Sometimes the neck of the retort is much too small to fit closely the neck of the receiver. In that case, a cork must be provided, that fits the latter, and must have a hole burnt or bored through it, of a sufficient size to hold the former. The plan with the cork will not answer, however, when corrosive fluids are distilled. We must then use an instrument of glass, called an *adopter*. This is represented at fig. 20, *b* is the adopter, *a* the neck of the retort going into the wide end of it, *c* the neck of the receiver enclosing the narrow end of it. The joinings are, as represented in the figure, secured by *lutes*.

341. Heat may be applied to glass retorts by means of the lamps, figs. 21, 24, properly regulated, to make a regular flame. Earthen-ware and iron retorts are exposed to the naked fire. In order that the vapour may be condensed in the receiver, as fast as it comes over from the retort, the body of it is either placed in a tub of cold water, or kept cool by the continually-renewed application of wet cloths.

342. Sublimation is a process, by which volatile substances are raised by heat, and again condensed in the solid form. This operation is founded on the same principles as distillation, and its rules are the same, as it is nothing but a dry distillation. The apparatus for sublimation is very simple: that represented by fig 26, and described under "distillation," with the head *b*, wanting the neck *c*, will answer for most purposes.

343. Crystallization.—The nature of crystallization has been already explained (see 112 to 115). The mode of obtaining crystals of certain bodies, differs according to the nature of those bodies. If it is desired to obtain crystals of a salt that is more soluble in hot water than in cold, (there are many salts of this kind,) all that there is to do, is to put into hot water as much of that salt as it will dissolve; in short, to make a hot saturated solution—and then to allow it to cool gradually; the slower the better. As the caloric which contributed to the fluidity of the salt flies off, crystals will be deposited. Salts that are soluble in equal of cold water and hot, can only be crystallized by driving the water of solution off in vapour. But this must be done very slowly; for a rapid evaporation leaves a salt, not in a crystallized state, but in that of a solid irregular mass. By the operation of crystallizing, salts, which differ in their degrees of solubility, or whose solution is unequally accelerated by heat, may be obtained separately from the same solution. Thus, if one salt be much more soluble in hot than in cold water, and another be equally soluble at any temperature, on evaporating the solution sufficiently, the latter salt will crystallize while the liquor is hot; on cooling, the other will shoot into crystals; and by alternate evaporation, and cooling, the two may be obtained uncombined, though perhaps with a little intermixture of each other.

344. The only general rule that can be given to the young student, for the purpose of directing him to crystallize bodies, is this: slowly evaporate the solution until a pellicle (or thin skin) is formed on the surface of it; then set it in a cool place, where it will be free from dust, and can remain undisturbed.—This rule will not, by any means, apply to all salts, nor is there any other rule that will. Nothing but experience, and a knowledge of the habitudes of the various crystallizable substances, can be of much avail.

345. The Wedgewoods-ware evaporating bason, fig. 4, may be generally used. Metallic vessels are used in the large way.

346. Precipitation.—Sometimes when two bodies (one

at least of them being in a liquid state) are placed together, chemical action ensues, and a powder is formed and thrown to the bottom of the vessel. This powder is called a *precipitate*, and the process which causes its production, *precipitation*. Figs. 6, 7, 8, 9, 14, 16, 17, represent jars which may be used for this purpose.

347. Granulation; the method of dividing metallic substances into grains or small particles, in order to fit them for different purposes. It is performed either by pouring the melted metal into water from a considerable height, or by shaking it in a box, previously well-rubbed with chalk, till the moment of congelation, at which instant it becomes converted into powder.

348. Fusion.—The act of converting a solid into a fluid by means of heat. The operation is generally performed in vessels called *crucibles*, which must necessarily be less fusible than the substances they are intended to contain. Crucibles are made of various forms and of different substances, whatever they are made of, however, ought to be of a very refractory nature, in order that they may be lasting. Figs. 1, 2, 3, represent the general forms of this utensil. The figure over the *second* crucible is a cover for it, which, for particular purposes, is obliged to be luted on. Those of the shape of fig. 1, are frequently made of black-lead. But the most common kind of crucible is that shewn by fig. 3, which is formed of earthen-ware, is very strong, and very cheap. A tobacco-pipe with a large bowl may be used as a crucible in a vast number of processes.

349. In order that the substances to be fused, may be submitted to the necessary degree of heat, instruments of different forms and sizes, termed *furnaces*, are employed; and, in most books on chemistry, particular directions are given for the construction of them. But we do not intend to give any descriptions of furnaces in this work; because, first, for the simple experiments here recommended, the use of furnaces is not required; as the heat of a clear kitchen fire, urged by common bellows, will answer every object; and, secondly, because the student would do wrong in buying or building furnaces, for which perhaps he might never have use.

350. REDUCTION.—The operation by which metals are restored to their metallic state, after having been deprived of it, either by combustion, as the metallic oxides, or by the union of some heterogeneous matters which disguise them as fulminating gold, horn silver, cinnabar, and other compounds of the same kind. These reductions are also called *revivifications*. The operation is performed in crucibles, by the aid of heat, and with the addition of certain substances, which act chemically upon the body to be reduced.

351. For a great number of chemical processes, in the small way, heat may be applied, in the very best possible manner, by means of a lamp.—Refer to what is said in the description of the *lamp*, fig. 21, and of the lamp-furnace, fig. 23.—The characteristics of operations performed by means of instruments, such as those we recommended are simplicity, quickness, and cheapness,—qualities which few students know not how to prize.

352. Every effect of the most violent heat of furnaces, may be produced by the flame of a candle or lamp, urged upon a small particle of any substance, by an instrument called the *blow-pipe*. This consists of a conical brass pipe, about 8 inches long, $\frac{1}{4}$ of an inch diameter at the top, with a curvature near the lower end, whence the point tapers off, with a very small perforation for the wind to escape. For nice purposes, the blow-pipe is provided with a bowl or enlargement, in which the vapours of the breath are condensed and retained, and also with two or three moveable nozzles, having holes of different diameters, to afford a larger or smaller flame. Fig. 59, represents a blow-pipe agreeing with the above description;—*a* is the part of it that is taken into the mouth, *b* the bowl which condenses the humidity of breath, and *c* the point directed against the flame.

353. There is an artifice in the blowing through this pipe, which is more difficult to describe than to acquire. The effect intended to be produced is a continual stream of air for many minutes, if necessary, without ceasing. This is done by applying the tongue to the roof of the mouth, so as to interrupt the communication between the mouth and the passage of the nostrils; by which means the

operator is at liberty to breathe through the nostrils, at the same time that, by the muscles of the lip, he forces a continual stream of air from the anterior part of the mouth, through the blow-pipe. When the mouth begins to be empty, it is replenished by the lungs in an instant, while the tongue is withdrawn from the roof of the mouth, and replaced again in the same manner as in pronouncing the monosyllable *tut*. In this way the stream may be continued for a long time without any fatigue, if the flame be not urged too impetuously, and even in this case, no other fatigue is felt, than that of the muscles of the lips.

254. A candle with a thicker wick than they are generally used with, may be conveniently employed for occasional experiments. It should be snuffed rather short, and the wick turned on one side toward the object, so that a part of it should lie horizontally. The stream of air must be blown along this horizontal part, as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof, that the hole is not round or smooth; and if the flame have a cavity through it, the aperture of the pipe is too large. When the hole is of a proper figure and duly proportioned, the flame consists of a neat luminous blue cone, surrounded by another flame of a more faint and indistinct appearance. The strongest heat is at the point of the inner flame.

355. Considerable disadvantages, however, attend the use of candles. The difficulty of getting good ones, or such as have thick wicks, is frequently great. By far the best flame that can be employed, is that of a lamp, because it is large, and easily and cheaply obtained. Fig. 44, represents a blow-pipe lamp, of perhaps as simple a construction as could be devised.—Refer to the description of that figure.

356. The substance intended to be acted upon by the blow-pipe ought not to exceed the size of a pepper-corn. It may be laid upon a piece of close-grained, well-burned charcoal; using, not the ends of the fibres, but the sides; otherwise the substance, when fused, instead of forming a round bead, is scattered about. In general, a small hole is made in the charcoal, and the body put into it. When

the substance under examination is of such a nature as to sink into the pores of the charcoal, or to have its properties affected by the inflammable qualities of that substance, *then*, instead of being laid on charcoal, to be exposed to the heat, it is placed in a small metallic spoon, formed of gold, of silver, or of platinum. Some information regarding a spoon of this kind may be obtained from fig. 60, and the description of it.

357. Small plates of clay, prepared as directed below, are found to be a very useful addition to the blow-pipe apparatus. The colours of bodies melted with borax, &c., are shewn to great advantage on them; and quantities of matter too minute to be tried on charcoal, or in the platinum spoon, may on them be readily examined, either alone, or with fluxes. *Process for forming clay-plates.* Extend a white, refractory clay, by blows with the hammer, between the folds of a piece of paper, in the same manner as gold is extended between skins. Then, the clay and paper together, must be cut with scissars, into pieces about half an inch long and a quarter of an inch wide, and afterwards hardened in the fire in a tobacco-pipe.

358. The heat of the blow-pipe should be communicated gradually. The flame should not be immediately applied to the substance under examination, but directed a little above it, or else to the part of the spoon just beneath it. When the alteration which the substance undergoes by the mere action of heat has been observed, it will be necessary to examine what farther change takes place when it is melted with various fluxes. These fluxes are,

359. Microcosmic Salt.

360. Sub-carbonate of Soda.

361. Calcined Borax.

362. They must all be in a state of purity; methods of obtaining them thus, will be detailed in a succeeding section of the present work. The fluxes are to be kept powdered in small phials; and when used, a sufficient quantity may be taken up by the moistened point of a knife: the moisture causes the particles to cohere, and prevents their being blown away when placed on the charcoal. The flux must then be melted to a clear bead, and the substance to

be examined placed upon it. It is then to be submitted to the action, first of the exterior, and afterwards of the interior flame, and the following circumstances to be carefully observed:—

363. (*a.*) Whether the substance is dissolved; and, if so,

364. (*b.*) Whether with or without effervesence, which would be occasioned by the liberation of carbonic acid, sulphurous acid, oxygen, gaseous oxide of carbon, &c.

365. (*e.*) The transparency and colour of the glass while cooling.

366. (*f.*) The same circumstances after cooling.

367. (*g.*) The nature of the glass formed by the exterior flame, and

368. (*h.*) By the interior flame.

369. (*i.*) The various relations to each of the fluxes.

370. If the glass bead becomes opaque as it cools, so as to render the colour indistinct, it should be broken, and a part of it mixed with more of the flux, until the colour becomes more pure and distinct. To render the colour more perceptible, the bead may be either compressed before it cools, or drawn out to a thread.

371. The *reduction* of metals is effected in the following manner: The glass bead, formed after the manner already pointed out, is to be kept in a state of fusion on the charcoal as long as it remains on the surface, and is not absorbed, that the metallic particles may collect themselves into a globule. It is then to be fused with an additional quantity of soda, which will be absorbed by the charcoal, and the spot where the absorption has taken place is to be strongly ignited by a tube with a small aperture. By continuing this ignition, the portion of metal which was not previously reduced will now be brought to a metallic state; and the process may be assisted by placing the bead in a smoky flame, so as to cover it with soot that is not easily blown off.

372. The foregoing directions will enable the student to discriminate certain *characteristics*. It might be now proper to answer a question which will very naturally arise —what bodies do these appearances indicate? or in other

words, to what substances do these characteristics belong? We would very gladly give the young analyst such information as we are in possession of upon this subject, but it would take up a considerable space; and we have already devoted perhaps too much room to the blow-pipe, in describing the manner of using it. The relations of the earths, the metallic oxides, and the particular mineral species, before the blow-pipe, are minutely described by several persons who have written expressly on the subject; and we must refer those who desire such information, to works of this kind. We may particularly point out a late treatise of Burzeliuss, translated by Mr. Children. In all descriptions of minerals also, even in the concise accounts of them contained in a chemical dictionary, their habitudes with the blow-pipe are always mentioned.

373. Many advantages may be derived from the use of this simple, and valuable instrument. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation. The most expensive materials, and the minutest specimens of bodies, may be used in these experiments; and the whole process, instead of being carried on in an opaque vessel, is under the eye of the observer from beginning to end. It is true, that very little can be determined in this way concerning the quantities of products; but in most cases, a knowledge of the contents of any substance is a great acquisition, which is thus obtained in a very short time, and will, at all events, serve to show the best and least expensive way of conducting processes, with the same matters, in the larger way.

374. For Performing Experiments on Gases, many articles of apparatus, not hitherto described, are absolutely necessary. These consist, partly of vessels for containing the materials which afford the gases, and partly of vessels adapted to contain them, and submit them to experiments.

375. Some gases are procurable by the mere mixture of the substances, which upon combining evolve them; but others cannot be obtained without submitting the materials to heat. For these different modes of proceeding, different vessels are requisite of course.

376. Fig. 29, (plate 3.) represents a glass bottle with

two necks, one of which has a glass stopple fitted to it by grinding. This utensil is employed, when a gas is to be obtained without the aid of heat. The materials which are to afford the gas are put into the bottle. The solid part being broken into small pieces, to facilitate action, and the liquid being poured in through a funnel, to avoid soiling the neck of the bottle. The stopple is then inserted in the neck to which it is fitted, and the gas, as it is formed, escapes through the neck that remains open. Now, in order to convey the gas thus evolved into a proper recipient, the instrument represented by fig. 30, is employed. This is a bent glass tube, with one end closely fitted in a cork that fits the open neck of the bottle fig. 29. This tube is fixed in its proper place, before the materials for evolving a gas are put in the bottle; and, if it is thought necessary, the juncture is luted. The gas, therefore, when formed, escapes from the open end *b* of this tube.

377. For procuring the gases that are producible by the aid of heat, the retort (fig. 18) is generally employed. The materials are inserted through the tubulure (or opening at the top of the body of the retort) which is then closed by a glass stopple; and the round part of the retort (which must be very thin in order that it may bear the application of heat) is then placed in one of the rings of the lamp-furnace, over a lamp giving a gentle heat. The materials will then give out the gas, which of course escapes through the neck *b* of the retort.—In many cases, a Florence flask (fig. 54) with a cork perforated by a bent glass tube, or even by a tin pipe, will serve instead of a retort, and it is much cheaper.

378. For receiving the gases, glass jars, of various sizes and shapes, (figs. 34, *a* 35, 36, 37, 51, 52,) are indispensible. The descriptions of these different figures will explain the peculiarities of each. Read, therefore, those descriptions.

379. To contain these jars, when in use, the *pneumatic trough* (fig. 25) is required. The description of figs. 25 and 27, gives a minute account of this apparatus, and must now be read. When the pneumatic-trough is used, water must be poured into it, till it rises about one inch above

the upper surface of the shelf (to the point marked *g* in fig. 27). When the glass jars *e* and *f*, (fig. 27) or any other vessels, open only at one end, are plunged under water, and inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for, in this case, the water in the jar, is sustained by the pressure of the atmosphere, in the same manner as mercury in a barometer. It may without difficulty be imagined, that if common air, or any other fluid resembling common air in lightness and elasticity, be suffered to enter these vessels, it will rise to the upper part, and the surface of the water will subside. If a bottle, a cup, or any other vessel, in that state which is usully called empty, though in reality full—of *air*, be plunged into the water with its mouth downwards, scarcely any water will enter, because its entrance is opposed by the elasticity of the included air: but if, while the vessel is immersed, its mouth be turned upwards, the air will rise in bubbles to the surface of the water, leaving that body to occupy its place in the vessel. Suppose this operation to be performed under one of the jars which are filled with water, the air will ascend as before; but, instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, we see, that air may be emptied out of one vessel into another by an inverted pouring. Just in this manner are gases collected in vessels placed in the pneumatic trough: the jars which are to receive certain elastic fluids, are filled with water, and placed, mouths downwards, upon the shelf, over the holes; and the necks of retorts, and ends of tubes, from which gases are evolved, are directed below the holes under the jars: then, the gases, as they issue forth, rise in bubbles through the holes, enter the jars, driving thence the water, and occupying its place. When, therefore, the jars are thus emptied of water, they are filled with gas.

380. When air is to be poured from a vessel with a wide mouth (such as fig. 36) into one with a narrow mouth, (such as fig. 34 and 37), the instrument (fig. 15,) called an *air funnel*, is employed: it is held under the shelf of the

trough, and its neck is put through one of the holes in the shelf, so as to enter the mouth of the receiver.

381. Many kinds of gas combine with water, and therefore cannot be collected in jars placed in the water-trough described above. For retained gases of this kind, the chemist usually employs a trough containing mercury; but this mode is much too expensive for the student to proceed in. A readier and cheaper plan of filling vessels with the only gases of this kind, whose properties the student need be acquainted with, is described in the experiments on ammoniacal gas, and carbonic acid gas. It is founded on the difference in the specific gravity of the airs.

382. An apparatus, almost indispensable in experiments on this class of bodies, is an *air-holder*, which enables the chemist to collect and preserve large quantities of gas, and to apply it to certain purposes, with great convenience. See fig. 61, and the description of it.

383. When trial is to be made of any kind of air, whether or not it is fit for maintaining combustion, the air may be put into a long narrow glass vessel, the mouth of which, being carefully covered, may be turned upward. A bit of wax candle being then fastened to the end of a wire, which is so bent that the flame of the candle may be uppermost, is to be let down into the vessel, which must be kept covered till the instant of plunging the lighted candle into it. Fig. 46, is a representation of this mode of making experiments.

384. Where the change of dimensions, which follows from the mixture of several kinds of air, is to be ascertained, an instrument called an *eudiometer* is made use of. This is represented by fig. 34. See the description of that figure. It should be accompanied by a glass tube containing exactly either one or two cubical inches.

385. It is frequently an interesting object, to pass the electric spark through different kinds of air. But, for the performance of this kind of experiment, an electrifying machine (an instrument which many persons may not have) is necessary; as also is an eudiometer of a peculiar construction. Fig. 63 shows this eudiometer, and the description of that figure, explains the method of using it.

386. As, for the purpose of experiment, it is frequently necessary to fill bladders with gases, we shall describe the mode of doing it.—This is *represented* by figure 35—*a* is a glass receiver, holding 3 pints or 2 quarts, open at the bottom, and having a short neck at the top. To this neck is cemented a brass cap, on which is screwed a stop-cock. We are to suppose, in the present case, that this receiver is standing on the shelf of the pneumatic trough, and that it is filled with gas. Take a bladder, with a stop-cock fastened to its neck by means of a ferrule, one end of which screws upon the stop-cock, and the other end of which has the mouth of the bladder tied securely round it. The bladder must be moistened, to render it flexible, and then pressed or wrung, to expel all the common air from it. *(This is necessary to prevent accidents.)* Shut the stop-cock, and then screw it to the stop-cock on the top of the receiver. Next, open both the stop-cocks, hold the apparatus in the manner shown by the figure, gently slide the receiver off the shelf, and press it down into the water: the gas will soon enter and fill the bladder, being forced through the opening, by the upward pressure of the water. The stop-cocks are then to be closed, the receiver replaced on the shelf, and the two vessels disunited.

387. When it is necessary, in order to make room on the shelf of the trough, to move some of the filled jars off it, proceed thus: if the jar to be removed has a wide mouth, it must be gently slid off the shelf into a flat dish filled with water. See figure 36. But if the jar has a narrow mouth, like figure 37, all that is necessary, is to insert in its neck (while it remains under water) a ground glass stopple, or a good cork. Some gases, such as oxygen, may be kept in common wine bottles, for several months, secured merely by corks.

388. If any thing, as a gallipot, is to be supported at a considerable height within a jar, a stand of wire (represented by fig. 48) is employed. This answers better than any other kind; because it takes up but little room, and is easily bent to any height or figure.

389. The method of *weighing gases* with accuracy is very simple, but it requires the aid of an air-pump. We deem

it, therefore, unnecessary to detail it; but shall show, amongst the experiments on gases, how to ascertain readily whether the specific gravity of a gas is greater or less than that of atmospheric air.

390. Previously to undertaking experiments on other gases, it will be well for an unpractised experimentalist to accustom himself to the dexterous management of gases by performing, with common air, the processes of filling bladders, transferring from vessel to vessel, &c.

391. In several cases of *distillation*, the substance raised is partly a condensable fluid, and partly a gas; which gas is incondensable by itself, but capable of being condensed by being transmitted through a liquid. The apparatus required by a process, in which this double purpose is effected, is represented by fig. 57, and is commonly termed Woulfe's apparatus. It is a series of receivers connected in a particular manner, and more or less in number as the case may require. The distilling vessel made use of, is the *retort*, (fig. 18,) into the tubulure of which, instead of a glass stopple, is inserted the safety-tube fig. 58.—See the description of that utensil. The first receiver *(a)* is joined to the retort, and has a right angled glass tube, open at both ends, fixed into its tubulure. *b* The second receiver, is a bottle to which, besides its usual neck at top, has an opening just at the place where its sides fall in to form the top: into this opening a glass tube is fixed diagonally, and the juncture is secured by the application of a lute. The lower end of this tube must be about an inch from the bottom of the receiver. *c* Is in every respect the same as *b*. The openings spoken of are at *g g*, and the tubes fixed in them are shown by *d d*. The small tube *e*, which rises from the first receiver passes down the diagonal tube in the second receiver; and another small tube, likewise marked *e* rising from (and luted in) the neck of the second receiver, passes down the diagonal tube in the third receiver. If there were more receivers, they would be like *b* and *c*, and connected in the same manner. The lower ends of the tubes *e e*, must project as far beyond the ends of the tubes *d d*, as they can do without touching the bottom of the bottles. The liquids by which the gas is to be absorbed are put into

the second, and subsequent receivers, each being filled two-thirds full. The nature of this liquid is regulated by the nature of the gas to be absorbed. For gases that are rapidly absorbed by water, (such as sulphurous acid, muriatic acid, &c.,) distilled water is made use of: for other gases (the carbonic acid for instance) solution of caustic potass is employed. In general, it is adviseable to put water into tho second receiver, and the alkaline solution into the third: the *first (a)* is always left empty.

392. The materials being introduced into the retort, the arrangements completed, and the joints secured by lutes, the distillation is begun. The condensable vapour collects in a liquid form in the receiver *a*, which is kept cool by being placed in water, or by having wet cloths applied to it. In the meantime, the evolved gas passes through the bent tube *e*, into the water contained in *b*, which continues to absorb it (if it is a gas absorbable by water) till it is saturated. When saturation takes place, or when no absorption ensues, the gas bubbles up through the water, passes through the second pipe *e*, and enters the receiver *c*. —And so the process continues till the liquids in all the bottles are saturated; and, then, if any gas continues to be produced, it escapes through the neck *f* of the last receiver. Should it be required to preserve this overplus gas, it may be conducted into a receiver placed in the pneumatic trough, by fitting into the neck *f*, the bent tube, fig. 30.

393. It will be now proper to point out the use of the tube of safety, (fig. 58), and of the wide diagonally-fixed tubes *d d*. Supposing the retort to be closed by a stopple as usual; and supposing the bottles to be destitute of those tubes, and, consequently, that *e e*, were luted into the receivers at *g g*, the process would be then liable to be interrupted by an accident: for if, in consequence of the irregularity of the beat, or other circumstances, a vacuum should be produced in the retort, by the re-absorption of gas, the liquids in the different receivers (being acted upon by the pressure of the atmosphere at *f*) would rush from one into another to supply that vacuum, and by such a mixture of products the whole experiments would be spoiled. If, on the contrary, gas were to be evolved faster than it could

be absorbed by the different liquids, or than it could escape at *f*, the apparatus might burst, with considerable danger to the operator. Should the operator close *f* as well as all the other places, then the apparatus would be destroyed, if either absorption or expansion took place; for in the one case the external air would press the vessels till they broke, and in the other, the same effect would be produced by the elasticity of the gas confined within. Now all these inconveniences are obviated by the employment of the different tubes. If an absorption takes place, when these tubes are fixed in the manner that has been described, the vacuum is instantly supplied by the external air, which rushes down the tubes *d d*, into the receivers, and down the tube of safety into the retort. The experiment being thus prevented from failing altogether, at the price of having a small portion of common air mixed with its products. On the other hand, no gas can escape, for any pressure within is instantly followed by the formation of a high column of liquid in the tubes *d d*, which resists the egress of gas, as long as is consistent with safety.

394. We have now described all those chemical processes, which the experimentalist is in general called upon to conduct; as likewise, the apparatus he finds it necessary to employ: and in such a manner, as, we hope, will render our instructions beneficial to those who consult us. But besides the instruments used in the general operations, many others are requisite for the obtainment of various particular objects. The figures on the annexed plates, with the following explanation of them, will give the student an idea of a vast variety of the most useful and necessary articles of *the* chemical apparatus with which, in consistence with economy, he may provide himself.

395. Fig. 1, 2, 3, (plate 1.)—Crucibles.—These vessels are of indispensable use in the operation of *fusion*. They are formed of the following substances: earthenware, black-lead, silver, platinum. The best kind of earthen-ware ones, are those called Hessian crucibles. These are of the shape represented by fig. 3. They support a very intense heat without melting: but unfortunately, are liable to crack unless heated and cooled very

gradually. The crucibles made of black-lead, are *not* liable to be cracked by alteration of heat; but they are unfit for the fusion of alkaline or saline matters. For these last mentioned bodies, crucibles of silver must be used; and, for exposing bodies to a very great heat, those of platinum are necessary.

396. But for all ordinary purposes, the earthen-ware crucibles are the best in every respect. They are strong and cheap, and those are the grand points. You may buy at an iron-mongers, a set, (of shape fig. 3,) containing six, of different sizes, for *ninepence*. The metallic crucibles are sold by the ounce. Crucible covers (see fig. above fig. 2,) cost from *2d.* to *6d.* each.

397. Fig. 4.—A Wedgewoods-Ware Evaporating Basin. This is an utensil of great utility. The substance of which it is formed, is so compact, that a strong heat may be suddenly applied to it, without any danger of its breaking. It also has the advantageous property of being unacted upon by acids. For the convenience of pouring liquids out of it, it is furnished with a spout. The student will find, that, for the numerous operations of evaporation and crystallization, he will require two or three of this article. Let him buy, at the shops where Wedgewoods-ware is sold, one at *6d.* one at *9d.* and at *1s.* These will measure (across the top) from $2\frac{1}{2}$ to 5 inches. Sometimes, for evaporating small portions of fluids, small capsules, resembling watch-glasses, are employed. These like all glasses intended to be heated, must be thin at the bottom.

398. Fig. 5.—A Wedgewood's-ware Pestle and Mortar. This, like the article just described, has the properties of strength and unalteration by acid menstrua. It is so useful an utensil that the student *must* have it. He may buy, at the place where he gets the evaporating basin, a mortar measuring 4 or 5 inches across the top. This is a very convenient size: such an one will cost about *2s. 6d.*

399. The *Carron Company* sell *cast iron mortars*, at very low prices. The writer of this bought of one of their Agents, (an Agent for the Carron Co. is to be found in most large towns,) a strong neat pestle and mortar, weighing 7 pounds, for *fourteen-pence*. This iron

mortar should be got, (if convenient,) in *addition* to the one of Wedgewood's-ware.

400. Fig. 6, 7, 8, 9, PRECIPITATING AND DECANTING GLASSES of various shapes and capacities. The height of them is about 6 or 7 inches. Their other proportions may be calculated from this standard. The kind employed for decantation, are the ones with spouts. Go to a glass-house for these articles. No. 6, will cost 9*d.*; No. 7, 1*s.* 6*d.*; No. 8, 1*s.* 6*d.*; No. 9, 1*s.* They should be made of thick glass so as to be strong; for they are frequently used: and the glass must be clear, otherwise the colours produced by the action of the precipitant, or test, will not be visible.

401. Fig. 10.—A GLASS FUNNEL *with a long neck.*—It should be about twelve inches in length. Its use is described in the experiments for the performance of which it is necessary. This, like all other glass utensils, must be got at a glass-house. It will cost 1*s.*

402. Fig. 11.—A DROPPING TUBE.—This is a glass tube, six inches in length, with a bulk about one inch in diameter blown in the middle of it, and having its lowermost point drawn out till the opening in it is very small. It is used to convey from one vessel into another, a small quantity of water, or of any other liquid that the purpose may require. The manner of using it is this: while the lower end is immersed in the liquid, the ball is filled by the action of the mouth which is applied to its upper surface. The latter is then closed by the finger; the water remains suspended in the tube, until it is removed to the place where it (the water) is to be put, when, by cautiously removing the finger, it is expelled in drops. Filters may be washed very neatly by means of this tube. A glass-blower will make the instrument for sixpence. When the student can manage the blow-pipe, he may easily make such things as this himself.

403. Fig. 12.—A GRADUATED JAR FOR MEASURING LIQUIDS.—This is a cylindrical glass vessel, which holds, when filled to a certain mark made near the top, two ounces of distilled water, at the temperature of 60°, in short, two ounces of clear cold water. It has other marks all down it, as low as one drachm; so that any quantity of

water from one drachm (or, indeed the $\frac{1}{2}$ or $\frac{1}{3}$ of a drachm) to sixteen drachms, may be readily obtained for any required purpose.

404. But, besides the utility of this utensil for measuring water, it may be also employed, when the purpose does not require great accuracy, to measure liquids whose specific gravities are different. If, for example, we wish to obtain an ounce of sulphuric acid, we proceed thus: knowing, that the specific gravity of sulphuric acid is to the specific gravity of water, a little less than as 2 is to 1; and, consequently, that if an ounce of water occupies a certain number of divisions in this tube, then an ounce of the acid can only occupy a little more than half that number; of course, an ounce of sulphuric acid is readily obtained by pouring that liquid into the tube till it rises a little above the mark for $\frac{1}{2}$ an oz. of water. We proceed in like manner for other fluids, calculating the bulk according to the specific gravity. It is by no means intended, by the recommendation of this manner of measuring liquid in general, to do away with more accurate modes: we only point out a method of proceeding in common cases, calculated to save time.

405. It may be observed here, that when, in giving directions for the performance of an experiment, we say, "an ounce *by measure*," it signifies by the measure for water. "An ounce of sulphuric acid by measure" is really almost two ounce of that liquid.—The price of this jar is about 2*s*. 6*d*.

406. Fig. 13.—A Ribbed Glass Funnel used for *filtration*, and described under that head. It costs about 6*d*. or 8*d*. according to the size.

407. Figs. 14, 16, 17.—Test Glasses.—The name is here expressive of the nature. They are used to hold small quantities of liquids to which *tests* or *re-agents* are to be applied, in order to discover what bodies those liquids hold in solution. They are also used for the purposes to which figs. 6, 7, 8, 9, are applied. Fig. 17, is quite round and smooth at the bottom, so that any substance which may subside, can be readily taken out for the purpose of being weighed. The price of these is about 6*d*. each.

408. Fig. 15.—A Glass Funnel *used to convey Gas from a wide mouthed vessel into one having a narrow mouth.* It may measure five inches across the wide part, and be about 4 inches in depth. Get it made at a glass-house: it will cost 8*d.*

409. Fig. 18.—A Tubulated Glass Retort, which, as well as its use, is described under the head "*distillation,*" at 377, and other places. Retorts are made of various sizes; one of which the body *(a)* will hold 8 or 10 ounces of water, is a very convenient size for ordinary purposes. The price of such an one is about 2*s.* 6*d.* Note.—*In selecting, at the glass-house, a retort, or any other utensil to be placed over a lamp or in a sand-bath, be careful to take one with as thin a bottom as can be got. Thin glasses are the only ones that will bear the application of heat; thick ones crack immediately upon being put to the fire.*

410. Fig. 19.—A Tubulated Glass Receiver, whose use is described under "distillation." One holding 10 ounces (which is a very good size) will cost about 2*s.* Both *receivers* and *retorts* may be had without *tubulures,* and they then cost less than the others; but we recommend the student to get those that *are* tubulated, because the difference in price is more than overbalanced by the convenience of them.

411. Fig. 28.—An Adopter; a tube of glass of unequal dimensions; used for lengthening the necks of retorts, and for fitting retorts to receivers. It may be made by the help of the blow-pipe, from a piece of glass tube. When bought ready-made, it costs about 6*d.* or 8*d.*

412. Fig. 21, (plate 2.)—A Chemical Lamp for the table furnace, fig. 23. This instrument affords the means of obtaining either a strong or a gentle heat, for a number of hours at once. It is simple in its construction, and, therefore, the more convenient for those who are inexpert.

413. *a* Represents the body of the lamp, or that part of it which contains the oil. This (which is circular) measures in altitude 1½ inches, in diameter 3 inches. Fig. 22, represents the top of it: *b* is the outer extremity, *a* is a tube passing through (but of exactly the same length as) the lamp, serving as a passage for a current of air which is necessary to support the combustion of the oil. This tube

is supported in its place, by having its lower end soldered to the bottom of the lamp at the place where it cuts it. Round its upper end, but a little below the top of it, is fitted a rim of brass, which has six cylinders of tin an inch in length, and 1.6th of an inch in diameter, soldered in so many holes made at equable distances in it to receive them. This is shown by fig. 22. Only about the $\frac{1}{4}$ of an inch of the length of these small pipes projects above the top of the rim, the long parts go down into the body of the lamp. These tubes are, as will readily be imagined, intended to hold the wicks. The rim is fastened in its place, by another brass rim which *screws* on above it. *d* Figs. 21, and 22, show a small pipe, through which the oil is introduced, and which, when the lamp is filled, is closed with a brass screw. At *e* fig. 22, is a small hole intended to receive the wire *e*, fig. 21. This wire rises two inches perpendicularly from the top of the lamp, and then turns off horizontally, terminating in a ring of the same size and hanging directly over, the afore-mentioned rim of brass which bears the wicks. Into this ring is fitted a tin cylinder (*b*) (which must be kept *bright)* of such a length as to come to 5.8ths of an inch from the tops of the little tubes whence the cotton issues. The wire *e* fits easily into the hole that receives it, so that it may be readily moved about. The use of the cylinder is to condense the flame. Its action differs in no respect from that of the glass ones used in common; but it is to be preferred to them, on account of its being cheaper, and not liable to be broken. Its opacity is no argument against it; because the flame of this lamp is not valued for the *light* it furnishes, but for the *heat*.

414. From what has been said, and from an inspection of the accompanying figures, a clear idea of the construction of this instrument may readily be obtained.

415. By depressing three of the wicks, and lighting the remainder, a small flame is produced. By lighting all the wicks a strong flame is produced. The heat is kept up very regularly; and *no smoke arises*. Any tin-smith will be able to make a lamp of this kind, and the price of it will be about 3*s*. 6*d*.

416. Fig. 23.—A Table Lamp-Furnace.—This is an

NATIONAL LIBRARY OF SCOTLAND

instrument of great utility. There may be performed by its aid a vast variety of chemical operations on a small scale, in a very easy and expeditious manner. It consists of a rod of iron *a*, two feet long, and rather less than half an inch thick, screwed into a foot of the same metal. Upon this upright slide three sockets with horizontal arms terminating in rings, (all made of iron) which are in diameter $2\frac{1}{2}$, $3\frac{1}{2}$, and $4\frac{1}{2}$, inches; and they are fixable at any height, or may be turned round in any direction, by means of screws affixed to the sockets. These rings serve for supporting glass alembics, retorts, flasks, evaporating basins, &c.; for performing distillations, digestions, solutions, evaporation, analyses with the pneumatic apparatus, &c. &c. *c* Is an evaporating basin placed on a ring in the manner described. The lamp (either fig. 21, or 24) which is to furnish the heat, is placed beneath the utensil to be heated at any distance which may be required. If a strong heat is wanted, the distance must be small; if a gentle heat, the distance may be greater.

A working smith, or iron-monger, will make a stand of this kind (*not* including a lamp, of course) for 4*s.* 6*d.* Sometimes in addition to the three rings, the stand has another arm with a board fixed to it for supporting a lamp (see the figure;) but it is as well to lay a piece of board across one of the rings, or to give the lamp a separate support.

417. Fig. 24. A Spirit Lamp. This, for experiments in the small way, where but a moderate degree of heat is required, is an excellent contrivance. It is a glass vessel, of a flattish-globular shape, with a wide neck, and holding somewhat less than a common wine glass. On the neck is laid a circular concave piece of brass, with a small cylindrical pipe, an inch long, passing through the middle of it, to contain the wick (which is of common cotton). The price charged for this lamp, by the chemical instrument makers, is 1*s.* 6*d.* Alcohol burns with a flame which is large or small, according to the size of the surface of the cotton wick. It gives no smoke, it has no disagreeable smell, nor does it spoil any thing if it happens to be overturned. But with its many advantages, it has one great

disadvantage, namely, that it cannot be used much, on account of the great expense attending the consumption of the spirit of wine.

419. Fig. 25.—A PNEUMATIC TROUGH.—This is a strong, square, water-tight, wooden box; the internal dimensions of which are as follows: depth eight inches, length and breadth each sixteen inches. A shelf, sixteen inches long, and eight inches wide, having four holes cut in it, as is represented in the figure, is fixed on one side of the interior of the *trough*; at such a height as to leave a space of two inches and a half between *its* top and the top of the box.—For an account of the uses of the pneumatic trough, see 379.

419. Fig. 27, is a section of the box: *a* is the body or open part of the trough, *b* is the shelf, *e* and *f* are two glass jars, inverted over two holes (*c* and *d*, made in the shelf.)—If the retort is used, (in the manner directed in paragraph 377,) the neck of it is most conveniently brought under the hole *c*; but if the bottle, (fig. 29,) is employed, the end *b* of the bent tube, (fig. 30,) which is fitted to that bottle, is put through the opening *d*, in such a manner as that its point may turn up directly under a jar placed as *f* is.

420. Sometimes pneumatic troughs are made of tin, but wooden ones have many advantages; and the only great objection to them is, that they are not always water-tight. If, however, the carpenter who makes the box, takes care that the joinings of it, are, by dove-tailing and rebatting, fitted closely together; and if a strong coat of paint be applied to it, both within and without, it will bear water without losing a drop. The shelf may be made moveable, and a moveable top may be fitted to the box, which may be also furnished with a lock and key. All these things are useful. When the box is not to be used for some time, place the shelf at the bottom of it, upon that, place the instruments formed of glass, then lock on the lid of the box, and all will be free from injury. For a box, made of strong wood, according to the directions here given, the writer of this paid—to the Carpenter, 8*s*.—to the Painter, 2*s*.

421. It may not be amiss to observe, that in a case of

emergency, a good substitute for a pneumatic trough, is a wash-hand basin, or small wooden tub, with a board, which has a hole in it, large enough to admit the neck of a common wine bottle, laid across it.

422. Fig. 26.—A GLASS ALEMBIC for distillation and sublimation, described at 339. The head must be made to fit the body of it very exactly, or the substance that is volatilized will escape between them, and be lost. It must likewise be depressed round its lower part, so that a circular channel may be formed, to conduct the condensed fluid into the pipe *c*. An alembic, of which the body will hold a wine-pint, with a head proportionably large, will be of a sufficient size for common purposes, and will cost about *5s.*

423. Fig. 28.—A SMALL GLASS RECEIVER.—This is sometimes fitted to the neck *c* of the *alembic*, to serve as a recipient of the product of distillation, in lieu of the vessel *d*, fig. 26.

424. Fig. 29. (plate 3.)—A WOULFE'S BOTTLE *with two necks*, one of which is furnished with a glass stopple, fitted closely to it by grinding. This apparatus is much used in experiments on gases.—See 376. It may be had at any glass-house. One capable of holding twelve ounces of water is a good size, and such an one will cost *2s. 3d.* or *2s. 6d.*

425. Fig. 30. Is a glass tube, of the size shewn by fig. 55, bent in such a manner, and of such a size, as fits it to convey a gas from the bottle, fig. 29, into a receiver placed in the pneumatic trough, fig. 25; *a* is a cork fitted to one end of the tube, and adapted to the neck of Woulfe's bottle; *b* is the end of the tube which is to be directed under a receiver.—See 376, and 419. This bent tube cannot be provided till both the trough (fig. 25) and the bottle (fig. 29) are ready for use: when the student has these, he must bend a piece of wire into the exact figure of which the tube (in order to fit the two instruments) must be a counterpart. Then, according to this pattern he must bend his tube; but if he cannot manage that himself, he must get it done at a glass-house, where he will have to pay about *8d.* for it.

426. Fig. 31.—A Jet-Pipe for making some experiments with hydrogen gas. It is simply the shank of a tobacco-pipe cemented into a cork, which fits one of the necks of the Woulfe's bottle, fig. 29.

427. Fig. 32.—A Stop-Cock represented on a large scale—And such an one as ought to be fitted to a bladder. *a* Represents a screw on which is fitted the ferrule or plug that goes into the neck of the bladder.—See 386. This ferrule must be indented or roughened on the outside, in order that the string by which the bladder is bound upon it, may have something to hold by. At the end of the stop-cock marked *b*, there are two screws; an internal one which fits the screw of fig. 49, and an external one adapted to the screw *b* of fig. 50, and to the screw *b* of the receiver *a*, fig. 35. *c* Is a screw that opens or shuts up the communication through the stop-cocks. It may be observed here, once for all, that whenever stop-cocks, or other apparatus are screwed together, great care must be taken to fit them closely. Every juncture must be rendered air tight, by the interposition of circular pieces (or rings) of oiled leather. These stop-cocks are made of brass, and may be bought of the tradesmen who fit up the gas-pipes in shops, at 1*s.* to 1*s.* 3*d.* each.

428. Fig. 34.—An Eudiometer, or graduated glass tube used to measure the purity of air. *How* the purity of air is ascertained will be shown amongst the experiments: we have here to describe the instrument. Its length is 18 inches, and its diameter 1 inch; its bottom is shaped like a funnel, in order that it may stand firmly, and its side has a scale drawn down it, graduated into equal measures of capacity—into cubical inches, or halves, or fifths, or tenths of cubical inches. One graduated to half inches will be sufficiently fine for all the purposes a student will require it.

429. One method of graduating (or drawing scales on) glass jars is as follows: fix the jar to be graduated mouth upwards, in such a manner as to make it stand firm without being held by the hands, then take a vessel capable of holding a certain quantity of water—for want of one holding a cubical inch, or half a cubical inch, use the graduated jar,

fig. 12, and mark half-ounces by it; fill this measure with cold water, pour the water into the jar, and make a mark on the jar, exactly at the surface of the water, with a file, or (which is much better) a glazier's diamond. Continue thus to pour in succession equal measures of water, and mark its surface at each addition.

430. Fig. 35.—A Representation of the Mode of Filling Bladders with Gases.—See 386. *f* Is part of the pneumatic trough fig. 25; *h* is the shelf; *g*, shows the height of the water in the trough; *a* a glass receiver, holding three pints, open at bottom, and with a narrow neck at top; *c* a brass cap cemented on the neck of the receiver, and having a screw adapted to one of the screws of the stop-cock *b*; *d* is a bladder into which gas is being driven from the receiver; and *e*, *b*, are the stop-cocks of the bladder and receiver fitted together to open a communication. A jar of this capacity may be got made for 3*s*. and the brass cap will be fitted on by a furnishing ironmonger for 1*s*. 6*d*. The prices of the other parts of this apparatus are mentioned elsewhere.

431. Fig. 36.—A Gas Receiver of a very convenient form. It is of glass, holds a quart, is open at bottom, and has a nob by which it may be held at top. It is represented as filled with gas, and standing in a dish filled with water, which forms a portable pneumatic trough.—See 387. Such a jar costs 1*s*. 6*d*.

432. Fig. 37. A Gas Bottle *for experiments on the combustion of bodies in oxygen gas*. It must hold about a quart; and be *thin* round the sides, in order that it may not be cracked by the heat produced by deflagrating a body within. When this utensil is used, it is filled with gas, in the common method, over water, and its mouth is secured by the insertion of a ground glass stopple. In this state it may stand upright on a table, and is ready for an experiment. The price of a gas bottle of this kind, with the stopple, at a glass-house, is about 1*s*. 6*d*.

433. Fig. 38. A Copper Deflagrating Ladle for containing substances that are to be immersed, in a state of combustion, in the oxygen gas contained in the bottle, fig. 37. The bowl of the ladle is about the size, and the piece

of metal it is made of about the thickness, of a shilling. The thin part or shank of the ladle passes through a cork that is adapted to the neck of fig. 30. When the cork is fitted into its place, the bowl of the ladle must be about $\frac{1}{4}$th of the whole height of the bottle from the bottom of it. The price of this ladle is 1*s.* Any coppersmith will make it.

434. Fig 39.—A Spiral Iron Wire with a cork on its upper part that fits the neck of the gas bottle, fig. 37, and on its lower extremity, a bit of tinder. This apparatus is employed in the experiment which exhibits the formation of a metallic oxide, by the combustion of a metal in oxygen gas. The kind of wire that is used is about 1.30th of an inch thick, and is called by the ironmongers who sell it, *binding-wire.* In order to bring it into the spiral, or cork-screw shape, it is coiled lightly round a stick of half an inch diameter, and then drawn off it. Afterwards, the cork is fitted on it, it is drawn out to a proper length, ($\frac{3}{4}$ that of the bottle, say,) and has a morsel of tinder, charcoal, or thread dipped in brimstone or turpentine, fixed upon its lower end. Twopence worth of this wire is enough for a great many experiments.

435. Fig. 40.—An Economical Galvanic Apparatus. Obtain a number (say thirty) of the smooth old penny pieces; and the same quantity of plates of zinc of the same size. The pieces of zinc may be easily cast in a mould made of clay, for that metal is of about the same degree of fusibility as lead. Crude zinc to make them of, may be purchased at a brass-foundry, at tenpence a-pound. In addition to the plates of copper and zinc, it is necessary to be provided with the same number of pieces of woollen cloth, rather smaller than them in size. Let these be soaked in a solution of common salt, till they have thoroughly imbibed it: when they are to be used, they must be taken out of the solution and gently squeezed, in order to force out the superabundant water.

436. The *Voltaic Pile* (*a*, fig. 40) is to be formed of these materials in the following manner: lay down on a circular piece of wood a plate of zinc, upon that a plate of copper, and then a piece of moistened cloth—let this arrangement be continued—zinc, copper, cloth—zinc, copper, cloth,

till all the pieces that have been provided are laid on. As the pile began with zinc it must be concluded with copper. The number of pieces of each substance must be at least twenty, and may be advantageously extended to fifty; for the more pieces there are, the greater will be the effect produced by the pile which they form.

437. But a pile thus formed, is, when tall, very liable to be overthrown, and must, therefore, in order to avoid this accident, be supported. The method usually adopted to hold it up steadily, is to fix into the piece of wood on which the pile is formed, three rods of glass, which may touch the pieces of metal at three equidistant points. Down these rods may slide a piece of wood similar to the bottom piece, for the purpose of keeping by its pressure the different parts of the pile in close contact. Fig. 33, is intended to represent this top—the circle in the centre shows the situation of the pile—the three small circles, between the outer and inner large circles, show the places where holes are cut for the reception of the glass rods. The upper side of the piece of wood *b*, and the under side of the other piece of wood, must be lined with tin foil. In the figure is represented the arrangement employed in decomposing water. *c* Is a glass tube filled with water, and having the ends closed by corks: *d* and *e* are wires, one of them having an end fixed to the top of the pile, and the other an end fixed to the bottom of it. The other ends of these wires are passed through the corks, and in the tube *c*, approach to within a quarter of an inch of each other.

438. The zinc plates in the voltaic pile become oxydated after being used a certain time, and then the galvanic action ceases; but they may be cleaned by being put into diluted muriatic acid, by which the oxide is dissolved. They may also be cleared of the oxide by being filed.

439. A Specific-Gravity Bottle.—The use of this is described at 322. It is a little globular bottle with a flat bottom. It has a glass-ground stopple, with a small hole through it. When the bottle is filled with water, or any other liquid, and the stopple put in its place, the superfluous water escapes through the hole, and the bottle remains quite full, without any portion of air. A bottle holding

1000 grains (but a smaller one will do) costs about 2*s.*— A weight to counterpoise the bottle must be obtained, made of brass or lead.

440. Fig. 42. (Plate 4.)—APPARATUS FOR EXHIBITING SOME OF THE PROPERTIES OF HEAT.—*a* Is a glass tube of the thickness of fig. 55, and about ten inches long. *b* Is a ball or globe blown at one end of the glass tube. A glass-blower will charge about 9*d.* for this instrument. *c* Is a small stool, having a hole in the top, through which the lower end of the tube *a* is put, in order that it may be kept steady, and upright.

441. Fig. 43.—DR. WOLLASTON'S CRYOPHORUS, or *frost-bearer.* It is a glass tube of the thickness of fig. 55, and about twelve inches long. At each end of this tube is a ball of one inch diameter, and the tube is bent to a right angle at the distance of half an inch from each ball. One of these balls (as *a*) should be somewhat less than half full of water, and the remaining cavity should be as perfect a vacuum as can readily be obtained; which is effected by making the water boil briskly in the one ball before sealing up the capillary opening left in (*b*) the other ball. A glass-blower will charge about 1*s.* 3*d.* for this instrument.

442. Fig. 44.—A LAMP to be used with the blow-pipe. *a* Is a little oblong tin dish, similar to those that tarts are baked in; *c* is a tin tube soldered to the bottom of it, and is used to hold the lamp on a candlestick. Over half, or three-fourths, of the top of this vessel is fixed a broad piece of tin, and through the part remaining open, rises in a diagonal direction, a wide tin tube (*b*) intended to hold a cotton wick.—A tinsmith will make this lamp for 4*d.*

443. Fig. 45.—APPARATUS FOR PRODUCING MUSICAL SOUNDS BY THE COMBUSTION OF HYDROGEN GAS.—*a* The bottle whence hydrogen gas is issuing through the pipe *b*. *c* A glass tube eighteen inches long, and one inch wide, held over the flame produced by the burning gas.

444. Fig. 46.—APPARATUS FOR ASCERTAINING WHETHER A GAS WILL SUPPORT COMBUSTION.—See 383.

445. Fig. 47.—APPARATUS FOR SHOWING THE COMPOSITION OF WATER BY THE COMBUSTION OF HYDROGEN GAS.—

a Is a glass vessel held over the flame produced by the burning of the hydrogen gas.—See 443.

446. Fig. 48.—A Wire-Stand.—See 388. The wire should be 1-10th of an inch thick; the metal may be brass or iron. The foot is a solid lump of lead.

447. Fig. 49.—A Jet-Pipe, made of brass. The lower end is a screw, adapted to the screw of a stop-cock, on a bladder.—See 427. The opening at the point of the pipe must be very small, like the jet of a blow-pipe. The length of this jet-pipe must be about three inches. It may be procured at the place where the stop-cocks are purchased. The price of it will be 1*s*. 3*d*.

448. Fig. 50.—Apparatus for Filling Soap-Bubbles with Hydrogen Gas.—*a* Is a piece of a common tobacco-pipe. *c* The end of a small brass cylinder into which the pipe is cemented. *b* The end of the brass cylinder in which there is a screw fitting a screw on the stop-cock of a bladder.—See 427. Before the end of the tobacco-pipe is put into the end of the brass tube, it should have a piece of thin oiled leather wrapped round it, to make the juncture air-tight. The piece of brass may be about an inch long; it can be made by the person who makes the jet-pipe, and will cost 1*s*.

449. Fig. 51.—Apparatus for obtaining without the aid of the Pneumatic Trough, Gases that are lighter than Common Air.—See the experiments on ammoniacal gas.

450. Fig. 52.—Apparatus for obtaining, without the aid of the Pneumatic Trough, Gases that are heavier than Common Air.—See the experiments on carbonic acid gas.

451. Fig. 53.—A Mattrass, or Bolt-Head.—*a* Is a glass tube six inches long, and wide enough to allow a sixpence to pass down it. *b* Is a ball of rather more than two inches diameter blown at the end of the tube. The ball must be very thin at the bottom, as it is to be exposed to heat. For the use of this instrument see 331, 334. The glass-blower charges about 1*s*. 3*d*. for it.

452. Fig. 54.—A Florence Flask; an instrument of great utility in performing the operations of digestion, so-

lution, &c. being made of very thin glass, it bears the sudden application of heat excellently; but, on account of *that* thinness, is very liable to be broken by a slight blow: it therefore requires to be handled carefully. The student should be provided with several of them. They are to be had of oilmen, who sell the empty flasks, after having disposed of the Florence oil they contained. Sometimes they are charged 4*d.* at other times 3*d.* and 6*d.*

453. Fig. 55.—A PIECE OF GLASS TUBE of the size generally employed to convey gases from the vessels they are formed in, to the receivers which are to contain them. *b*, *b*, show the thickness of the tube; *a*, *a*, show the width of the internal part of it. The instruments represented by figures 30; 58; *e*, *e*, fig. 57; *a*, fig. 42; and fig. 43; are all formed of tubes of this size.

454. Every chemist should be provided with an assortment of glass tubes of different lengths and thicknesses; for in various operations he is obliged to employ them, and whenever he wanted a bit of tube, it would be a very great waste of time to have to go and buy it. The student should go to a glass-house, and choose out about a pound, or half a pound weight of tubes, sorted. The thinnest about the size of a small quill, the thickest about an inch in width. The tubes marked *d*, *d*, fig. 57, should be $\frac{3}{4}$ of an inch in diameter.—These tubes cost from 3*s.* to 4*s.* a pound. The highest-priced ones being those which are very regular in the bore, and are used to form barometers and thermometers. For many purposes, green glass tubes will suffice, and they are much cheaper than the others. A considerable quantity may be bought at a bottle work for 1*s.*—Glass tubes may be easily cut to any required length by a small file, and (if thin) they may be bent (as fig. 30, and *e*, *e*, fig. 57, are, or in any other directions), by the aid of the blow-pipe. But for boltheads, and other apparatus made of thick tubes, drawings must be given to a glass-blower.—Occasionally, for conveying gases, metallic tubes are employed. Gases that have no action on metals (such as oxygen and hydrogen) may be economically transferred through tubes of tin, lead, or copper. Small gas-pipes

are easily procured, are cheap, and durable, and very flexible; they may be easily bent into any required shape.

455. Fig. 56, *(Plate 5.)*—THE COMMON STILL.—This figure is given to illustrate the ordinary method of distilling, and has been described already—see 338, article *distillation*.

456. Fig. 57.—WOULFE'S APPARATUS described at 391, 392, 393. The retort used with the apparatus is that represented by fig. 18. The receiver *a* is represented by fig. 19. The receivers *b*, *c*, may each hold 10 or 12 ounces, and will cost (without any of the tubes) about 2*s*. each. They are to be had at the glass-houses.

457. Fig. 58.—A TUBE OF SAFETY.—This is a glass tube as thick as fig. 55, and of about sixteen inches in length, bent as represented in the figure. One end of this is fastened into a cork, and the other made into the form of a small funnel. *a* Is the cork, *b* the funnel. In cases of distillation in which sudden absorption, or expansion may take place in the retort,—see 391, 393; this utensil is fitted into the tubulure, and the bended part of it *(c, c)* filled with water. Then, if a vacuum happens to be produced in the retort, the external air forces its way through the tube to supply that vacuum; and, on the contrary, if expansion takes place, the elastic fluid gains room by forcing the whole water between *c*, *c*, up into the straight part of the tube under the funnel *b*. A number of other uses to which the safety-tube is applicable, are described in particular experiments. It costs about 1*s*. when bought ready made, but it is easily formed out of a glass tube.

458. Fig. 59.—A BLOW-PIPE.—For an account of the mode of using this instrument, see 352. The blow-pipe is generally formed of brass; a single plain tube without a bowl for condensing the vapour, may be bought for 1*s*. This is the kind that working jewellers use. The blow-pipe for very accurate experiments (young students need not have this) *must* have the enlargements, and be provided with moveable nozzles. Such an one will cost 5*s*. Chemists frequently employ blow-pipes made of glass, chiefly because it is more easy to give to glass than to brass a small smooth opening; but glass ones have the disadvantage of

being easily broken. A glass blow-pipe resembling fig. 59, may be bought for 1*s.*

459. Fig. 60.—A Platinum Blow-Pipe Spoon.—See 356, for an account of the use of this instrument. *a*, The bowl, should measure $\frac{1}{2}$ an inch across the top; *b* is the handle made of wood; *c* is the shank, made of platinum, or sometimes (for cheapness) of silver. The whole length of the instrument should be about six inches. The metal platinum being almost infusible, bears uninjured a very strong heat; but it cannot be used with alkaline fluxes, because it has a strong tendency to combine with those substances. Whenever, therefore, these fluxes are employed, charcoal, or spoons of silver, must be used. The platinum blow-pipe spoon costs 2*s.*

460. Fig. 6, (plate 6.)—A Gas-Holder.—(This apparatus is sometimes made sufficiently large to hold eight gallons; but *the student* need not get one larger than that which is described here.) *a* Is the body, or reservoir, of the gas-holder; which is of a circular figure, and measures in diameter $8\frac{1}{2}$ inches, in height, 10 inches. It holds about nineteen wine pints. This reservoir is made of tin plate; as, indeed, are all the other parts of the apparatus, except where the contrary is mentioned; and the whole of it is japanned. *b* Is a shallow cistern, fixed by four small supports over the reservoir, at the height of four inches; *c* and *d* are stop-cocks, communicating with both the reservoir and the cistern; *d* just enters into the top of *a*; but, to *c*, there is a tin tube affixed, which goes to half an inch from the bottom of *a*. This tube is rather less than half an inch in diameter. The tops of the stop-cocks (or rather of the tubes in which they are inserted) are exactly level with the bottom of the cistern *b*. *e* Is a funnel, the pipe of which is two feet long, and half an inch in diameter. It is made to fit the pipe of *c*; but can be readily taken away, when required. *f* Is a glass tube, of a quarter of an inch bore, communicating at both ends with the reservoir. The manner in which it is properly fixed in its place is shewn by fig. 62; where *a* represents the body of the gas-holder; *b*, and *c*, two tin tubes projecting from it, and *d*, (dotted lines,) the glass tube, fastened, by glazier's putty, into the tin

tubes. *g* Is a short tube issuing from the bottom of the reservoir; and *h* is a stop-cock communicating with the top of the reservoir; *i* is a blow-pipe affixed to the stop-cock *h*, and serving to direct a stream of gas, upon a substance held to it on the stand *k*; *l* is one of the handles by which the machine is lifted.

461. The following is an account of the cost of the gas-holder of which the above is a description. 3 Stop-cocks, 3*s*. 6*d*.; brass screw for *g*, 1*s*.; glass tube *f*, 3*d*. To the tinsmith, for reservoir, cistern, funnel, for putting all together, and for varnishing, 5*s*. 6*d*. *k* and *i* are supernumaries. Such a blow-pipe as *i*, however, costs 1*s*.

462. When it is intended to fill this apparatus with gas, the funnel *e* is removed, (*that* being wanted in particular cases only), the tube *g*, and the stop-cock *h*, are closed, and the stop-cocks *c*, and *d*, are opened. Water is then poured into the cistern, and is thence conveyed into the reservoir, by the tube affixed to *c*; while the air in the reservoir is forced out through *d*. Thus, in a short time, the body of the gas-holder is filled with water and all the air is driven out of it. When this is the case, shut *c* and *d*, and open *g*, into which introduce the beak of the retort, or the tube, whence gas is issuing. The mode of introducing the tube into this opening is shown by fig. 67.—The water does not run out at the aperture *g*, when the screw is taken from it; because the stop-cocks, *c*, *d*, cut off the pressure of the atmosphere. But, as gas which issues from a tube put in *g*, rises through the water to the top of the reservoir, the displaced water, must, of course run out at the opening *g*, where the gas-pipe is introduced. By looking in the tube *f*, we can readily see how much gas the reservoir, at any period, contains; and, in order to determine this with precision, we may affix a scale to the tube in the manner showu by the figure. When, while filling the reservoir with gas, we perceive, in the tube *f* that it is nearly full, the beak of the retort, or other vessel, must be withdrawn, and the opening *g* must be closed by its screw. The gas-holder being now filled with gas, may be removed to any place where it may be required to make use of the gas.

463. If a jar such as fig. 37, is to be filled with the gas, the jar must be first filled with water, and inverted, in the cistern *b*, (also filled with water,) over the stop-cock *d*; *d* and *c* are both opened; the water descends through *c*, and forces the gas out through *d*, into the jar, which, when filled, (the stop-cocks being then immediately closed), may be removed from the cistern, as directed 387.

464. If the bladder *d*, fig. 35, is to be filled with the gas, the stop-cock (*e*, fig. 35) affixed to that bladder, must be screwed to the stop-cock *h* of the gas-holder. The squeezing of the bladder, &c., (see 386), being observed particularly. Then pour water into the cistern, and open the stop-cocks, *e*, *h*, when the gas will be forced into the bladder.

465. When the funnel *e* is fixed into the cock *c*, the pressure of a column of water is obtained, and the gas is forced out through the cock which may be opened with considerable force. If a blow-pipe, as *i*, is screwed on *h*, and a stream of oxygen gas driven through it, in the manner just described; and if a burning substance be exposed to this jet of gas, a heat of very great intensity is produced instantaneously. The stand *k* is employed to expose bodies to this blow-pipe: the top of it is of iron, and can be fixed at a greater or less height, by means of a screw.

466. Perhaps there is no instrument which can enable any one to perform so many beautiful experiments as this improved gas-holder. We shall, hereafter, mention a few more of the very many uses to which it may be applied.

467. Fig. 63.—Doctor Ure's Eudiometer.—The analysis of gases, by explosion with the electric spark, furnishes, when it can be applied, one of the speediest and most elegant methods of chemical research. The risk of failure to which the chemist is exposed, in operating with the simple tube, (see fig. 65.) from the ejection of the mercury, and escape or introduction of the air; or of injury from the bursting of the glass, by the forcible expansion of some gaseous mixtures, has given rise to several modifications of apparatus.

468. A very simple form of this instrument occurred to me about two years ago; and this, which I have frequently used since that time, I can now recommend to the chemical world, as possessing every requisite advantage of convenience, cheapness, safety, and precision.

469. It consists of a glass syphon, having an interior diameter of 1-4th of an inch. Its legs are each six inches long. The open extremity is slightly funnel shaped; the other is hermetically sealed; and has inserted near it, by the blow-pipe, two platinum wires. The outer end of the one wire is incurvated across, so as nearly to touch the edge of the aperture; (look at the top part of figure 63), that of the other is formed into a little hook, (see fig. 64), to allow a small spherical bottom to be attached to it, when the electrical spark is to be transmitted. The two legs of the syphon are from one-fourth to one-half of an inch asunder.

470. The sealed leg is graduated by introducing successively equal weights of mercury;—137 grains of that metal occupy the space of the 1-25th of a cubic inch. (The graduations may be marked by a diamond, a file, or a piece of rock crystal). The instrument is then finished.

471. To use it, we first fill the whole syphon with mercury or water, which a little practice will render easy. We then introduce into the open leg, plunged in a pneumatic trough, any convenient quantity of the gases, from a glass measure tube, containing them previously mixed in determinate proportions. Applying a finger to the orifice, we next remove it from the trough in which it stands, like a simple tube; and by a little dexterity, we transfer the gas into the sealed leg of the syphon. When we conceive enough to have been passed up, we remove the finger, and next bring the mercury to a level in both legs, either by the addition of a few drops, or by the displacement of a portion, by thrusting down into it a small cylinder of wood. We now ascertain, by careful inspection, the volume of included gas. Applying the fore-finger again to the orifice, so as also to touch the end of the platinum wire, we then approach the pendent ball or button to the electrical machine, and transmit the spark. Even when the included gas is considerable in quantity, and of a strongly explosive power, we feel at the instant, nothing but a slight push or pressure at the tip of the finger. After explosion, when condensation of volume ensues, the finger will feel pressed down to the orifice by the superincumbent atmosphere. On gradu-

ally sliding the finger to one side, and admitting the air, the mercurial column in the sealed leg will rise more or less above that in the other. We then pour in this liquid metal, till the equilibrium be again restored, when we read off as before, without any reduction, the true resulting volume of gas.

472. As we ought always to leave two inches or more of air, between the finger and the mercury, this atmospheric column serves as a perfect recoil spring, enabling us to explode very large quantities without any inconvenience or danger. The manipulation is also, after a little practice, as easy as that of the single tube. But a peculiar advantage of this detachable instrument is, to enable us to keep our pneumatic trough, and electrical machine, at any distance which convenience may require; even in different chambers; which, in the case of wet-weather, or a damp apartment, may be found necessary to ensure electrical excitation. In the immediate vicinity of the water pneumatic cistern, we know how often the electric spark refuses to issue from a machine. Besides, no discharging rod or communicating wire is here required. Holding the eudiometer in the left hand, we turn the handle of the machine, and approaching the little ball, the explosion ensues. The electrician is well aware, that a spark so small as to excite no unpleasant feeling in the finger, is capable, when drawn off by a smooth ball, of inflaming combustible gas. Even this trifling circumstance, may be obviated, by hanging on a slender wire, instead of applying the finger.—*Extracted from a paper by Dr. Ure, in the Transactions of the Royal Society of Edinburgh.*

473. Fig. 65.—VOLTA'S EUDIOMETER.—A strong glass tube, three-fourths of an inch in diameter, and twelve inches long. The bottom end of it is shaped like a funnel, in order that, when placed upright, it may stand firmly. Into the top end, a piece of brass wire, or better platinum wire, is seated hermetically. It must, like the other eudiometers, be graduated.

474. When this eudiometer, containing the gaseous mixture that is to be detonated, is standing over water, introduce into it, a brass wire; one end of which must ter-

-minate 1-10th of an inch from the upper wire, and the other end of it project from the bottom of the tube, and be attached to the electrical apparatus, to form part of a circuit. The gas in the tube is exploded by completing the circuit externally, and thereby sending the electric spark from one wire to the other, in the tube. When the spark is thus passed, the tube must be held firmly, either by the hand, or some other contrivance.—It will be seen that this eudiometer is much inferior to Dr. Ure's.

475. Fig. 66.—Part of an apparatus *for ascertaining the quantity of carbonic acid discharged from any substance by the addition of an acid.* It is a piece of glass tube, of half the diameter of fig. 55, bent into a zig-zag form, (which may be easily done by the blow-pipe), with a cork fitted on one end, and the other end drawn out to a small point.

*** We promised to give, along with the descriptions of the different utensils, a list of chemical preparations and miscellaneous articles, which the student should be provided with, to enable him to perform the experiments; but upon farther consideration, we have thought it best to place this list among the chemical tables in the APPENDIX.

EXPERIMENTS.

SECTION I.—ON THE PROPERTIES AND EFFECTS OF CALORIC.

476. HEAT AND COLD PRODUCED BY THE SAME LIQUID AT THE SAME TIME.

Process.—Put your right hand into a basin containing water made as hot as you can well bear it, and put your left hand into a basin containing cold water. After a few minutes, take out both hands, and instantly plunge them into water warmed moderately: what effect will be produced? The water will *cool your right hand* and *warm your left.*

477. *Explanation of this experiment.*—What we call *heat*, is the effect produced by the presence of the peculiar substance which chemists call *caloric*. *Cold* is merely a negative quality: it signifies the absence of heat, or rather, a diminution of heat. This producer of heat (caloric) always tends to an equilibrium; that is to say, heated bodies placed among cool ones, always part with their heat to the cool ones, till all are brought to the same temperature. Of course, by such a process, the cool bodies are heated, and the heated ones, cooled. This doctrine of the distribution of heat enables us fully to comprehend the the phenomenon of the above experiment. A hot hand put into cold water, communicates a part of its heat to that water, and thus becomes cooled. Again, a cold hand put into hot water, takes a portion of heat from that water, and consequently is heated. Hence, we readily discover, how water of a medium temperature heated the hand that had been cooled by cold water, and cooled the hand that had been heated by hot water.

478. People very generally imagine that the sensation of heat is an accurate test of temperature, and they are thereby frequently led to miscal things. They come into this room from the open air to-day, and exclaim "How warm it is!" To-morrow, they will again come into it from a still warmer room, and will cry "How cold it is!" In the first case they gain heat, and therefore call the room warm; in the latter case, they lose heat, and then they term it cold. While, in reality, the air of the room continues, during the whole time, heated precisely to the same degree of temperature.

479. Two men were travelling on a high mountain; one of them was ascending it, the other, descending it. About the middle they met. "Bless me!" exclaimed he who was going down, "how extremely hot it is to day." "Hot?" cried the other, "why I never felt so cold in all my life." These two men judged from their sensations, and truly expressed what they felt. At the top of the mountain, the air was cold; at the bottom of it the air was warm. He, who was descending came, therefore, into warm air, and was heated; on the contrary, he who was ascending was, by coming to the cool air, cooled. We learn from this, that our sense of feeling can never inform us respecting the true temperature of the bodies by which we are surrounded.

480. Heat Expands Bodies, as the following experiments will prove.

Process 1.—Take a piece of iron that exactly fits a ring made to receive it. Put it in a fire, and make it red-hot. It will be then so much enlarged in bulk, that it will not go into the ring.

481. *Process* 2. Put into the bulb of the instrument represented by fig. 42, some cold water, or alcohol. Then, holding the part *a* of the instrument in the hand, plunge the bulb into hot water: upon this the enclosed liquid, as it gains heat from the hot water, will rise in the tube. The expansion will be seen more clearly, if the liquid in the bulb be coloured.

482. *Process* 3. Let a bladder, partly filled with air, be [illegible] at the neck, and held near a fire. The small quantity

of air enclosed will immediately expand and fill the bladder completely.

*** That, in all these cases, the expansion of the different bodies is really occasioned by the caloric they acquire, is very evident, from the circumstance, that when they become cool again, they become small again.

483. *Remarks on this phenomenon.*—Of all the properties of heat, none is more remarkable than its power of expansion. Matter of every description, bodies in every state, are, by an accession of caloric, enlarged in bulk. When, on the contrary, bodies are deprived of heat, they are reduced in bulk.

484. In order to account for so curious a phenomenon as increase of size by the addition of invisible matter, philosophers have supposed caloric to be a peculiar fluid, possessed of so subtile a nature, as to be capable of forcing itself between, and consequently of driving asunder, the particles of matter of even the very densest kind. By this means it is that it is able to overcome the attraction of cohesion, and thereby to dilate bodies.

485. The fact shewn by process 1, is taken advantage of by coopers in fastening the staves of a cask with iron hoops: before the hoops are put on, they are heated, and of course enlarged; they then, on cooling, contract, and the cask is tightly bound.

486. The expansion of fluids (process 2,) has been very usefully applied in the construction of thermometers, by which it is made the means of measuring the variations in the quantity of caloric contained in other bodies. A thermometer is a small tube of glass, with a bulb at the end of it; the bore of the tube is very small, and perfectly cylindrical; the bulb is entirely, and the tube partly, filled with the fluid by whose expansion the degrees of heat are to be measured. The tube is applied to a scale, formed on fixed principles, and the expansion of the fluid is thereby measured with accuracy. The fluid with which thermometers are generally filled is the metal mercury, that being formed to combine more advantages than any other fluid. The *scale* just mentioned, is divided into two hundred and twelve equal portions, which are called degrees; the two

hundred and twelfth degree (usually written 212°) being the topmost one. The mark at the bottom of the scale, near the bulb, is 0°.

487. When the thermometer is immersed in melting ice, the surface of the mercury stands invariably at the 32nd degree, (shortly said, at 32°), and this is on that account called the *freezing point of water*. When the thermometer is plunged into boiling water, the mercury rises to 212°, which, therefore, is called the *boiling point of water*. All bodies that are as hot as boiling water, make the mercury rise as high as boiling water does; and all bodies that are as cold as melting ice, (or freezing water), make the mercury sink to 32°. If the thermometer is immersed in a mixture of equal parts of water at 32° and 212°, the mercury stands level with 122°; we have, in this case, an excellent illustration of what has been said (477) regarding the tendency which caloric has to an equilibrium: the hot water communicates 90° of heat to the cold, and its own temperature is thereby reduced 90°.

488. The thermometer does not tell the precise quantity of caloric contained in the bodies it is applied to: it only shows by how many degrees of heat the temperature of certain substances exceeds that of others. For we cannot deprive any body of all the caloric it contains. The mercury rises by abstracting heat, and falls by communicating it. If the mercury is sunk to 0° by being plunged into a certain mixture, still we cannot say that that mixture is deprived of heat, since it is evident, that the mercury fell upon giving out part of *its* heat to the mixture, and became stationary upon the production of an equilibrium. Though the lowest point on the thermometer scale is 0°, yet cold can be produced by many degrees more intense than that; so, also, can much greater heat than that of boiling water be produced. Thermometers for chemical purposes are sometimes marked to 600° above 0°, and to 40° below it; which marks show the boiling and freezing points of mercury.

489. We must now notice a very remarkable exception to the laws of expansion upon increase of heat. When water at 32° is heated, instead of expanding as other bodies

in the same situation would do, It contracts, continuing to do so, more and more, till it arrives at 40°, after which it regularly expands! When water at 212° is cooled, it contracts till it comes to 40°, and then it gradually expands till it comes to 32°! This property of water is a very beneficial one, as we shall presently see.

490. DIFFERENT BODIES EXPAND IN DIFFERENT DEGREES. As may be proved by the following

Process.—Fill the bulb of the instrument, fig. 42, with water, and fill the bulb of another instrument exactly like that with alcohol. The two liquids had better be coloured by some vegetable infusion. Now, take the two tubes, and plunge the bulbs together into hot water: both the liquids will expand and rise in the tubes, but the alcohol with far more rapidity than the water. The cause of the difference in the expansibility of bodies is unknown.

491. HEAT PASSES QUICKLY THROUGH SOME BODIES—SLOWLY THROUGH OTHERS. Bodies through which it passes are called *conductors;* those through which it passes *quickly* are termed *good* conductors, and those through which it passes *slowly*, *bad* conductors. Dense bodies are, in general, the best conductors, light porous bodies, the worst. Bodies which are the worst conductors of heat, have the greatest capacity for it; that is to say, they take a greater quantity of heat than good conductors, to raise an equal bulk to a given theometric temperature within a certain time. When bodies are compressed, heat is evolved; because, as, by their condensation, their conducting powers are increased, so are their capacities for heat diminished. The following experiments *prove* the conducting powers of bodies to be different.

Process 1.—Take a rod of iron a foot long, and a rod of wood just the same size. Put one end of each into a fire, and hold the other extremities by the hands. When the one end of the iron has become red hot, the other end will be almost unbearably hot; but the wood will scarcely give any heat to the hand, though held till nearly all consumed by the fire. Hence we learn, that iron is a good conductor of heat, but wood a bad one.

492. *Process* 2.—Prepare a number of equally-sized rods

of different substances, copper, lead, tin, iron, glass, bone, and wood of various sorts. Coat one end of each, by dipping it into melted wax or tallow. When they are all ready plunge their uncoated extremities into boiling water, or hot sand,—in a short time the wax or tallow will be melted; but it will be observed, that all the coatings do not melt together, but, that of each particular rod in the order of its power of conducting heat. The metallic rods (these too in their particular order) produce the effect first, next the glass, and last of all the wood.

493. Curious Motion produced in Liquids by Heating and Cooling them.

Process.—Fill a large phial with water, and put into it a small quantity of powdered amber. Immerse the phial in a glass of hot water; upon which a very singular internal motion will be immediately perceived. A current of the fluid will rise up the sides of the phial, and another descend in the centre of it. Now take the phial out of the hot water, and observe the effects of its cooling. The currents will be reversed: the external one will descend, and the internal one ascend.—The use of the powdered amber (a substance which is of the same specific gravity as water, and therefore floats indifferently in any part of it) is to make the opposite currents into which the water is thrown, visible.

494. *Rationale of this Experiment.*—The manner in which a quantity of water, put in a vessel over a fire, is heated throughout, is by the constant agitation of its particles; for though heat is transmitted from one particle of a fluid to another, in the same manner as in solid bodies, yet it is only so in a very small degree. As the particles of water immediately at the bottom of a vessel, are expanded by heat, they become, of course, specifically lighter than the rest of the fluid; and consequently rise to the surface, communicating, in their progress, part of their heat to the colder particles around them. Successive portions are thus heated at the bottom, and rise to the surface; and this agitation continues till all the liquid is brought to the greatest degree of heat it can acquire, namely, to its boiling point. If a liquid is heated at the surface, the particles being specifically

lighter than those below, cannot descend, and therefore no agitation can be produced to communicate the heat to the bottom of the water. It was once asserted that heat could not descend, and in apparent proof of this, the upper surface of a vessel of water can be boiled and evaporated, while a cake of ice remains frozen at the bottom. See 500. But, it has been proved that heat *is* propagated downwards, (by transmission from particle to particle,) though but slowly.

495. In the experiment just performed, the water rises at the sides—this is because the heat is communicated through the medium of the sides of the bottle. The descending current in the centre, is occasioned by the sinking of the water which parts with a portion of its heat, to the atmosphere, at the surface. When the fluid was held out of the water, the currents were reversed, because the external particles being in contact with cool air, are cooled; they therefore descend and force up the central particles, which are lighter because warmer.

496. From what is said at 489 and 494, it will be seen, that water in large quantities, as, for instance, in deep lakes, when cooled by the atmosphere in winter, sinks in successive portions, till the whole bulk of it is of the temperature of 40°; after which, as it cools to 32°, (its freezing point), it continues unagitated, that is, its cool particles, being lighter than its warm ones, remain at the surface, and are at last converted into a sheet of ice. How manifest is the wisdom and goodness of the Great Artificer of the world in this arrangement! If water continued to condense to 32°, the water on the surface of our rivers, would sink as it froze, another sheet of water would freeze immediately, and sink also; the ultimate consequence of which would be, that the beds of our rivers would become depositories of immense masses of ice, which no subsequent summer could unbind; and the world would have been shortly converted into a frozen chaos!

497. To prove that Water Expands when Freezing.

Process.—Fill a small phial with water, cork it securely, and place it in a situation where the water in it may be frozen: whenever solidification takes place the bottle will burst.

498. The force with which water expands when iu the act of freezing, is immense. A small brass globe, which would have required a force equal to 27700 pounds to have burst it, has been bursted by the freezing of a little water in it. By the expansion of water during frosts, trees and rocks are often split asunder, Slate is dug from quarries in large blocks, which are placed, edge-uppermost, exposed to the rain; this penetrates their fissures, and, when a frost takes place, expands, and splits the slate into thin layers.

499. To Show that Hot Water is Lighter than Cold.

Process.—Pour gently hot water into a tall glass nearly filled with cold water; it will remain on the surface: but if cold water be poured upon hot water, it will sink to the bottom. This experiment may be rendered more striking by colouring that portion of water which is poured in.

500. To cause Water to Boil on the Surface of Ice.

To effect this, first freeze a quantity of water in the bottom of a long glass tube, closed at one end, either by exposure to cold air, or by means of a *freezing mixture* (of which we shall speak presently). Then cover the cake of ice by a quantity of water, and hold the tube (without handling the part of it containing the ice) in such a manner over a lamp, that the surface of the water may be heated to the point of boiling: for this, the tube requires to be placed in a diagonal direction, which is such as allows the water at the top of it to be heated, while the ice remains unheated below.

501. Sudden Conversion of a Liquid into an Invisible Fluid or Vapour, and Re-Conversion of it into a Liquid.

Process.—Put into the instrument, fig. 42, two teaspoonfuls of sulphuric ether, and then fill it (tube and all) with water. The instrument should, for this experiment, be sufficiently large to hold about half-a-pint, and the water may be coloured. Let the mouth of the tube (the bulb being turned upwards) be put into a vessel of water: it may be kept in this situation by being fixed into a hole made in a little stool; just as it is represented by the figure above referred to. Next pour boiling water gently upon the top of the ball: the sudden addition of heat will instantly change the ether into a vapour, which, by its expansion, forces the coloured water out of the vessel, and occupies its place. It is proper, however, not to allow the whole of the water to be forced out; but, after expansion has proceeded to a certain degree, to pour then *cold* water upon the vessel. This will immediately re-convert the vapour into a liquid, and cause the water to rush up into the bulb, to supply the vacuum.

502. *Rationale.*—This experiment is intended to show that heat has great influence on the forms or state of bodies. When solids are heated they become liquids, as is proved in every instance of fusion; and when liquids are heated, they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. They retain this form or state as long as their temperature remains sufficiently high, but re-assume the liquid form when cooled again. Different fluids pass into the aëriform state at different temperatures: the temperature at which a liquid becomes changed into a vapour, is called its *boiling point*.

503. To cause Water to Boil by the application of Heat, and to cease to Boil by the application of Cold.

Process.—Provide a Florence flask, a good cork that fits it closely, and a piece of bladder softened by having been soaked in water. Fill the flask half full of water, and place it over a lamp, by means of the stand, fig. 23, till the water boils; then remove the flask, instantly cork it securely, and tie the moistened bladder over the neck and cork, so as to prevent the least access of air. The boiling of the water, which continues a little while after the flask is removed from the lamp, soon ceases entirely; but it will immediately recommence if the flask is plunged into cold water, and cease again, when the flask is held near the fire.

504. *The explanation of the experiment is this:* The boiling points of liquids are regulated by the pressure of the

atmosphere. The greater the pressure, the greater is the degree of heat requisite for making the liquor boil; and, consequently, the degree of heat required to cause the ebullition of a liquid is small, under a small pressure. If the pressure on the surface of the earth could be entirely removed, every substance, whatever, would begin to boil instantly.

505. Now, in what manner do these facts explain the curious phenomena of the above experiment? why, when the flask was taken from the lamp, in order to be closed, the upper part of it was filled with vapour, the quantity of which was increased by that generated during the short time that the water continued to boil, after being removed from the lamp; and it was the great pressure of this body of vapour, which made the still hot water cease to boil. The boiling recommenced when the flask was cooled, because, by that cooling, the vapour was condensed into water, and a vacuum formed. This being the case, the water will boil at a very low temperature; and the heat that it retains is sufficient for the purpose. The boiling of the water ceased again, upon the flasks being heated, because the vapour formed by that means, renewed the pressure on its surface.

506. *** Sometimes Florence flasks are so thin, that, when the vapour is condensed, the glass is broken by the pressure of the atmosphere. The following is another mode of showing this experiment, calculated to obviate this inconvenience. Provide a six ounce medicine phial, half fill it with water, and place it in a pan of boiling water over a fire, till the water it contains boils also. Then cork it closely. Stand this phial, thus prepared, in a tea saucer; pour cold water upon it; when the water in the phial will boil—next, pour hot water upon it, when the water in the phial will cease to boil.—The *rationale* need not be repeated.

507. To Freeze Water by putting it into a Pan on the Fire.

Process.—Prepare a Freezing Mixture as directed in the Appendix, and place the pan containing it over the fire; then immediately plunge into it a tube of thin glass, about 3-8ths of an inch in diameter, containing a small quantity of water. In a short time, by the liquefaction of the freezing mixture, the water in the tube will be converted into ice.—Care must be taken not to let it remain too long, or the ice will be melted.

508. During the liquefaction of bodies, a quantity of heat is absorbed, which is essential to the state of fluidity, and which does not increase the sensible or theometric temperature. The same may be observed of the conversion of liquids into vapours. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it; much of the heat of the hotter body being consumed in rendering the solid colder body *liquid*, before it produces any effect upon its sensible temperature.

509. Equal parts of *water* at 32°, and of *water* at 212°, will produce, on mixture, a mean temperature of 122°. But equal parts of *ice* at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the water being employed in thawing the ice, before it can produce any rise of temperature in the mixture. Here the water is cooled 160 degrees, while the ice is heated only 20; consequently 140 degrees of heat have disappeared, this having in fact united to the solid water (ice) to produce fluidity. Heat thus rendered insensible, or combined, is termed *latent heat*.

510. The same phenomena are observable in all cases of liquefaction, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water. Upon this principle the action of freezing mixtures depends.

511. In the above experiment (507) the water becomes solid, by giving out its *heat of fluidity* to the mixture.

512. To Freeze Water, in a few minutes, even in the Midst of Summer.

Process.—Take a thin glass tube, four or five inches long, and two or three eighths of an inch in diameter. This must be closed at one end, and have water poured into it to the height of an inch. Now, by means of the dropping tube, (see 402), let a stream of sulphuric ether fall upon that part of the tube where the water is. The ether, as soon as exposed to the atmosphere, rapidly evaporates; but, in order to be converted into vapour, it requires a considerable quantity of caloric; and it therefore immediately robs the water in the tube of its heat of fluidity. The consequence is, that the water is changed to ice; and if a thin spiral wire (such as fig. 39) be previously put into the tube, the ice will adhere to it, and may be drawn out.

513. Cold is produced in all cases of evaporation. The inhabitants of warm climates cool their liquors for drinking, by wrapping the vessels containing them in wet cloths, and hanging them up in the same. The water in the cloth evaporates quickly, and thus produces cold. A person whose clothes are wet, feels cold, even when near a fire: it is because the water, as it evaporates, robs his body of caloric. —Under certain circumstances, the cold produced by evaporation is very great, being even sufficient to freeze water. This has been proved by the above experiment; and is also most elegantly shown by that which follows.

514. Dr. Wollaston's Cryophorus.—This instrument is described at 441. It was invented to demonstrate the relation between evaporation at low temperatures, and the production of cold. To make use of it, prepare a freezing mixture, and plunge the ball *b* into it: upon which the water in the other ball will be frozen in a few minutes.

515. By referring to 441, and to 505, we see, that the instrument, as it was closed while the water in it was boiling, is filled with vapour. This vapour, when the ball *b* is plunged in the freezing mixture, is condensed by the common operation of cold; and the vacuum produced by this condensation gives opportunity for a fresh quantity of vapour to rise from the opposite ball. Now, the small quantity of water which rises from *a* to supply this vacuum, takes, in order to be converted into vapour, a large quantity of heat from the remainder of the water; and it is by the reduction of temperature thus effected, that the water is eventually changed into ice.

516. Instantaneous Crystallization: a curious example of the production of heat by the conversion of a liquid into a solid.

Process.—Into two ounces of boiling water, put as much sulphate of soda, as it will dissolve (about 3 ounces). Pour as much of this saturated solution, when boiling hot, into a phial as nearly, but not quite, fills it; cork the phial closely, and let it stand to cool. When cold, the solution is still fluid; but the instant you draw the cork, a very beautiful but confused crystallization of the whole mass will immediately take place; and, at the same time, so much heat is evolved, as to make the phial warm.

517. The explanation of the experiment is this: water will dissolve more sulphate of soda when hot than when cold; and cold water will dissolve more in proportion as the pressure of the atmosphere is diminished. The hot water was here saturated, and, had it been suffered to cool in an open vessel, would have deposited part of the salt. But in this case, none was deposited, for by suffering the solution to cool in a close vessel, a partial vacuum was produced at the surface of it, (the steam which occupied the top part of the phial when the cork was inserted, being, by the subsequent cold condensed), and the water, when cold, was thus enabled to hold in solution, all the salt which, when hot, it had dissolved. As soon, however, as, by drawing the cork, you admitted the usual pressure of the atmosphere, the cold water was rendered incapable of holding so much salt in solution, and part was, therefore, instantly crystallized. The heat which was evolved, was the heat of liquidity of the portion of the salt which thus became solid.

518. If, when the salt has crystallized, you plunge the phial containing it into hot water, it will be again dissolved. You may then cork the phial, as before, and the same solution will serve for a repetition of the experiment.

519. To produce a boiling hot liquid by mixing together two cold ones.

Process.—Take a small phial about half-full of cold water; grasp it gently in the left hand, and from another phial pour sulphuric acid very gradually into the water. The mixture will immediately become so hot, that the phial cannot be held.—If a thin glass tube, three-eighths of an inch in diameter, containing a small quantity of water, be plunged into a mixture of one part water to four parts acid, the water in the tube will *boil.*

520. *Rationale* of this experiment. Whenever two liquids unite chemically, the compound has greater density than the mean density; and whenever density of bodies is increased, they evolve heat.

SECTION 2.—ON CHEMICAL AFFINITY.

521. To show what Chemical Affinity is.

Process.—Shake together, in a small phial, a quarter of an ounce of olive oil, and the same quantity of water; then allow the mixture to settle, upon which the oil and water will seperate. Now, add to the mixture a drachm of a solution of an alkali (either potass or soda) and shake the phial again. Upon this, these three bodies will form a substance resembling thick cream.

522. *Rationale.*—Oil has no affinity for water, and, therefore, does not combine with it; but, it has a strong affinity for alkalies, with which it readily combines, and forms a *soap.* The cream-like appearance of the above mixture, is occasioned by the diffusion of the soap that is formed, through the water.

523. Proof that a Substance has different degrees of Affinity for different Substances.

Process.—To the product of the preceeding experiment, add a little diluted sulphuric acid. The soap will instantly be decomposed. For the acid combines with the alkali (having a stronger affinity than the oil for it), and forms a *salt,* which is dissolved in the water: while the liberated oil rises to the surface of the mixture.

524. Curious Examples of Chemical Affinity.

Process 1.—Take a little solution of sulphate of iron, and a little infusion of galls, both diluted till colourless, pour them together,—the mixture will be black. *Rationale.* The gallic acid contained in the infusion of galls has a stronger affinity for iron than sulphuric acid has. Consequently, the sulphate of iron is decomposed, and gallate of iron immediately produced.

525. *Process* 2. Into the black liquor, which is the product of the preceeding experiment, pour a little diluted muriatic acid: the mixture will immediately become colourless.—*Rationale.* Muriatic acid has a still stronger affinity for iron than even gallic acid. We, therefore, in this experiment, form muriate of iron, which gives a colourless solution.

526. *Process* 3.—To the limpid liquid produced by the last experiment, add a little solution of potass, (which is colourless,) the mixture will again become black.—*Rationale.* Here the muriatic acid quits the iron to unite with the potass, and the disengaged iron is caught up by the gallic acid which remains in the solution, to re-produce the black gallate.

527. *Process* 4. Pour mercury into a wine-glass: its upper surface will be convex. Next, pour some into a tin cup; then its surface will be concave.—*Rationale.* Glass, having no affinity for mercury, repels it on all sides, and thereby raises the centre of the mass. But, the tin, having a strong affinity for mercury, attracts it all round, and, consequently, the centre of the mass is depressed.

528. *Process* 5.—Immerse a piece of gold—a coin will do—in a glass of mercury. After a few seconds, take it out: it will be apparently transformed into silver. Drop the silver-looking metal into a little diluted nitric acid: upon taking it out, after a little while, it will be found to have resumed its natural appearance.—*Rationale.* Mercury has a strong affinity for gold, so that amalgation takes place whenever the two metals are placed in contact. The coin, in the above case, becomes cased in an amalgam of gold. The nitric acid, into which the metal is afterwards put, dissolves the mercury, but does not act upon the gold.

529. *Process* 6.—Take an ounce of mercury and an ounce of sulphur; melt them together in a crucible, stirring the mass continually—pour the mixture on a piece of marble or glass, greased and warmed. The substance thus obtained is sulphuret of mercury, which, if you have an alembic, you may sublime, (see 422), and you will then form the beautiful pigment called vermillion.—*Rationale.* This experiment is an example of simple affinity, by which

bodies combine and form a substance differing entirely from its constituents. Mercury is white, brilliant, and fluid, and sulphur is yellow. Now, the body formed by their union is a solid of a red colour.

530. *Process* 7.—Take equal parts of muriate of ammonia and lime, (newly burnt), these bodies are inodorous: triturate them in a mortar; upon this, a very pungent smell is immediately produced. If the operation is performed quickly, and the mixture put in a bottle, well closed, it serves as a smelling bottle for a long time.—*Rationale.* The muriatic acid which is a constituent of the muriate of ammonia, has a stronger affinity for the lime, than for the ammonia. It therefore combines with the lime, and yields up the ammonia in the state of gas. It is this ammoniacal gas which has the pungent smell.

531. Order of the Affinities of some of the Acids for Potass.

Acetic greater than Carbonic.—Put some solution of carbonate of potass into a tumbler, and pour over it a solution of acetic acid. The carbonic acid will be expelled with effervescence, and acetate of potass will remain.

532. *Muriatic greater than Acetic.*—Into the newly-formed acetate of potass, pour muriatic acid as long as acetic acid (known by the smell) continues to be evolved. The new compound, muriate of potass, is a salt that may be crystallized.

533. *Nitric greater than Muriatic.*—Into the solution of muriate of potass, pour nitric acid; the muriatic acid (which has a very pungent smell) will be expelled; and nitrate of potass (saltpetre) will remain.

534. *Sulphuric greater than Nitric.*—Pour sulphuric acid into the solution of nitrate of potass obtained in the last experiment. A solution of sulphate of potass will result.

535. *** If this series of experiments was performed in a retort, and the gaseous acids were discharged thence into proper receivers, and examined by tests, (in the manner hereafter described), the results would be far more satisfactory.

536. COMPARATIVE AFFINITIES OF SEVERAL SUBSTANCES FOR SULPHURIC ACID.

Ammonia greater than Iron.—Into a solution of sulphate of iron, contained in a test glass, drop as much liquid ammonia as will precipitate the whole of the oxide of iron. The *then* solution will be sulphate of ammonia.

537. *Magnesia greater than Ammonia.*—Having decanted the solution furnished by the last experiment into a clean tumbler, stir in it as much carbonate of magnesia (common magnesia) as can be dissolved. The magnesia will be separated from the carbonic acid, which flies off in the state of gas, as likewise does the ammonia; and there remains in the solution, sulphate of magnesia (Epsom salt).

538. *Soda greater than Magnesia.*—Into the solution of sulphate of magnesia, pour a solution of carbonate of soda until the whole of the magnesia is precipitated. The carbonate of soda is decomposed: the carbonic acid unites to the precipitated magnesia, and the soda with the sulphuric acid form sulphate of soda, which remains in solution.

539. *Potass greater than Soda.*—Pour a solution of carbonate of potass, till the commencement of effervescence, into the solution of sulphate of soda. Here the sulphuric acid seizes the potass, and the liberated carbonic acid combines with the soda. There is no precipitate; because both the compounds are very soluble. But, that decomposition certainly takes place, may be proved by crystallizing the product of the experiment, when the salts may be distinguished from each other.

540. *Strontia greater than Potass.*—Into the solution of sulphate of potass, pour a solution of pure strontia in cold water, or of carbonate of strontia in hot water: sulphate of strontia will be precipitated.

541. *Barytes greater than Strontia.*—Dissolve the last mentioned precipitate in boiling water, and pour in a solution of barytes, or of muriate of barytes. The sulphuric acid will now make one more election—seizing on the barytes, and forming with it a very insoluble salt, sulphate of barytes.

542. *** The foregoing experiments, showing the comparative affinities of different substances for one of the

strong acids, form a very interesting lesson. We recommend the young student to perform them with care; and, in order to prove that the products do really contain the bodies specified, he may try them by means of appropriate tests.

543. Mutual Decomposition of two Salts—an Example of Compound Affinity.

Prepare a solution of carbonate of soda, and a solution of muriate of barytes, (both transparent liquors),—mix them together in a test glass; this done, a very heavy white powder will be thrown down immediately. Here, a mutual decomposition, and formation of two new salts, carbonate of barytes, and muriate of soda, take place. The former is precipitated: whilst the latter remains in solution, and may be crystallized into that salt known by the name of *table salt*.

544. The Density of Bodies is Altered by Chemical Action.

Process 1.—If two cubical inches of copper, and the same bulk of tin, are melted together, they form an alloy of the size of only three cubical inches. One fourth of their bulk, therefore, is lost; while, in weight, they are unaltered.

545. *Process* 2.—If one part of sulphuric acid, be mixed with three parts of water, the compound will occupy less space than the bodies did when separate.

SECTION 3.—ON GASES.

546. To procure Oxygen Gas.—Put into the retort, fig. 18, an ounce of black oxide of manganese, in powder, and pour over it as much sulphuric acid as will convert it into a thin paste. Stir the mixture with a glass rod. Proceed next as directed, 377. Give a very gentle heat. The gas will shortly be evolved; and may be collected in jars as directed 379, 419. Or, the gas may be collected in the gas-holder, fig. 61.—See 462. There are several other methods of procuring oxygen gas; but this is the one generally adopted, for small quantities.

547. *Note:*—The first portion of gas (of whatever kind

it may be) that is evolved from the vessel in which it is formed, is always contaminated with the common air, with which the said vessel was filled in the first instance. A quantity of the first air received, rather more than the capacity of the vessel in bulk, must, therefore, in order to avoid accidents and failures, be thrown away.

547. TO PROVE THAT "OXYGEN GAS IS AN EMINENT SUPPORTER OF COMBUSTION."

Process 1.—Plunge a lighted candle into a quantity of the gas contained in a glass, in the manner directed at 383. The cover to confine the gas till it is wanted, may be a piece of glass, or pasteboard.

548. *Process* 2.—If the light of a taper be blown out, and the taper be let down into a glass of this gas while the snuff (which should be a thick one) remains red hot, it instantly rekindles, with a slight explosion. When the taper is re-lighted, it continues to burn, as in the preceeding case, with a rapidity, a brilliancy of light, and an evolution of heat, truly wonderful.

549. During *combustion in oxygen gas* the volume of the gas is decreased, and, if the combustion continues long enough, the gas wholly disappears. This is owing to a combination which takes place between the oxygen of the oxygen gas, and the body that is burnt in the oxygen gas. The result of this union is either an oxide, or an acid.—See 13.

550. Sometimes the product of such combustion is a gaseous body, and sometimes a solid. Thus, sulphur produces sulphuric acid gas, and carbon, carbonic acid gas; but phosphorus produces phosphoric acid, which is deposited in a solid state, and a vacuum is produced in the vessel wherein the combination of the two elements take place. The caloric of the oxygen gas goes off in the heat which the combustion invariably occasions.

551. When combustion takes place in *common air*, the same phenomena occur, but less rapidly, and to a less extent. By burning substances in a given portion of common air, the bulk of that portion of air is diminished one-fifth, and the remaining quantity will neither support combustion, nor animal life. The portion of air thus ab-

stracted has been proved to be oxygen, and the air remaining is nitrogen. By mixing nitrogen gas and oxygen gas in the above-mentioned proportions, a compound is obtained which possesses precisely the same properties as common air. Thus, therefore, the composition, and the proportions of the constituents, of atmospheric air, is proved both by analysis and synthesis.

552. The grand uses of air being to maintain life and combustion, and its pure part being abstracted thereby, a continual supply becomes necessary wherever those processes are carried on. This shows us how important it is to renew the fresh air of the rooms we live in, in order that breathing, and the burning of fires and candles, may be carried on.

553. Charcoal burns brilliantly in Oxygen Gas, and produces an Acid—the Carbonic.

Process 1.—Fill the bottle, fig. 37, with oxygen gas, as directed 432. Then, put a piece of red-hot charcoal into the spoon, fig. 38, and plunge it into the gas; allowing the instrument to be sustained in its place, by the cork which is laid upon (not fastened into) the neck of the bottle. As soon as the red-hot charcoal comes into contact with the gas, it begins to burn very vividly, its combustion proceeds with great splendour, and brilliant scintillating sparks are thrown out in all directions. When the combustion is at an end, it will be found that the oxygen gas has been converted into carbonic acid gas. This is instance of the formation of an acid, by the union of a simple body (carbon) with oxygen.

554. The reason that the cork to which the spoon is attached must not be screwed tightly into the neck of the bottle, is, that the gas, upon being heated, expands, and would burst the bottle, were it closely fastened up.

555. *Process* 2.—The preceding experiment may be performed on a smaller scale, by employing a jar that holds less gas, and using a copper wire, with a bit of charcoal fastened to the end of it. In this case, beautiful sparks will be thrown out, as before.

556. Sulphur burns beautifully in Oxygen Gas, and produces an Acid—the Sulphuric.

Process.—A piece of sulphur, the size of a pea, is to be put into the copper spoon, set fire to by a candle and blow-pipe, and plunged into the same jar, and in the same manner, as directed for performing the experiment with charcoal. The sulphur will burn with a beautiful violet-coloured scintillating flame, and the jar will shortly be filled with a brown vapour, which is sulphuric acid gas. This gas, if water has been put into the jar will speedily combine with it, and produce sulphuric acid.

557. Splendid Combustion of Phosphorus in Oxygen Gas, and Production of Phosphoric Acid.

Process 1.—The light of phosphorus in combustion in oxygen gas, is the most splendid that can be, by any means, produced. Place the size of a small pea of phosphorus in a little hemispherical tin cap, raised, by means of the wire stand, (fig. 48), an inch or two above the surface of water contained in a broad shallow dish. Fill the receiver *a*, fig. 35, with oxygen gas, and screw on the top of it the bladder *d*, (compressed—see 386); next open the stop cocks *b*, *e*, so as to make a communication between the receiver and the bladder; and then press over the mouth of the receiver, as it stands in the pneumatic trough, a circular piece of pasteboard, rather exceeding its diameter. Now, instantly cover the phosphorus, when an assistant has set fire to it, with the vessel of oxygen gas, retaining the pasteboard in its place till the receiver is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas can escape. The inflammation of the phosphorûs will be so extremely brilliant, that it will be found almost impossible for the eyes to bear the light. The use of the flaccid bladder is to receive the expanded gas, which is thus prevented from escaping into the room, and proving disagreeable by its suffocating smell.—The odorous compound produced being phosphoric acid, which at last settles on the sides of the receiver in white flakes.

558. *Process* 2.—The foregoing experiment may be more easily, but less agreeably, performed, by fastening a bit (of the size of half a pea) of phosphorus to a wire, or putting it in the copper spoon, and then immersing it in a bottle. See 553, 555. The student is particularly cau-

tioned against using larger pieces of phosphorus than those directed.

559. Iron may be Burned in Oxygen Gas: the Combustion is attended by a Brilliant Light, and the Product is a Metallic Oxide.

Process.—Prepare a bottle of oxygen gas, as directed 432; and, also, prepare the wire, fig. 39, as directed 434. Light the inflammable matter at the bottom of the wire, and plunge it into the bottle, suspending the whole by the cork. The flame will be instantly communicated to the wire, which will continue to burn with an appearance inconceivably brilliant and striking: proceeding with a meteor-like body, in a spiral form, and throwing out beautiful sparks in all directions.

560. These sparks, upon being examined when cold, will be found to be very different from the iron of which they were formed: they are brittle, and destitute of metallic lustre. The weight of the drops, too, is greater than that of the metal made use of; so that, in burning something must have been added to them: this something is the oxygen, which united to caloric, formed oxygen gas; and the term applied to this compound is *oxide of iron*. When the drops fly off in their firy state, they are so hot, that unless the bottom of the jar be covered an inch or so with sand or water, they will perhaps crack it.

561. Combustion of Zinc, and Formation of Oxide of Zinc.

Process.—Substitute, for the phosphorus in experiment 557, a small ball formed of turnings of zinc, in which about a grain of phosphorus is enclosed. Set fire to the phosphorus, and cover it expeditiously with the jar of oxygen. The zinc will be inflamed, and burn with a beautiful white light.

562. Proof that Metals are Increased in Weight by Combining with Oxygen.

Process.—Coil up a drachm of very slender iron wire, (see 434), and put it into the bowl of the pipe, fig. 50, which place in a clear fire. Have ready the bladder *d* fig. 35, filled with oxygen gas. When the iron in the pipe is red hot, force from the bladder, through the pipe, a stream of oxgen gas. The iron will burn very rapidly, and, by combining with the base of the gas, be converted into oxide of iron—see 560. If the bowl of the pipe is kept free from dust, the iron, upon being weighed, will be found to have increased from 1 drachm, to 1 drachm and 20 grains, by its oxygenation.

563. Ready and Elegant Mode of Burning Metals.

Process 1.—Have ready a quantity of oxygen gas in the gas-holder, fig. 61. Fix the blow-pipe *i* to the stop-cock *h* of the instrument; and let the funnel *e* be placed as in the figure. The stand *k* is to be put directly under the opening of the blow-pipe. Take now a small square piece of charcoal, and set it on fire at top by means of a common blow-pipe. Lay this charcoal, when red-hot, upon the stand *k*, open the stop-cock *h*, and pour water down the funnel *e*. As the water descends, the gas will issue from *i* with great violence, and falling directly against the inflamed charcoal will produce a very intense heat. Now, drop iron filings upon this charcoal, and they will exhibit a very brilliant light. The process being, in fact, only a variation of experiment 559.

564. *Process* 2.—The same as the last, only, in place of iron filings, use tin filings, or tin finely granilated.

565. *Process* 3.—The same as the preceding, with the exception of employing copper filings. These burn with a beautiful greenish flame.

566. *** We shall give no directions, though they might easily be multiplied, for oxydising other metals thus; because the student may try the effects of the gas upon any substances he may have at hand. By means of this apparatus, which is represented complete in plate 6, a series of most beautiful experiments may be performed with great ease.

567. To Procure Hydrogen Gas, or Inflammable Air.

Process 1.—Fix fig. 30 into fig. 29, closing the juncture very accurately, by the application of putty, or any other lute which may be found necessary or convenient—see 376.—Into the bottle thus prepared, introduce one ounce of clean iron filings, and the same quantity of sulphuric acid, diluted with five or six times its quantity of water. Close the bottle with the stopple: the gas will be rapidly evolved, and may be collected over water, as directed 419, or in the gas-holder.—See 492.

568. *Process* 2.—Instead of the materials mentioned above, use one ounce of granulated zinc, half an ounce by measure, (see 405), of sulphuric acid, and four ounces of water. This mixture yields a very large quantity of gas.

569. In these experiments, the hydrogen gas is furnished at the expense of the water, which latter, is, by the metal, assisted by the acid, decomposed: its hydrogen escapes in the form of gas; its oygen combines with the metal, and thus renders it fit (for it is not fit in its pure state) to be dissolved by the acid. The solution which remains behind, is, therefore, a sulphate, either of zinc or iron, according to the metal that is made use of.—The student will not, of course, throw this residuum away, as useless; but filter, evaporate, and crystallize it.

570. Note.—It will be recollected, that the first portion of gas which is collected in this, as well as in all other cases, must be rejected. See 547.

571. Miniature Balloons—a mode of Illustrating the Extreme Lightness of Hydrogen Gas.

Process.—Fill a bladder with hydrogen gas, in the manner directed 386, 464. Fix to the stop-cock of the bladder the pipe fig. 50. Prepare a strong solution of soap, (a lather such as children use to blow common soap bubbles with), dip the bowl of the pipe into it, and by compressing the bladder, after having opened the stop-cock, fill soap bubbles with the hydrogen gas. These, when shaken from the pipe, instead of falling downwards, like common bubbles, will rapidly ascend to the ceiling of the room. This experiment affords not only a proof of the comparative little specific gravity of hydrogen gas, but also a good illustration of the principles of *Aërostation:* for it is with hydrogen gas that air-balloons are generally inflated.

572. If one of these soap bubbles be arrested in its flight by the application of a lighted paper, the hydrogen gas will explode, and the bubble burst with a vivid flash of light.

573. Note:—Take care and not inflame the bubbles till

they are detached from the pipe, or the whole of the gas in the bladder may explode.

574. DETONATING BALLOONS.—Fill a bladder with a mixture of two parts of hydrogen gas, and one part of oxygen gas. Bubbles blown with this mixture will ascend, though not so rapidly as those filled with pure hydrogen. But, upon the application of flame, they will explode with far greater violence; without, however, occasioning any accident, unless they are fired before they are away from the pipe.

575. THE PHILOSOPHICAL TAPER—AN ILLUSTRATION OF THE COMBUSTIBILITY OF HYDROGEN GAS.

Process.—Fit the jet-pipe, fig. 31, into one of the necks of the gas bottle, fig. 29. Then, introduce through the other neck, materials for producing hydrogen gas (see 568.) In a short time, the gas will be heard issuing from the top of the pipe *a*. Let it escape, till you think as much has issued, as served in the beginning to fill the bottle; then, apply to the top of the tube, a lighted paper; upon this the gas will be inflamed, and will burn with a blueish-coloured jet, as long as it continues to be produced.—The reason that a quantity of air must be suffered to escape is explained by *note* 547. Hydrogen gas mixed with common air, violently explodes when inflamed, so that particular care is requisite, in this experiment, to let all the common air escape.

576. *Another mode of performing this experiment*, is by fixing the pipe, fig. 31, into the top of the stop-cock *d* of fig. 61. Then pouring water down *e*, and inflaming the gas, which, of course (see 463) will issue from the pipe. Or, the jet-pipe, fig. 49, may be fixed to a bladder filled with gas, (571), and the gas inflamed as before. When, by pressing the bladder more or less, a very pretty jet or stream of fire, either large or small, is easily produced. No danger need be apprehended, because the smallness of the hole in the end of the pipe prevents the flame from entering into the bladder.

577. *Artificial Fireworks* are made by passing hydrogen gas through metallic tubes, bent into various forms, and having a number of small orifices bored in them at certain

distances. These tubes are affixed to a main pipe which enters the bag or bladder containing the gas; and the gas is forced through them by pressing the bladder. The gas then issues from the small orifices into the atmosphere, and is there inflamed by the application of a lighted candle. If the machine is made partly, or in whole, moveable, a considerable increase is made to the effect.

578. We account for the luminous appearace in the sky, called the AURORA BOREALIS, or *northern lights*, by supposing that a stratum of hydrogen gas, above the atmosphere of common air, is lighted by the electrical fluid, and burns slowly where it comes in contact with common air. The levity of this gas, accounts for its ascending to so high a region; and as it can only burn when in contact with the latter, the appearances we observe in the *aurora borealis* are exactly such as we should expect from such a cause.

579. HYDROGEN GAS EXTINGUISHES FLAME. To show this, take a phial which holds about two ounces of water, and fill it with hydrogen gas in the usual manner (419). Then, raise it from the shelf of the pneumatic trough, (holding the mouth downwards), and immerse a lighted taper in the gas: the flame will be extinguished.—*Note.* The phial should be made of strong glass, and a handkerchief should be folded round it when used, to prevent injury being received from the glass in case of bursting.

580. *Hydrogen Gas only burns in the presence of air.* Fill a medicine phial with a narrow neck with hydrogen gas, and cork it while under water. Stand it then on a table, withdraw the cork gently, and apply a light; the gas will burn with a pretty blue flame, just at the mouth of the phial, sinking at last into the phial, and then disappearing.

581. FORMATION OF WATER BY THE COMBUSTION OF HYDROGEN GAS. The mode of exhibiting this experiment is shewn by figure 47. It consists in holding a bell glass over the flame of the *philosophical taper* (575). The hydrogen gas, as it burns, combines with the oxygen of the atmosphere, and forms water, which rises in vapour, and is deposited on the internal surface of the glass, in a kind of fine dew.

582. MUSICAL SOUNDS PRODUCED BY THE COMBUSTION OF

Hydrogen Gas.—Take a tube, either of glass, earthenware, or metal, from 18 to 24 inches long, and from 1 to 2 inches wide, and open at both ends. Bring it down a few inches over the flame of the *philosophical taper*, (575),—see figure 45,—and very strange but pleasing sounds, somewhat resembling those of an Æolian harp, will be immediately produced. By raising or depressing the tube, or by using tubes of different sizes, the intensity of the musical chord may be greatly varied. The production of the sound is occasioned by the rushing of air into the tube, to supply the vacuum repeatedly formed by the condensation of the oxygen of the air into water, as it combines with the burning hydrogen.

583. To procure Carbonic Acid Gas.

Put into the gas-bottle, fig. 29, an ounce or two of chalk or marble, broken into pieces the size of peas, and pour over that 3 or 4 ounces of water. Next, fit the conducting tube, fig. 30, in its place, and fit into the other neck of the bottle, instead of its glass stopple, the hydrostatic funnel, fig. 58. This instrument should, for this purpose, be shorter in the bended part than is represented in the figure, and the bottom end of it should go into the water in the bottle. All things being ready, pour gradually into the funnel, either sulphuric acid, or muriatic acid. A violent effervescence will be produced, as soon as the acid descends into the water: carbonic acid gas is disengaged, and may be collected over water, in the same manner as hydrogen gas, (567). Sometimes the acid and water are mixed before they are put in the bottle, and the funnel is not used; but, so violent is the action which takes place, that when this mode is adopted, a quantity of gas escapes before the apparatus can be properly secured.

584. To show that Carbonic Acid Gas extinguishes Flame, and destroys Animal Life.—Fill a glass (such as fig. 46) with carbonic acid gas, as directed 383, and plunge a lighted candle into it: the flame will be extinguished. A person who is quite a stranger to the properties of this kind of gas, will be agreeably amused by extinguishing lighted candles, or blazing chips of wood, on its surface; as the smoke readily mixes with the gas, and little or none of it

escapes into the atmosphere. The smoke floats, in a very curious manner, on the surface of the gas, forming a smooth well-defined plain, which, if the vessel be agitated, is thrown into the form of waves. Insects, which it is desirable to preserve in their true form and brilliancy of colours, for cabinets, may be instantly killed by immersion in carbonic acid gas.

585. Pleasing mode of shewing the great weight of Carbonic Acid Gas.—Place a lighted candle in the bottom of a jar which has its open part uppermost, (the jar being filled with atmospherical air); take then a jar filled with carbonic acid gas, and invert it over the jar in which the candle is placed: the effect is very striking: the invisible fluid descends like water, and extinguishes the flame. The whole, to spectators who have no idea of substance without sensible matter, having the appearance of *magic!*

586. An illustration of the characteristic powers of Oxygen Gas, Carbonic Acid Gas, and Atmospherical Air, with respect to Combustion.

Set three jars resembling fig. 46 or 52, of equal size, mouths upwards, on a table. The first must contain common air; the second, carbonic acid gas; and the third, oxygen gas. Take a lighted candle with a pretty large wick, and lower it, by means of a wire, see fig. 46, into the *first* jar—the flame will have its usual brightness. Lower it next into the *second* jar—the flame will be extinguished. Lower it now, while the wick continues red, into the *third* jar—it will be re-lighted, and will burn for some time with a dazzling splendour. To ordinary spectators, this experiment will be the subject of much wonder. The whole of the jars will, by them, be deemed *empty;* and the different effects resulting from plunging the same candle into seemingly similar vessels, will be quite incomprehensible.

587. To Procure Liquid Carbonic Acid.

Having filled a quart bottle with carbonic acid gas, pour into it half a pint of pure water, then cork it securely, and shake it violently for a few minutes. Let it now remain for a quarter of an hour, (cork downwards), and then shake it again. Continue to do this for three hours. At the expiration of which time, the water, if very cold when put into the gas, (for the colder it is the more gas it absorbs,) will be very strongly impregnated.

588. To form Carbonate of Potass.

Process 1.—Fill a common phial with carbonic acid gas. Apply the thumb to its mouth, and invert it in a solution of pure potass, contained in a cup, and rather exceeding in quantity what is sufficient to fill the phial. The liquid will instantly rise in the phial, and the gas, if it be pure, will disappear entirely; being all absorbed. Pour out the alkaline liquor into the cup, fill the phial again with gas, and again invert it in the solution. The absorption will take place again. Repeat the process till the alkali is saturated.

589. *Process* 2.—Take such a bottle as *c*, fig. 57. Put into it a solution of pure potass, and then connect it, by means of one of the tubes *e*, fig. 57, with the gas-bottle fig. 29. Now, put into the latter, materials for producing carbonic acid gas, as directed 583. The gas, as it is formed, passes of course into the solution of potass, by which it is absorbed. The neck *f* of the bottle *c* is to be closed. Then when the solution of potass is saturated with gas, it will be forced up the tube *d*, by the superfluous gas which presses its surface in the bottle.

590. To form Carbonate of Lime.

Process.—Mix lime water with water impregnated with carbonic acid gas, (587). These liquids are individually transparent, but the mixture is opaque: a white powder gradually sinks to the bottom of the vessel.—*Rationale.* The affinity of carbonic acid for lime is very strong: here, therefore, the two bodies, quitting the water which held them in solution, unite and form an insoluble salt, carbonate of lime (chalk).

591. Illustration of the mode of collecting Gases that are Absorbable by Water, without the aid of a Mercurial Trough.

Process.—Prepare the apparatus whence the gas is to be evolved, as described 583. But let the part *b* of the tube fig. 30, be sufficiently long to reach to the bottom of a long cylindrical jar, just as the tube *a*, fig. 52, reaches to the bottom of that jar. Then, the carbonic acid gas, as it is evolved, forces the common air, which is lighter than itself, out of the jar, and occupies its place. We discover when the jar is filled with the gas, by holding to the top of it a piece of wetted litmus paper, the blue colour of which is changed by the gas to a red.

592. It will be observed, perhaps, that carbonic acid gas, is *not* incapable of being collected over water. That is true: but we only give directions for obtaining *this* gas without the trough, by way of example. It will be seen, that this mode can only be efficient, when the gas to be collected is heavier than common air: another plan is to be adopted, when the gas is lighter than common air.—See 610.

593. To procure Nitrogen Gas.

Process 1.—Introduce a lighted taper under a glass jar, which stands over water, and is filled with common air. The light will shortly be extinguished, a cloudiness will be perceived, which, however, soon subsides, and the water in the basin rises in the jar.—*Rationale.* The atmospheric air is decomposed; the oxygen is absorbed by the burning taper, and the nitrogen remains. The cloudiness proceeds from the unconsumed smoke of the taper. The water rises in the jar, because the included volume of air, is, by the absorption of its oxygen, diminished.

594. *Process* 2.—Mix equal weights of clean iron filings and sulphur into a paste with water, and place the mixture over water, in a cup supported by the stand, fig. 48: then invert over it, a jar, full of common air, and let it remain thus for a day or two, when the air will be diminished in bulk one-fifth, and nitrogen gas will remain. The mixture having absorbed the oxygen of the air.

595. *Process* 3.—Wash a piece of lean beef well, and cut it into very small pieces; put these into a retort, and pour upon them nitric acid, diluted with a considerable quantity of water. Apply a gentle heat. Collect the gas over water.

596. To prove that Nitrogen Gas does not support Combustion. *Process* 1.—The same as process 579. Only that the gas employed must be nitrogen. The light of the candle will be instantly put out. *Process* 2.—The

same as process *555*. But with the difference mentioned in the preceding experiment.

597. TO COMPOSE ATMOSPHERICAL AIR.

Mix four parts of nitrogen gas, with one part of oxygen gas. Examine this mixture—by plunging a lighted taper in it, or by any other test you please—it will be found to possess all the properties of common air.

598. TO PROCURE NITROUS GAS.

Process.—Put some shreds of copper into the retort, fig. 18, and add a portion of nitric acid diluted with five times its weight of water. Apply a gentle heat, and collect the gas, which will be rapidly evolved, as directed *546*.—For an account of the manner in which the gas is produced, see 201.

599. TO CONVERT NITROUS GAS INTO NITROUS ACID GAS.—*Process* 1.—Open a bottle of nitrous gas (which is colourless) in the atmosphere: *red fumes* appear.

600. *Process* 2. Fill the eudiometer, fig. 34, with water, and stand it on the shelf of the pneumatic trough; pass up into it, three parts of nitrous gas, and two parts of oxygen gas. The gaseous mixture will become of an orange colour and will then disappear.

601. In both these cases, nitrous acid gas is produced by the combination of oxygen gas and nitrous gas: in *process* 1, the oxygen is taken from the air of the atmosphere; in the latter case, the acid is absorbed by the water.

602. WHEN AN INFLAMED TAPER IS PLUNGED INTO NITROUS GAS, THE LIGHT IS INSTANTLY EXTINGUISHED. But, inflamed phosphorus burns in it with great brilliancy.—*Rationale.* The burning phosphorus decomposes the nitrous gas, and absorbs its oxygen; but the heat of the inflamed taper is not sufficiently intense to do that.

603. TO PROCURE NITROUS OXIDE, OR INTOXICATING GAS.—*Process.*—Put a quantity of nitrate of ammonia into a glass retort, and apply the heat of a lamp, which must be gentle, and well regulated. The salt will in a short time liquefy, and must then be kept gently simmering, avoiding violent ebullition. The gas may be collected over water, and must be allowed to stand a few hours before it is used;

during which time it will deposit a kind of white vapour, and will become perfectly transparent.

604. Some of the properties of Nitrous Oxide Gas.

1. A candle burns in it with a brilliant greenish flame, and a crackling noise.—2. It is heavier than common air. —3. Phosphorus, charcoal, and sulphur burn in it,—as likewise does iron wire.—4. When mixed with oxygen gas, upon the application of flame, it detonates.—All these things may be proved, by proceeding as directed for performing the experiments which demonstrate the properties of oxygen gas. It must be observed, however, that bodies to be consumed in nitrous oxide gas, must, when introduced into it, be in a state of complete ignition.

605. Intoxicating power of Nitrous Oxide Gas.

Though this gas is not fitted to support life, yet it may be respired for a short time, and the effects produced by it upon the animal frame, are its most extraordinary properties. The manner of breathing it is this: put nitrous oxide gas that has been purified by standing over water, into a large bladder, or varnished silk bag, having a wide glass tube, or a stop-cock with a large bore, affixed to its neck. Then, hold the bladder by the tube (closing the mouth of the tube by applying the thumb) in the right hand; close the nostrils with the left hand; expel the air contained in the lungs by a long expiration; and instantly apply the tube of the bladder to the mouth, and breathe the gas from, and into, the bladder as long as possible, which, perhaps, will be about two or three minutes. What effects will be produced? Why it is impossible to say: for they differ greatly according to the constitutions of the persons by whom the gas is respired. In general, however, they are *highly pleasureable*, and resemble those attendant on the agreeable period of intoxication. "Exquisite sensations of pleasure —an irresistible propensity to laughter—a rapid flow of vivid ideas—singular thrilling in the toes, fingers, and ears —a strong incitement to muscular motion"—are the ordinary feelings produced by it. The celebrated Mr. Wedgewood "after breathing the gas sometime, threw the bag from him, and kept breathing on laboriously with an open mouth, holding his nose with his fingers, without power to remove them, though aware of the ludicrousness of his situation; he had a violent inclination to jump over the chairs and tables, and seemed so light, that he thought he was going to fly." What is exceedingly remarkable, is, that the intoxication thus produced, instead of being succeeded by the debility subsequent to intoxication by fermented liquors, does, on the contrary, generally render the person who takes it cheerful and high-spirited for the remainder of the day.

606. Carburetted Hydrogen Gas—that with which shops are lighted—produced on a small scale.

Process.—Fill the bowl of the largest tobacco-pipe that can be procured with pulverized coal of a good quality, and close the top of it by the application of pipe-clay, or, what is better, a mixture of sand and beer. When the lute is dry, place the bowl of the pipe in a clear fire: in a few minutes, a dense smoke will issue from the stem, which, on the application of a lighted paper, will inflame, and will continue in a state of beautiful combustion as long as any gas continues to be distilled from the coal. The body which will be found remaining in the bowl of the pipe is the substance called *coke*.

607. A Fountain of Fire—formed by Phosphuretted Hydrogen Gas.

Process.—Put fifteen grains of finely granulated zinc, and six grains of phosphorus, cut in small pieces, (cut this under water), in the glass, fig. 17. Mix, in another glass, a drachm by measure of sulphuric acid, with two drachms of water. Now, take the two glasses into a dark room, and there pour the diluted acid over the zinc and phosphorus in the other glass: in a short time, phosphuretted hydrogen gas will be produced, and beautiful jets of blueish flame will dart from all parts of the surface of the liquid, the mixture will be quite luminous, and a quantity of beautiful luminous smoke will rise in a column from the glass. A *fountain of fire* is a very apt name for the appearance that is produced. The experiment is a very easily performed, and very beautiful one.

608. To procure Sulphuretted Hydrogen Gas.

Process.—Put into the retort, (fig. 18), one part of sulphuret of antimony of commerce, or of sulphuret of iron, broken into a coarse powder, and pour upon it three or four parts of strong muriatic acid; apply a gentle heat, and receive the gas over water.

609. Liquid Sulphuretted Hydrogen.—Water may be impregnated with sulphuretted hydrogen gas, in the same manner that it is impregnated with carbonic acid gas. —See 587. This compound is chiefly used as a test.

610. To procure Ammoniacal Gas.

Process 1.—Take equal parts of muriate of ammonia, and quicklime, each separately powdered, and introduce them into the flask, fig. 54, then fit to the flask the pipe, fig. 31. Apply now a gentle heat, and the gas will be rapidly evolved. The *rationale* of the production of ammoniacal gas in this case, has been already described, (530). If this gas is conveyed into water, it is rapidly absorbed: the water acquiring the properties of what is known by the name of *liquid ammonia*. To collect it, we therefore, do not use the water trough, but proceed as follows: over the pipe whence the gas issues, we invert a glass jar, bringing it down till the top of the pipe nearly touches the upper part of the jar,—this is represented by fig. 51. This mode is founded on the difference between the specific gravity of this gas, and that of common air: for here, the gas, entering the jar at the top, forces down the heavier common air, and occupies its place. We discover when the jar is full of gas, by holding at the bottom of it a feather moistened with muriatic acid; for when the fume of muriatic acid comes in contact with ammoniacal gas, a white vapour is produced. Now, muriatic acid gas (of which we shall speak presently) must be collected in the manner shewn by fig. 52.—See 612. And, consequently, in order to discover when the jar is full of muriatic acid gas, we have only to hold at the mouth of it, a feather moistened with liquid ammonia.

611. *Process* 2. The same as the preceeding—only, instead of the powdered materials for producing the gas, use liquid ammonia.

612. To procure Muriatic Acid Gas.

Process.—Put a quantity of lumps of muriate of soda into the gas bottle, fig. 29, then fit the tube, fig. 30, and the funnel, fig. 58, into the bottle, as directed at 591. Pour strong sulphuric acid down the funnel, and muriatic acid gas will be rapidly evolved. For mode of discovering when the jar is full of gas, see the preceding experiment. *Rationale of this experiment.* The muriate of soda is decomposed by the sulphuric acid: the muriatic acid is discharged in the state of gas, and sulphate of soda (which may be easily crystallized) remains behind.

613. TWO PUNGENT AND INVISIBLE GASES UNITE AND FORM AN INODOROUS SOLID.

Process 1.—Fill a jar with ammoniacal gas, as shewn by fig. 51, (see 610), and fill a jar with muriatic gas, as shewn by fig. 52.—See 612. Apply the two jars mouth to mouth, and the above-mentioned effect will instantly be produced: muriate of ammonia being formed and precipitated on the sides of the jars. *Process* 2.—Dip a clean feather into muriatic acid, and moisten with it the interior of the glass, fig. 6. Moisten, in like manner, the interior of the glass, fig. 16, with liquid ammonia. The glasses, in this state, still seem empty; but, if they are put mouth to mouth together, the whole included space will be filled with a dense white vapour; which in the end settles on the sides of the glasses in the form of a white powder, (solid muriate of ammonia).—*Process* 3. If two jars, one containing ammoniacal gas, and the other containing carbonic acid gas, are thus put together, solid carbonate of ammonia will be formed in like manner.

614. TO PROCURE CHLORINE GAS.

Process.—Grind, in a mortar, three parts of common salt, with one part of black oxide of manganese. Introduce this mixture into the retort, (fig. 18,) and add two parts of sulphuric acid, diluted with the same weight of water. Instead of the above-mentioned materials, you may use one ounce of finely powdered black oxide of manganese, and two ounces of muriatic acid. In either case, apply a gentle heat, and chlorine gas will be evolved. Chlorine gas, being absorbable by *cold* water, must be received in bottles filled with, and inverted in, *warm* water, (of a temperature made by mixing two parts of cold, with one of boiling water). The bottles must be provided with accurately ground stoppers, which must be introduced under water, while the bottles remain full of gas, and inverted, and no water must be left in the bottle with the gas.

Note:—In experiments with this gas, great care should be taken that it does not escape, in any considerable quantity, into the apartment; as its action on the lungs is extremely injurious.

615. Liquid Chlorine.—This may be prepared by agitating chlorine gas with water, in the manner directed for such operations at 587. It possesses the property of destroying vegetable colours.

616. Illustration of the Art of Bleaching.—Put into a phial of liquid chlorine, strips of linen cloth, dyed of different colours: the colours will be quickly discharged.

617. To show that Chlorine Gas supports Combustion.—1. A candle, previously lighted, when plunged into a jar of it, burns with a red flame, and a copious emission of dense fumes. 2. Charcoal-dust; 3. tinfoil; 4. copper-leaf; 5. powdered antimony; 6. phosphorus; and some other bodies; when dropt in it, *inflame spontaneously*.

618. To procure Chlorate of Potass.

Process.—Pass chlorine gas, as it comes from the vessel in which it is formed, through a solution of pure, or sub-carbonate of potass. This may be done by means of Woulfe's apparatus, (fig. 57), using only the bottle into which the alkaline solution is put in addition to the receiver. But, for this purpose, the tube *e*, which passes into the solution must be half an inch wide, in order that it may not be choaked up by crystals which form during the process. The chlorine gas as it passes into the liquid alkali will be rapidly absorbed, and, if the carbonate of potass is used, the carbonic acid escapes with effervescence. The liquor is generally of a pinkish hue from the presence of manganese. When it is saturated, it may be put aside, in a cool dark place, for 24 hours, when it will be found to have deposited a considerable portion of crystallized chlorate, which may be taken out, drained, and purified by solution in boiling water, which, during cooling, deposits the salt in brilliant crystalline scales. Dr. Henry, in his directions for preparing this salt, says—"the solution, when saturated with the gas, may be gently evaporated, and the first products only of crystals are to be reserved for use; for the subsequent products consist of muriate of potass only. NOTE:—By passing the current of gas into the solution the water is decomposed: its oxygen unites to one portion of chlorine to form chloric acid; its hydrogen unites to another portion of chlorine to form muriatic acid,—see 137, 138,—hence a chlorate and a muriate of the alkali are simultaneously produced, and are to be separated by one of the methods above described.

SECTION 4.—ON THE PREPARATION OF SALTS.

619. CARBONATE OF POTASS may be formed by passing a current of carbonic acid gas through pure (or sub-carbonate of) potass, as directed 589. The salt may be crystallized by very slow evaporation.

620. SUB-CARBONATE OF POTASS may be obtained by dissolving the potash of the shops, and filtering and evaporating the solution. It does not crystalize.

621. NITRATE OF POTASS is obtained by adding to a solution of sub-carbonate of potass, nitric acid, as long as effervescence continues. The solution is then filtered and crystallized. To obtain cheaply, for purposes of experiment, nitrate of potass in a state of purity, dissolve common saltpetre in boiling water, nearly to the point of saturation; strain the solution while hot; and add a few drops of caustic potass. If precipitation ensues, continue to add the potass till it ceases. If no precipitation takes place, or when it is at an end, filter the solution, and crystallize by slow evaporation.

622. TARTRATE OF POTASS may be obtained by adding sub-carbonate of potass to cream of tartar, or crystallized tartaric acid, in solution, till the cessation of effervescence, 100 parts of cream of tartar, (which is a super-tartrate) require $43\frac{1}{2}$ parts of sub-carbonate of potass to make a neutral tartrate.

623. TO OBTAIN PURE SUB-CARBONATE OF SODA, dis-

solve soda of commerce in a small portion of water, filter the solution; this clears it from the admixture of earthy bodies. Slowly evaporate the filtered solution by a low heat, very small crystals of muriate of soda will form on the surface. Skim tbem off. When these cease to form, the solution may be suffered to cool, and the purified sub-carbonate of soda will crystallize.

624. Muriate of Soda (culinary salt) may be obtained by dropping into a saturated solution of sub-carbonate of soda, muriatic acid as long as effervescence takes place. The solution is then to be filtered, and crystallized by evaporation.

625. *To purify Muriate of Soda* for chemical purposes, dissolve it in boiled water; filter the solution; and add a solution of carbonate of soda as long as any milkiness ensues. Filter the solution, and evaporate till crystallization.

626. Sulphate of Soda is formed by adding sulphuric acid to a solution of sub-carbonate of soda, till effervescence ceases. The solution must be filtered and evaporated for a short time, and then set by to cool, when crystals will be deposited. The remaining solution must be again evaporated, and again cooled; and this must be repeated till all the water is driven off. *Note:*—If you put a ready formed crystal of the salt into the solution which you set by to cool, crystallization will take place very speedily.

627. Sub-Carbonate of Ammonia may be formed by combining carbonic acid gas, and ammoniacal gas, as directed, 613, *(process 3.)*

628. Carbonate of Ammonia is obtained by forcing a current of carbonic acid gas through a solution of the *sub*-carbonate.

629. Nitrate of Ammonia.—To form this; saturate nitric acid diluted with five parts of water, with carbonate of ammonia. Filter the solution. Then evaporate by a gentle heat, and, to supply the waste of the alkali, (which is volatilized by the heat,) add, occasionally, a little more of the carbonate. When the evaporation has proceeded to a certain extent (which experience alone can point out), the solution is set aside, and the salt upon cooling, crys-

talizes.—The chief use of this salt is to afford, by its decomposition, nitrous oxide.

630. Muriate of Ammonia may be formed by any of the following processes.—1. By saturating sub-carbonate of ammonia with muriatic acid, and filtering the product. —2. By combining the constituents in the gaseous state, see 613.—3. By putting into a wine glass a small quantity of liquid ammonia, and pouring upon it liquid muriatic acid till saturation, which will have taken place when the addition of the acid ceases to cause a white vapour to ascend.

631. Muriate of Barytes is formed by disolving native carbonate of barytes, in diluted muriatic acid. The solution, when saturated, must be filtered, and gently evaporated, when the salt will crystallize.

632. Nitrate of Barytes is formed in the same manner as *muriate* of barytes.

633. Sulphate of Barytes is formed whenever the acid and base which constitute it, or bodies containing that acid and base, are placed in contact. The salt is very abundant in a native state. To convert it into the *nitrate* proceed thus: reduce it to powder, mix it with charcoal powder, and keep it some hours red-hot in a crucible: during this operation, the oxygen of the sulphuric acid forms with the carbon and heat, and forms carbonic acid gas, which flies off, and leaves sulphuret of barytes behind. This product must be dissolved in water, and have nitric acid added to it: when the sulphur will be precipitated, aud nitrate of barytes will remain in solution. Filtration, evaporation, and crytallization then follow, as above directed.

634. Strontia Salts are prepared precisely in the same manner as the *salts of barytes*.

635. Nitrate of Lime. To form this, nitric acid, diluted with five or six parts of water, must be saturated with carbonate of lime, 63 parts of which are decomposed by 90 parts of nitric acid, and give 103 parts of dry nitrate of lime. When this solution is boiled down to the consistence of a syrup, and exposed in a cool place, the salt crystallizes.

636. Muriate of Lime. This may be obtained by dis-

solving carbonate of lime in muriatic acid. To be crystallized, it must be boiled down to the consistence of a syrup, and then set in a cool place. NOTE:—This salt, and the preceeding one, can only be preserved in the solid state by being kept in closed bottles.

637. SULPHATE OF MAGNESIA. To form this, saturate the common magnesia of the shops with diluted sulphuric acid, filter the solution, and crystallize the salt, by concentrating the solution, and then allowing it to cool. For the purposes of experiment, dissolve, filter, and recrystallize, the sulphate of magnesia (Epsom salts) of the shops.

638. NITRO-MURIATE OF GOLD.—This may be instantly formed when wanted, by putting a little pure gold leaf into nitro-muriatic acid.—See 244, 245.

639. TO MAKE NITRATE OF SILVER.—Put a small quantity of pure silver into a test glass, (fig. 17), and pour over it twice its weight of nitric acid and twice as much water as acid. The silver will be quickly dissolved, and at the same time nitrous gas will be discharged (see 201). The solution, if the metal and acid be both pure, will be transparent and colourless; but, if any copper be present, the solution will have a green colour; and if any gold be present, it will be precipitated in the form of a black powder. Should the nitric acid contain any muriatic or sulphuric acid, an insoluble white powder will be formed, which will be a muriate, or sulphate, of silver. Nitrate of silver may be crystallized.

640. NITRATE OF MERCURY is made by dissolving mercury in diluted nitric acid. The saturated solution is very ponderous and colourless; and yields, by evaporation, large transparent crystals.

641. TO MAKE NITRATE OF COPPER.—Put a quarter of an ounce of shreds of copper into a test glass, (fig. 17), and pour over them half an ounce of nitric acid diluted with its bulk of water. An effervescence instantly commences, which is accompanied by a copious evolution of nitrous gas. The liquor assumes a muddy greenish appearance; but afterwards becomes clear and of a beautiful blue colour, which is permanent; and a yellowish precipitate is found at

the bottom of the vessel. To crystallize this salt, evaporate the saturated solution till a strong pellicle is formed on its surface, then set it by to cool. The crystals have the fine blue colour of the solution.

642. To make Sulphate of Iron, all that is necessary is to pour diluted sulphuric acid over iron filings.—See 567, 569. The solution, by evaporation, yields crystals, which have a beautiful green colour.

643. Muriate of Tin is formed by digesting pure tin in concentrated muriatic acid, in the proportion of one part of the former to two of the latter. The vessel, fig. 53, may be made use of. The solution is colourless: it must be preserved in a well-stopped phial in a dark place.

644. Acetate of Lead is obtained by dissolving *white-lead* in distilled vinegar. When the solution is evaporated and cooled, the salt crystallizes.

645. Nitrate of Lead is formed by digesting lead with nitric acid. It forms crystals, when evaporated and cooled.

646. Sulphate of Zinc is formed by pouring sulphuric acid diluted with six parts of water upon granulated zinc. The water is decomposed by the metal: its oxygen forms an oxide by combining with the zinc, and this is dissolved by the acid, forming a colourless solution. The hydrogen of the water, escapes meanwhile, in the gaseous state—See 568. If the solution is rapidly evaporated to dryness, the salt is obtained in a mass which bears a resemblance to loaf-sugar. But, if slowly evaporated to the due degree of density, it shoots into regular crystals.

647. Nitrate of Bismuth.—Nitric acid dissolves bismuth with great rapidity. To one part and a half of nitric acid (undiluted) add, at distant intervals, one of bismuth, broken into small pieces. The salt is crystallizable. The solution cannot be diluted, for water precipitates the metal in the state of an oxide.

648. Nitro-Muriate of Cobalt.—Digest, in a sand-bath, for some hours, one part of cobalt or zaffre, with four parts of nitric acid, add to the solution, one part of muriate of soda and four times as much water as acid, and filter the solution. This is the green symphathetic ink.

SECTION 5.—ON CHEMICAL TESTS, OR RE-AGENTS.

649. Chemical Analysis consists of a great variety of operations, performed for the purpose of separating the component parts of bodies. It might seem an impossible task, to exhibit, in a separate state, five or six substances, the weight of some of which is, perhaps, less than the one-five-hundredth part of the whole; yet, to so wondrous a degree of perfection has the science of chemistry arrived, that we are enabled to do this with ease.

650. When, in an analytical pursuit, the object of inquiry is—what are the elementary parts of a certain compound?—we place that compound, under particular circumstances, to the action of certain bodies or powers, which it is expected will chemically act upon it; and which, when they do, produce changes so obvious to the senses, as to enable us to decide whether the compound does, or does not, contain the principles which it was suspected to contain. The bodies which produce these changes are called *tests*, or *re-agents;* the proper application of which constitutes the chief part of the proceeding called chemical analysis.

651. To illustrate the agencies of chemical re-agents, we shall subjoin some striking and beautiful experiments; but, first, it will be necessary to describe the most important tests individually.

652. Tincture of Litmus.—*Preparation.* Tie bruised litmus root in a linen rag and steep it in pure water. Strain the infusion, and add to it an eight part of alcohol: this is to keep it from spoiling. Should the tincture be more of a purple colour than of a blue, it must have a drop or two of liquid ammonia added to it.—*Use.* It is a test of most uncombined acid. Its blue colour is changed to red by water containing 1-20,000 of its bulk of sulphuric acid. The redness produced by carbonic acid and sulphuretted hydrogen, goes away when the mixture is heated. The other acids permanently redden the test: the red colour is changed to blue by the alkalies and alkaline earths,

653. Litmus Test Papers are prepared by staining slips of paper, four inches long, and half an inch wide, with the tincture. The tint should be pale,—the paper for this purpose must be *unsized writing paper;* or, if sized, must be well washed with warm water. The litmus papers are more conveniently applied than the tincture; but they are not so delicate a test. They are sensible, however, to acid diluted to 1-14000.—Test papers must be kept from light and air, or they will be spoiled.

654. Tincture of Cabbage.—To prepare this, pour boiling water upon sliced red cabbage, decant the clear infusion (which will be of a fine blue colour) when cold, and mix it with an eighth part of alcohol. Red cabbage leaves may be preserved for a long time, by drying them in a warm place till they are crisp, having previously cut them into small pieces. It is necessary to be provided with some of these dried leaves, because the tincture spoils by keeping. The blue colour of this test is changed to red by acids, and to green by alkalies and alkaline earths.

655. Tincture of Turmeric is prepared in the same manner as tincture of litmus. It has a fine yellow colour which alkalies change to a reddish-brown. The carbonated earths have no action upon it, so that, in solution, they may be thus distinguished from alkalies. It is a delicate test, being affected by a solution containing only 1-2000 of potass. *Turmeric test-papers* are prepared as litmus test-papers are.

656. Tincture of Galls is prepared by steeping bruised nut-galls in boiling water, filtering the solution, and adding to it an eighth part of alcohol. It is the test generally employed for detecting iron, with all the combinations of which it produces a black tinge. It is, likewise, owing to the *tan* contained in it, a good test for gelatin, with which it forms an insoluble precipitate.

657. Sulphuric Acid.—1. Discovers, by a slight effervescence, the presence of carbonic acid.—2. Barytes, for which it is the best test, is precipitated instantly, in the form of a white powder, which is a sulphate of barytes.—3. It throws down lime from most of its solutions.—4. It precipitates lead, as a white powder.

658. Oxalic Acid (in solution) is a most delicate test of lime, which it separates from all its combinations. *Oxalate of Ammonia* (which may be easily formed by saturating the carbonate of ammonia with a solution of oxalic acid) is preferable to the pure acid as a re-agent, being less affected by other substances.

659. Pure Alkalies, and Carbonates of Alkalies, (in solution), precipitate most of the earths and all the metals: the colour, and other properties, of the precipitate, determining the nature of it.

660. Lime Water, made by dissolving pure lime in rain water is chiefly used as a test for carbonic acid, with which it forms a white precipitate. On the same principle *liquid carbonic acid* is a test for lime. Lime water also shews the presence of corrosive sublimate by a sediment of a brick-dust colour.

661. Barytic Water is more effectual than lime water in denoting carbonic acid, and is more portable and convenient; since, from the crystals of this earth, the solution may be at any time readily prepared. The barytic solution is also a most sensible test for sulphuric acid, which it indicates by an insoluble precipitate.

662. Metals may be used as tests of each other on the principle of elective affinity. Thus, for example, a polished iron plate, immersed in a solution of sulphate of copper, soon acquires a coat of this metal—this is occasioned by the sulphuric acid seizing on the iron, and letting fall the copper; and the same in other instances.

663. Nitrate of Silver (in solution) is peculiarly adapted to the discovery of muriatic acid and muriates. For the silver combines with the muriatic acid, and forms a flaky precipitate, which, at first, is white, but on exposure to the sun's light, acquires a blueish and finally a black colour. Muriatic acid, consequently, is a test for silver.

664. Acetate of Lead (in solution) is a test for sulphuretted hydrogen, which occasions a precipitate of a black colour. It also forms a white precipitate with sulphuric acid, for which, however, it is not so good a test as the following.

665. Muriate of Barytes (in solution) is the best test

for sulphuric acid. A sensible precipitation is produced by it in water, containing only 1-910256 part of sulphuric acid. This is supposing the acid to be uncombined: for the acid in a state of combination (as in sulphate of soda, &c.) the test is not so sensible.

666. Prussiate of Potass is a very sensible test of iron, with the solutions of which in acids it produces a prussian blue precipitate. To render its effect certain, a little muriatic acid must be added previously, to saturate bodies which might interfere. It also precipitates many other metals, see 211.

667. Muriate of Lime (in solution) is sometimes used to discover sulphuric acid, with which it forms a white precipitate; but, it is not so good a test as muriate of barytes.

668. Solution of Soap in Alcohol is employed to ascertain the comparative hardness of waters. With distilled water it may be mixed, without any change ensuing; but if added to a hard water, it produces a milkiness, more considerable as the water is less pure; and from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is owing to the alkali quitting the oil whenever there is present in a water any substance for which the alkali has a stronger affinity than it has for oil. Thus all uncombined acids, and all salts, except those of alkalies, decompose soap, and occasion that property in waters which is termed hardness.

669. Carbonic Acid (applied either in the gaseous or liquid state) occasions a white precipitate in lime,—barytic, —or strontia—water, soluble, with effervescence, in muriatic acid.

670. Nitrate of Mercury (in solution) is the most sensible test of ammonia, one part of which, with 30,000 parts of water, is indicated by a slight blackish yellow tinge on adding the test.

671. Liquid Ammonia is an excellent test for copper, with which it strikes a fine blue colour.

672. Metallic Tin, and Nitro-Muriate of Tin, (in solution), throw down *Gold* in the form of a purple oxide.

On the same principle, nitro-muriate of gold serves as a test for tin.

673. LIQUID SULPHURETTED HYDROGEN is a test for both lead and arsenic; with the former it gives a black, and with the latter a yellow, precipitate.

*** The following experiments are intended to give an idea of the great power and usefulness of these tests.

674. A BEAUTIFUL GREEN LIQUID PRODUCED BY MIXING A BLUE ONE WITH A COLOURLESS ONE.—Nearly fill the test glass, fig. 6, with water, and add to it a spoonful of the tincture of cabbage. The mixture will be of a fine blue colour: add, next, a few drops of colourless liquid ammonia: the mixture will instantly become green. *Rationale.*—This experiment is designed to exhibit one of the distinguishing properties of alkalies, namely, that of changing vegetable colours. A solution of potash or soda produces the same effect as liquid ammonia; but, if the liquid made green by ammonia be boiled, it regains its blue colour—because that alkali, being volatile, is driven off in the gaseous state by the heat.—The following experiment shows the mode of using the common test for alkalies.

675. *Process.*—Into a test glass of water, pour a few drops of an alkaline solution, and then dip into the mixture a slip of turmeric paper. The pale yellow colour of the test-paper will be changed to a deep brown.

676. TO PRODUCE A BEAUTIFUL CRIMSON LIQUID BY MIXING A BLUE ONE AND A COLOURLESS ONE.—To a mixture of a tea-spoonful of tincture of cabbage with a glass full of which, add a few drops of sulphuric or muriatic acid; upon water, the blue colour given by the tincture will be changed to a red.—This is designed to show the influence of acids in changing vegetable colours. If a red colour is produced by dropping a little tincture of cabbage into a certain solution, we know that that solution contains an acid; and if the reddened solution upon being heated becomes blue, we learn that the acid is either carbonic acid, or sulphuretted hydrogen—as only those two acids are volatile.

677. TO CHANGE THE COLOUR OF A LIQUID FROM GREEN TO RED, BY ADDING A COLOURLESS ONE TO IT.—The green liquid is the one produced by experiment 674. The colour

is changed by pouring a little sulphuric acid into it. A portion of the acid neutralizes the alkali by combining with it, and another portion produces its ordinary reddening effect.

678. To make the same liquid alternately Red and Green by the addition of two Colourless liquids, you have only to add alternately a few drops of sulphuric acid and liquid ammonia, to diluted tincture of cabbage.

679. Water, contained in a tall glass, may be coloured Crimson at the bottom, Purple in the middle, and Green at the top.—Nearly fill a tall test glass with water, and colour it blue by adding a table-spoonful of tincture of cabbage—then make it green by adding a little liquid ammonia, and afterwards pour a little sulphuric acid gently down the sides of the glass: upon which the effect mentioned will be produced.

680. Three different Colours produced from the same Vegetable Infusion, by the addition of three Colourless Liquids.—Into each of three test glasses put a little diluted tincture of cabbage. To one, add a solution of alum, to the second, a little solution of potass, and to the third, a few drops of muriatic acid. The product of the first mixture will have a purple colour, that of the second, a bright green, and that of the third, a beautiful crimson.

681. Test for Muriatic Acid.—Add a drop of muriatic acid to a quart of a water; pour some of the mixture into a test glass, and let fall into it a single drop of nitrate of silver—the whole will instantly be pervaded by a milkiness, as the muriatic acid combines with the silver and forms muriate of silver, a salt highly insoluble. So great is the power of this test, that if a single grain of common salt is dissolved in 42,250 grains of water, the muriatic acid, though amounting to only the 1-108,333 part of the weight of the solution, is detected.

682. Tests for Sulphuric Acid.—Mix a drop of sulphuric acid with a quart of water, and pour some of this into four test-glasses. Then add to the four glasses separately, the four tests described 661, 664, 665, 667. In all the cases, there will follow a precipitation of a white powder: in the first case, sulphate of barytes (a salt highly

insoluble) is formed; in the second case, sulphate of lead; in the third, sulphate of barytes; in the fourth, sulphate of lime.—The muriate of barytes is the best test.

683. Tests for Iron.—*Process* 1. In a goblet-full of water, dissolve one grain of sulphate of iron, and add a very little tincture of galls: a purple or blackish colour will be produced immediately, showing that every drop of the water is united to a portion of iron.—*Process* 2. To a similar diluted solution of sulphate of iron, add a drop or two of a solution of prussiate of potass,—by which a beautiful prussian blue colour will be produced.

684. Test for Gold.—To a diluted colourless solution of nitro-muriate of gold, add a few drops of a solution of any salt of tin—or stir the solution of gold with a slip of metallic tin: in either case, the production of a beautiful purple or port-wine colour will be the immediate result.—If the mixture is allowed to settle, it becomes colourless; a purple powder (which is an oxide of gold combined with a little tin) being precipitated. This powder is employed in the painting of china, and is called the purple precipitate of Cassius.

685. To convert Iron (apparently) into Copper.—Dip a piece of polished iron (as the blade of a knife) into a solution either of nitrate or sulphate of copper: it will assume the appearance of a piece of pure copper. For an explanation of this phenomena, see 662.

686. Test for Copper—a beautiful Blue liquid produced by mixing two Colourless ones.—Add a few drops of a solution of nitrate of copper to a test glass of water—the mixture will be colourless: pour into it, a little liquid ammonia—the mixture will then assume a fine deep blue colour.—*Rationale.* The alkali precipitates the copper, and then dissolves it, forming a blue liquid ammoniuret of copper.

687. To produce a Colourless liquid by mixing a deep Blue one with a Colourless one. Add a little nitric acid to the product of the preceding experiment: upon which the effect described will be produced.—*Rationale.* The ammoniuret of copper is decomposed, and nitrate of of ammonia formed. The copper re-unites to the nitric

acid, and is dissolved in the water, which, on account of its quantity, renders the blue colour of the salt insensible.

688. Test for Lead.—Dissolve a grain of nitrate or acetate of lead in a glass of water, and add a little solution of sulphate of soda—a dense white precipitate (which is sulphate of lead) will be produced immediately; allow the mixture to settle, decant the clear part, and digest the precipitate in nitric acid: to the solution obtained by that means, add liquid sulphuretted hydrogen, upon which a precipitate of a black colour will be produced. Thus, in this experiment, the lead passes through the several states of an acetate, a sulphate, a nitrate, a hydrosulphuret.

689. Test for Silver.—Let fall a drop of a solution of nitrate of silver into a glassful of water, and add to it a grain of common salt.—Mutual decomposition of the salts will take place, and muriate of silver (in the form of a white powder) will be precipitated—see 663.

690. To Distinguish Iron from Steel.—Let a drop of diluted nitric acid fall on the metal; and after a few minutes wash it off with water. If the metal be steel, a black spot will be left on it; if it be iron, a whiteish-grey spot will remain.—*Rationale*. The nitric acid dissolves the iron in both cases; but the charcoal that enters into the composition of the steel, remains undissolved, and constitutes the blackness.

691. Test for the Purity of Wine.—Put into a phial, sixteen grains of sulphuret of lime (prepared by exposing to a red heat, in a covered crucible, equal weights of powdered lime and sulphur), and twenty grains of super-tartrate of potass (cream of tartar). Fill the phial with water, cork it well, and shake it occasionally for the space of ten minutes. Separate the clear liquid by decantation, and preserve it in a well stopped bottle for use.—A portion of this liquor fresh prepared, when added to wine containing lead, produces a blackish precipitate.

692. To detect Copper in Pickles or Green Tea.—Put a few leaves of the tea, or some of the pickle cut small, into a phial, with two or three drachms of liquid ammonia, diluted with one half the quantity of water.—Shake the

phial: when, if the most minute portion of copper be present, the liquid will assume a fine blue colour.

693. To determine whether water be hard or soft; that is, whether or not it be fit for domestic purposes.—To a glassful of the water, add a few drops of solution of soap in alcohol. If the water be pure, it will continue limpid; if it be impure, white flakes will be formed—see 668.

694. To determine whether Wheat Flour or Bread, be adulterated with Chalk.—1. Mix with the flour to be tried, a little sulphuric acid: if chalk or whitening be present, an effervescence (arising from the discharge of the carbonic acid of the chalk) will take place; but, if the flour be pure, no effervescence is produced.—2. Pour boiling water on some slices of bread, and then pour into the water a little sulphuric acid: if there be any chalk in the bread, an effervescence will ensue as before; but if none be in it, no effervescence ensues.

695. To discover if Bread is adulterated with Alum.—The bread must be soaked in water, and, to the water in which it has been soaked, a little of any test for Sulphuric acid must be added. (Solution of muriate of lime will do). Upon which, if any alum be present, the liquid will be pervaded with milkiness; but, if the bread be pure, the liquid will remain limpid.—*Rationale.* Sulphuric acid has a stronger affinity for lime than for the alumina and potass with which it forms alum; it therefore quits those bodies, to form sulphate of lime, with the lime of the test—which produces the milkiness.

696. Test for Jelly.—Let a grain of isinglass, glue, or any other gelatinous matter, be dissolved in a goblet-full of water, and let a few drops of tincture of galls be added to the solution: the immediate product will be an abundant flocculent precipitate. This precipitate is a compound of the *tan* of the gall, and the pure *gelatin* of the jelly.

697. Test for the purity of Magnesia.—The common magnesia of the shops (which is a carbonate) is frequently adulterated with chalk; this may be detected by adding a little diluted sulphuric acid, which, with magnesia, forms a very soluble salt, but with lime, a very insoluble

one. Pure magnesia (called *calcined* magnesia, in the shops) dissolves in diluted sulphuric acid entirely, and without effervescence.

698. TO DISTINGUISH A SOLUTION OF EPSOM SALT FROM A SOLUTION OF OXALIC ACID.—1. Taste the solution; Epsom salt is bitter; oxalic acid extremely sour.—2. Pour a little tincture of litmus into the solution: if Epsom salt be present, the blue colour will remain unchanged; if oxalic acid be present, the blue will be turned to red.—3. Tincture of cabbage, or any other vegetable infusion, or a slip of litmus test-paper, are all acted upon by the acid, (which changes their colours), but not by the salt.—What a pity it is, that people should poison themselves by swallowing the acid instead of the salt, when the method of distinguishing them is so easy!

SECTION 6.—MISCELLANEOUS EXPERIMENTS.

699. WRITING WHICH IS LUMINOUS IN THE DARK.—Trace letters or figures on a smooth board, or on dark coloured paper, with a stick of phosphorus, in the same manner as you would trace them with a crayon. Every line thus made will be beautifully luminous in the dark, and will continue so for some minutes.

700. *Rationale.*—The luminous appearance of the writing arises from a slow combustion of the phosphorus which adheres to the board.—In all experiments with this substance, the greatest degree of care is required, on account its very combustible nature. A very small portion of it (the quantity is generally mentioned in the experiments) should be operated upon at once. When it is taken in the hands, it never should be held for more than a few seconds, for the heat thus applied is sufficient to inflame it, if continued; and a burn from phosphorus is more painful than any other kind of burn. A basin of cold water ought always to be at hand, to dip the phosphorus in occasionally; and, when it is cut to peices, it must be cut in water. Phosphorus can only be preserved by keeping it in places where neither light nor heat has access. It is obtained from

druggists in rolls about the thickness of a quill; these are put into a phial filled with cold water, which has been boiled to expel air from it, and the phial is inclosed in an opaque case.

701. To show the Inflammable nature of Phosphorus.—1. Wrap a grain of it, dried on blotting paper, in a piece of brown paper, and rub it with some hard body: it will set fire to the paper.—2. Put into the middle of some dry cotton, a piece of phosphorus the size of a large pin's head, (previously dried, as before): strike it with a hammer and it will inflame.—3. Upon a piece of glass, lay a small piece of phosphorus, and place the glass upon the surface of hot water in a basin: the phosphorus will inflame.

702. Preparation of Phosphorized Ether. Suffer sulphuric ether to stand, for some weeks, over a quantity of phosphorus in a well-stopped phial. The solution is aided by occasional agitation.

703. Preparation of Phosphorized Oil. Put one part of phosphorus with six parts of olive-oil into a florence flask, and digest the mixture in a gentle sand heat for two hours. The solution must be kept in a dark place.

704. To make Waves of Fire on the surface of Water. On a lump of loaf sugar, let fall a few drops of phosphorized ether, and place the sugar in a glass of warm water; a very beautiful appearance will be instantly exhibited, and the effect is increased, if the surface of the water is made to undulate, by blowing gently with the breath.

705. To make Faces ann Hanns Luminous; so that, in the Dark, they Appear as if on Fire.—Though the phosphorized oil and ether are luminous in the dark, yet they have not the power to burn any thing; so that either of them may be rubbed on the face and hands without danger; and the appearance thereby produced is most hideously frightful. All the parts of the face that have been rubbed, appear to be covered with a luminous bluish flame, and the mouth and eyes appear as black spots.—When the bottles containing phosphorized oil and ether are opened in the dark, light enough to tell the hour on a watch is evolved.

706. Brilliant Combustion unner Water. Drop a

piece of phosphorus, half the size of a small pea, into a glass of warm water. It will immediately inflame. Then, force upon it, from a bladder with the jet-pipe, fig. 49, fitted to it, a stream of oxygen gas. Upon this, there will be produced a flame of great vividness.

707. PREPARATIONS FOR THE INSTANTANEOUS PRODUCTION OF LIGHT.—Put a little phosphorus, dried on blotting paper, into a small phial; heat the phial by placing it in a ladle full of hot sand, and turn it round, so that the melted phosphorus may adhere to its sides. Cork the phial closely, and it is prepared. Another method of preparing it, consists in mixing one part of flowers of sulphur with eight parts of phosphorus.—On putting a common sulphur match into this fire-bottle, stirring it about a little, and then withdrawing it into the air, it will take fire. Sometimes, however, it is found necessary to rub the match when withdrawn from the phial on a cork, before it will inflame.

708. CURIOUS PROPERTY OF PHOSPHURET OF LIME.—*Process* 1. Drop a small piece of phosphuret of lime into a wine-glass of water: in a short time bubbles of gas will be produced, which, rising to the surface of the water, will take fire and explode. After each explosion, a beautiful column of white smoke will ascend from the glass.—*Rationale*—see 196.—If the phosphuret of lime be not fresh made, it may be proper to warm the water it is added to. If the residue of the phosphuret of lime be taken out of the water, and, after being dried, has muriatic acid poured upon it, it will inflame.

709. *Process* 2. Into the glass, fig. 6, put one part of chlorate of potass, and two parts of phosphuret of lime in pieces about the size of peas (not in powder). Fill the glass with water, and put into it the funnel fig. 10, which will reach to the bottom of it. Through this pour six or eight parts of strong sulphuric acid, which will decompose the chlorate; and the phosphuret also decomposing the water at the same time, flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light.

710. TO ENGRAVE FIGURES ON GLASS.—Cover one side of a flat piece of glass, after having made it perfectly clean,

with bees' wax, and trace figures upon it with a needle, taking care that every stroke cuts completely through the wax. Next, make a border of wax all round the glass, to prevent any liquid when poured on from running off. Now, take some finely-powdered fluate of lime, (fluor spar); strew it evenly over the glass plate, (upon the waxed side); and then, gently pour upon it, so as not to displace the powder, as much sulphuric acid, diluted with thrice its weight of water, as is sufficient to cover the powdered fluor spar. Let every thing remain in this state for three hours then, remove the mixture, and clean the glass by washing it with oil of turpentine: the figures which were traced through the wax will be found engraven on the glass; while the parts which the wax covered will be uncorroded. —*Rationale.* The fluate of lime is decomposed by the sulphuric acid, and sulphate of lime is formed. The fluoric acid disengaged in the gaseous state, combines with the water that diluted the sulphuric acid, and forms liquid fluoric acid, by which the glass is corroded.

711. Method of Preparing and using a Fulminating Powder. Take three parts of nitrate of potass, two parts of sub-carbonate of potass, and one part of sulphur. Powder them separately, and dry them by placing them on a tile before the fire. Then, mix them intimately, by rubbing all together in a warm mortar; and preserve the compound in a corked phial.—Let half a drachm of this powder be spread on the bottom of a small iron ladle, and heated over a fire. It gradually blackens, and at last melts, at which instant, it explodes with a violent report: it is not, however, attended by any danger.—The explosion is occasioned by a sudden expansion of the solid powder into a variety of gases.

712. To make Gunpowder. Pulverize separately, 5 drachms of nitrate of potass, 1 of sulphur, and 1 of newly-burnt charcoal. Mix them together, with a little water, in a mortar, so as to make the compound into a dough; which must be rolled out into round pieces the thickness of a pin, between two boards. Lay a few of these pieces together, and cut them with a knife into small grains, which are to be placed on a sheet of paper, in a warm place, to

dry. During granulation, the dough must be prevented sticking to the board, by rubbing on it a little of the dry compound powder.—The effects produced by the explosion of gunpowder, are so well known that it would be useless to describe them. It may be observed, however, that the explosion takes place in consequence of the generation of a large quantity of various gases.

713. Fire Produced by the Mixture of two Cold Liquids. Into a gallipot, placed upon a hearth, pour about 3 teaspoonsful of oil of turpentine; then, mix in a phial about 3 teaspoonsful of fuming nitrous acid with $\frac{1}{4}$ part of sulphuric acid, and pour this mixture suddenly upon the oil of turpentine: instantaneous inflammation, accompanied by the production of a large quantity of black smoke, is the result.—It is adviseable to fix the phial from which the acid, is poured to the end of a long stick, as the sudden combustion sometimes occasions a part of the liquid to be thrown out of the vessel.

714. Ready Method of Ascertaining the Proportion of Alcohol in Wines, Beer, Cider, and other Spirituous Liquors.—*Process.* To 100 parts in volume of the liquid to be tried, add 12 parts of solution of sub-acetate of lead, (prepared as directed below), a'precipitation ensues; which, by a slight agitation, is rendered general. On filtering, a colourless liquid, containing the alcohol, is procured. By mixing with this dry and warm carbonate of potass, (calcined pearl-ash), as long as it is dissolved, we separate the water from the alcohol. The latter is seen floating above in a well-marked stratum; the quantity of which can be estimated at once, in a measure tube, (such as figure 12).—*Preparation of the solution of sub-acetate of lead.*—Boil 15 parts of pulverized (and calcined) litharge, with 10 of acetate of lead, in 200 of water, for 20 minutes, and concentrate the liquid by slow evaporation to one half; it must be kept in well corked phials, quite full.

715. To produce Coloured Flames, *which, in the dark, are very curiously reflected by the faces of the spectators.*—To do this, certain substances are mixed with burning alcohol.—A beautiful *rose*-coloured flame, is produced by inflaming four parts of alcohol poured over one part of

muriate of strontia, in a small iron ladle.—An *orange*-coloured flame is produced by burning spirits of wine on muriate of lime deprived of its water of crystallization.—A flame having a fine *green* tinge is produced by burning alcohol on boracic acid, or nitrate of copper.—A *yellow* flame is produced by burning alcohol on muriate of soda or nitrate of potass.—*Note*. It should be observed, that the ladle ought previously to be warmed, and ought to be kept heated while the alcohol is burning. The salts remaining behind, after being dried, may be used for the same purpose again.

716. Brilliant Inflammation, without the presence of Air.—Mix intimately together, eight parts of copper filings, and two parts of flowers of sulphur, and expose the mixture in the glass vessel, fig. 53, to a gentle heat, by means of the lamp-furnace. As soon as the sulphur is heated to a little above its melting temperature, combustion suddenly pervades the whole mass, and the two bodies unite with an explosion—the result being the formation of *sulphuret of copper*. The most curious circumstance attending this experiment is, that it succeeds equally well if the vessel is closed so as to exclude air, or even if filled with *nitrogen gas.* Here, then, is an instance of combustion taking place, without the presence of either oxygen or chlorine. So that the theory which terms those bodies the supporters—and the only supporters—of combustion, is erroneous. The modern notion of combustion, that "it is the result of intense chemical action," appears to be the more correct one.

717. A Metal which Bursts into Flame when thrown upon Cold Water.—Place a piece of potassium of about two grains weight, upon cold water in a basin: —the effect is described at 69.

718. Exhibition of Iodine.—This substance is prepared with great difficulty, and is very expensive. But, at some of the shops where chemical preparations are sold, small glass tubes, hermetically sealed, and containing two or three grains of it, may be purchased.—If one of these glass tubes is gently heated, by holding it over a lamp, the iodine is converted into a beautiful violet-coloured vapour.

719. The Chameleon Spirit—a Liquid which is

Blue when the bottle containing it is open, but Colourless when the bottle is closed.—Put some shreds of clean copper into a small phial, fill it with liquid ammonia, and cork it air-tight. Nothing will take place. Open the bottle and let it remain for a few hours. The liquid will become blue. Cork the phial. After some time, the liquid will be colourless. Re-open the phial,—the liquid will become blue again.—It will be found necessary, sometimes, to add to the mixture, after it has remained exposed to the air for some time, a little more copper.—*Rationale.* Metallic copper is not acted upon by ammonia; but if the copper is allowed to attract oxygen from the air, it then becomes soluble. But copper oxidised only so much as to render it soluble produces a colourless solution; and it is only when it is highly oxidised that the *blue* solution is produced. Thus, in the above case, the copper, when the phial was left open, acquired enough oxygen from the atmosphere to produce blue solution. When, however, the phial was closed, the blue colour disappeared—why?—because the remainder of the metallic copper took, in order to render *it* soluble, the super-abundant oxygen from the portion of copper which was dissolved. The blue colour returned, when the bottle was opened, because more oxygen was attracted.

720. Spoons which Melt in Hot Water.—Fuse together, in a crucible, eight parts of bismuth, five of lead, and three of tin: these metals will combine, and form an alloy, (of which spoons may be made possessed of the remarkable property of melting in boiling water).

721. To Melt a piece of Metal in a Nutshell.—Take three parts of nitre, (freed from water of crystallization by exposure to heat), one part of sulphur, and one of very fine dry saw-dust—mingle the whole intimately together. This is called the *powder of fusion*, and is a kind of chemical flux. Let a quantity of this be well-pressed into a walnut-shell, with a thin piece of copper coiled up in the midst of it, and then set on fire: it will burn rapidly, and the metal will be fused into a round globule, while the shell is only blackened.—A combination takes place be-

tween the metal and sulphur, (which is aided by the potass), and the result is the formation of a sulphuret.

722. To make a Powder which Inflames on Exposure to Air.—To the substance possessing this property, Is given the name of *Homberg's pyrophorus:* it is prepared in the following manner. Equal parts of alum and coarse brown sugar are to be mixed together and dried over the fire in an iron ladle, being diligently stirred all the while with an iron rod. The mixture melts, becomes thick, swells up, and runs into small dry lumps. These are coarsely powdered in a mortar, and again roasted till the operator is well assured that the mass contains not the least moisture, when it looks like a blackish powder of charcoal. This, while hot, must be put into a common phial, which must be previously luted on the inside, by being washed with a weak solution of borax, made as thick as cream, by the addition of pipe-clay, and which must have a narrow glass tube, six inches long, and open at both ends, luted into its neck. The phial, which, however, is to be filled three-fourths full only, is to be placed in a crucible, or deep iron pan, and covered with sand; and the crucible is to be put into a fire, and heated to redness: a thick smoke will rise from the tube for a quarter of an hour, which is succeeded by a sulphurous vapour, which must be inflamed. When this flame disappears, the operation is completed: the tube must be then closed by a plug of soft clay, and the crucible must be removed from the fire. As soon as the phial becomes cool enough to be handled, the contents of it are to be hastily transferred into a dry and warm stout glass phial, which must be secured by a ground glass stopple.—*Experiment.* Throw a little of this powder from the bottle upon some flat dry surface: in a short time it will burst into flame.—*Rationale.* The sulphuret of potass derived from the alum, attracts moisture, or (perhaps) a little potassium formed in the process, attracts oxygen, from the air, and generates sufficient heat to kindle the carbonaceous matter mingled with it.

723. Phosphorescence.—1. If coarsely powdered fluor spar be sprinkled in a dark room, on a fire shovel made hot, (but not to redness), a beautiful phosphorescent light

will be emitted for some time.—2. "About 4 drachms of the substance of a fresh herring were put into a solution of 2 drachms of sulphate of magnesia, in 2 ounces of water. On the succeeding evening, the whole of the liquor, upon shaking the phial, became beautifully luminous; and it continued luminous till the fourth night."—3. Herrings, whitings, and many other fish, if examined in the dark, shortly after being caught, will be found to possess a considerable share of this phosphorescence. The English glow-worm, the Chinese lanthorn-fly, and the West-India fire-fly, are *living* phosphorescent bodies. The cause of the curious property thus possessed by some bodies is unknown.

724. To make Canton's Phosphorus.—Take thick oyster shells, wash them, and keep them red-hot in an open fire for half an hour: then, select the whitest parts, and pound them in the Wedgewood's-ware mortar. Mix three parts of this powder with one part of flowers of sulphur, and ram the compound into a crucible, till it is nearly full. The crucible is then to be kept red-hot for at least an hour; and when it has afterwards become cold, the contents of it are to be turned out, and the whitest part scraped off, and preserved in a phial with a ground-glass stopple. If the bottle containing this phosphorus be exposed for a few minutes to the light of the day, and be then taken into the dark, light enough will be emitted to enable one to distinguish the figures on the dial-plate of a watch. If the bottle containing the phosphorus is heated the luminous appearance encreases; if cooled, it decreases. The phosphorescence ceases after a while; but is renewed when the phosphorus is again exposed to light.—*Rationale.* It is generally supposed, that light is capable of entering into bodies, and, after remaining in them, of being extricated unaltered.

725. Preparation of Ginger-Beer Powders.—Take 2 drachms of fine loaf sugar, 8 grains of ginger, and 26 grains of carbonate of potass, all in fine powder,—mix them intimately in a Wedgewood's-ware mortar. Take, also, 27 grains of citric or tartaric acid, (the first is the pleasantest, but the last the cheapest). The acid is to be kept separate

from the mixture. The *beer* is prepared from the powders thus: take two tumbler glasses, each half filled with water—stir up the compound powder in one of them, and the acid powder in the other: then mix the two liquors—an effervescence takes place—the beer is prepared, and may be drank off. The effervescence is occasioned by the discharge of the carbonic acid of the carbonate of potass, which is given up because the potass has a stronger affinity for the tartaric acid. If the beer is allowed to stand for a few minutes, it becomes *flat*: this is owing to its having lost all its carbonic acid.—The cost of these powders is 8*d*. a-dozen sets.

726. Method of preparing Soda Water.—Soda water is prepared (from powders) precisely in the same manner as ginger beer, (see preceding exp.) except that, instead of the two powders there mentioned, the two following are used: for one glass, 30 grains of carbonate of soda; for the other glass, 25 grains of tartaric (or citric) acid.

727. Lemonade.—Mix one part of citric acid with six parts of finely-pounded loaf-sugar: a very fine dry lemonade is thus prepared, which may be preserved for any length of time. The quantity of this mixture necessary to be put into a glass of water to make a pleasant drink, must be regulated by the taste of the person using it.

728. Instantaneous production of Curds and Whey from Milk.—A very ready and elegant mode of procuring curds, and also a pleasant acidulous whey, is, by adding to a glassful of milk a little solution of citric acid—taking care not to add too much; an experiment or two will readily show the quantity necessary to effect the purpose.

729. To make beautiful Golden Figures upon Silk.—Dilute a solution of nitro-muriate of gold with thrice its quantity of water, and with the solution paint flowers, or shrubs, on a piece of white silk; then expose the silk (kept moist by being wetted with pure water) to a current of hydrogen gas, which is to be forced through a pipe, from the vessel containing it, as directed 575, 576. The hydrogen gas will reduce the oxide of gold,—the colour of the paintings will change from yellow to green,—and the

figures will soon shine with all the splendour of the finest gold. *Note:*—Unless the silk is kept wet, the effect will not be produced.

730. To make beautiful Silvery Figures upon Silk.—Immerse a piece of silk in a diluted solution of nitrate of silver, and expose it while *wet* to a current of hydrogen gas (as described in the preceding experiment) the silver will quickly be reduced; various colours,—blue, purple, red, orange, yellow,—accompany the reduction, and at last, the threads of the silk appear like silver wire.

731. To make Cinders, or little Wicker-baskets, appear as if they were Crystallized.—Saturate water, *kept boiling*, with alum; then set the solution in a cool place, suspending in it, by a hair, or fine silk thread, a cinder, a sprig of a plant, or any other trifle; as the solution cools, a beautiful crystallization of the salt takes place upon the cinder, &c. which resemble specimens of mineralogical spars.

732. To make a piece of Charcoal appear as though it were Coated with Gold. Dilute a saturated solution of nitro-muriate of gold with 5 times its bulk of water, place a thin slip of fresh-burned charcoal into it, and apply heat, gradually increasing which, till the solution gently boils.—The heat will make the charcoal rob the oxide of gold in solution of its oxygen, whereby the metal is rendered insoluble, and is precipitated on the charcoal, in the form of brilliant spangles.

733. To give a piece of Charcoal a rich Coat of Silver. Lay a crystal of nitrate of silver upon a piece of burning charcoal,—the metallic salt will deflagrate and throw out the most beautiful scintillations that can be imagined. The silver is reduced, and, in the end, produces upon the charcoal an appearance very brilliant.

734. Beautiful precipitation of Pure Metals from Metallic Salts.—*Process* 1. Let a small piece of phosphorus be scraped to free it from oxide, and dried by immersion in alcohol. Pass a thread through it with a needle, and then suspend it in a solution of nitro-muriate of gold. In a few minutes, the phosphorus will be covered with pure gold.—*Process* 2. Suspend, in like manner, a

bit of phosphorus in a solution of sulphate of copper, for a few hours; the result will be a precipitation of pure copper. —*Process* 3. Let the same be suspended, for a day or two, in a solution of nitrate of silver—a brilliant precipitation of silver will ensue.—*Rationale.* The oxygen which enter into the composition of the metallic salts by forming soluble oxides with the metals, is abstracted by the phosphorus; and the metals, being in its absence insoluble, are precipitated.

735. To show the Fixity of the Noble Metals.—Expose to a current of oxygen gas, in the manner described, 563, an alloy of silver and lead: as soon as the alloy is in a state of complete fusion, the lead will begin to burn, and, in a short time, will be entirely dissipated in a white smoke; the silver being left behind in a state of purity.

736. To make a beautiful Green Paint.—Add, to a hot solution of sulphate of copper, a little solution of carbonate of soda—a beautiful powder (known by the name of French Green) will be precipitated.—The powder is a sub-carbonate of copper.

737. To show that the Atmosphere contains Water, even in the Driest Weather.—1. Expose to the open air, for a few days, a spoonful of dry sub-carbonate of potass, or muriate of lime, spread on a saucer: the salt will attract so much moisture from the air, that it will become liquid.—2. Put a certain quantity of strong sulphuric acid into a vessel exposed to the air; re-measure it after a few days: its bulk will be found to have increased.

738. To show that the Atmosphere contains Carbonic Acid.—Expose to the open air, in an open vessel, a quantity of transparent lime water; a white crust will soon form on its surface, which on being broken, falls to the bottom of the vessel, and is succeeded by another—this precipitate, upon being examined, proves to be carbonate of lime—therefore, carbonic acid is attracted from the atmosphere by the lime in solution.

739. To show that Carbonic Acid is contained in Air Respired from the Lungs.—*Process* 1. Put into a test glass a little water tinged blue by tincture of cabbage; then, blow into this water, through a tobacco-pipe, air from

the lungs—the blue colour will be soon changed to red. This proves that the air blown from the lungs contains *an acid*—now, *query*, which acid is it? Let us see.—*Process* 2. Warm the product of *process* 1, the blue colour will be restored—hence the acid is volatile, and must be either carbonic acid or sulphuretted hydrogen. That it is *not* the latter, may be known by its want of smell; that it *is* the former, may be proved thus;—*Process* 3. Blow air, in the manner described above, into lime or barytic water. The transparent solution will be shortly rendered opaque, by the formation of carbonate of lime, or of barytes.

740. Chemical Miracle! two limpid Liquids converted by mixture into a Solid Mass.—*Process* 1. If a saturated solution of muriate of lime be mixed with a saturated solution of carbonate of potass, (both transparent liquids), the result is the formation of an opaque and almost solid mass.—*Rationale*. Mutual decomposition of the salts takes place—muriate of potass, and carbonate of lime, are formed; and the latter absorbs the whole of the water of solution—and thus a degree of solidity is produced.—*Process* 2. Drop sulphuric acid into a saturated solution of muriate of lime: in this case also an opaque mass is produced.—*Rationale*. The muriate is decomposed, and sulphate of lime (a highly insoluble salt) is formed.—*Process* 3. Pour a saturated solution of caustic potass into a saturated solution of sulphate of magnesia (Epsom salt)—a nearly solid mass is again produced.—*Rationale*. The sulphuric acid leaves the magnesia (which is then precipitated in the form of a white powder) in order to combine with the potass, for which it has a greater affinity. *** If a little nitric acid be added to the product of *process* 1, the solid mass will be changed to a transparent liquid: the insoluble carbonate of lime being converted into the soluble nitrate.

741. A Fluid produced by rubbing together two Solid Metals.—Triturate an amalgam of lead with an amalgam of bismuth—the product will be fluid, like mercury. Fluids are likewise produced when any of the mixtures which follow are triturated: acetate of lead and sulphate of zinc—or, sulphate of soda and nitrate of am-

monia—or, sulphate of soda and carbonate of potass.—These salts should be all fresh crystallized.

742. A Green coloured Solid produced by mixing a Blue one with a White one.—Triturate crystallized sulphate of copper with crystallized super-acetate of lead. In this process, acetate of copper (which is of a green colour) is formed.

743. An Alloy which may be kept in Fusion upon a Paper held over a Candle.—Melt together in a crucible—lead one part, zinc one part, bismuth one part.

744. To make the admired Cosmetic called Pearl Powder—Dissolve bismuth in nitro-muriatic acid, and gradually add to the solution cold distilled water: upon which, a beautiful white powder, which is an oxide of bismuth, will be precipitated.—See 266.

745. Metallic Trees.—Some of the metals, when precipitated in a particular manner from their solutions, crystallize into the appearance of very beautiful trees or plants, which are usually known by the Latin name of *arbors*. These experiments are not only curious and entertaining, but very simple; and, therefore, we subjoin the processes for working them.

746. Formation of the Silver Tree, or Arbor Dianæ.—Mix one part of a saturated solution of nitrate of silver with twenty parts of distilled water, and pour the mixture upon two parts of mercury in a phial. After some time (the phial being left standing quietly) the branches and figure of a tree formed of brilliant silver will appear to grow from the mercury, in a very beautiful manner.—*Rationale*. The silver in solution is robbed of its oxygen by the metallic mercury, and is then consequently precipitated.

747. Formation of the Iron Tree, or Arbor Martis.—Add a saturated solution of sub-carbonate of potass to a solution of nitrate of iron. The mixture swells up considerably, then sinks to rest, and metallic branches spring out in a very curious manner on the surface of the glass.

748. Formation of the Lead Tree, or Arbor Plumbum.—Dissolve two drachms of acetate of lead (sugar of lead) in six ounces of rain water; filter the solution; and

pour it into a clean wide phial. Then, suspend a thin roll or a granule of zinc, by a thread or wire fastened to the cork of the phial, in the middle of the solution, and place the phial where it will not be disturbed. After a few hours, the lead (which is de-oxidized by the zinc) is precipitated on the zinc in the shape of scales or leaves, which have a very brilliant appearance.

749. Easy Production of Silver Shrubbery.—*Process* 1. Bend a piece of copper wire into the shape of a tree, (but *flat*), or any figure you choose, and lay it upon a piece of glass or slate over which you have previously spread a few drops of nitrate of silver. In a few hours, the copper will be covered by brilliant ramifications of silver.—*Process* 2. Drop a little solution of nitrate of silver upon a clean plate of copper; in a short time, a very elegant and pleasing metallic vegetation will be observed to branch out.

750. Easy method of making beautiful Golden Figures upon Steel.—Add, to a saturated solution of nitro-muriate of gold, about a fourth part of sulphuric ether; shake the mixture, and then allow it to settle. The ether will take the gold from the acid, and will separate itself from it also and form an upper stratum in the vessel. Carefully pour this ethereal gold into another glass, and immerse in it any steel utensil that is highly polished, then take it out and instantly plunge it into water—when the surface will have acquired a coat of pure gold, the beauty of which may be increased by burnishing.—You may use a pen, and draw figures on razors, &c., and the gold will remain on them, as just described.

751. To make Fulminating Quicksilver.—Dissolve 100 grains of mercury in an ounce and a-half (by measure) of nitric acid, assisting the solution by heat. When the solution is cold, pour it upon two ounces (by measure) of strong alcohol, previously introduced into a small glass retort, and apply a moderate heat till effervescence is excited. (Do not forget that the mercurial solution must be *poured upon the alcohol*, and not the alcohol upon the solution.) A white fume then begins to undulate on the surface of the liquor, and flows through the neck of the retort; and a white

powder is gradually precipitated. As soon as any precipitate ceases to form, quickly pour the contents of the retort upon a filter, well wash the powder with distilled water, and cautiously dry it by a heat not exceeding that of boiling water. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid; and while any of that acid adheres to it, it is very subject to be decomposed by the action of light. From 100 grains of mercury, about 120 or 130 grains of the fulminating powder are obtained.—*Experiments.*—1. Lay about a grain of the powder on a smooth iron, and strike it with a hammer—it will detonate with violence.—2. The third of a grain of it may be enclosed between the ends of two slips of card pasted together, and the other end of the card marked by a notch. If that end of the card which contains the powder be held over a candle, detonation takes place.—3. Half a grain of the powder may be wrapped up with a hard pea in a piece of tissue paper. This, (which is the *fulminating ball*, or *Waterloo cracker*,) when thrown on the ground forcibly, explodes.—4. The other fulminating curiosities, such as *spiders*, &c., are too well known to need describing, and may be easily prepared. Note:—This compound is less dangerous than the fulminating compounds of gold and silver, as it never explodes spontaneously; but yet it cannot be handled with too much caution; and no student should attempt to make it who is not tolerably expert at chemical processes in general.

752. To make Brass.—Put into the bowl of a large tobacco-pipe, a portion of copper filings, mixed with about twice its quantity of finely granulated zinc; cover it with charcoal powder, and press it well together; then, expose it to the action of a clear fire for some time:—the two metals will combine and form brass.

753. To Silver Copper.—Precipitate silver from its nitric solution, by the immersion of polished plates of copper. Take of this silver 20 grains, of super-tartrate of potass 2 drachms, of common salt 2 drachms, and of alum half a drachm; mix the whole well together. Take then the article to be silvered, clean it well, and rub some of the mixture, previously a little moistened, upon its surface;

the silvered surface may be polished with a piece of soft leather.—The dial-plates of clocks, scales of barometers, &c. are all plated thus.

754. Exhibition of the Powerful Detonating Properties of all Mixtures of Inflammable Bodies with Chlorate of Potass.—Note: In the performance of experiments with chlorate of potass, proceed very cautiously. Never use more than the prescribed quantities. Let the hands be covered with stout gloves, and keep the mixtures and vessels containing them as far as possible from the face. Chlorate of potass must never be kept ready mixed with inflammable bodies; for such mixtures sometimes explode spontaneously.

Process 1.—Rub two grains of chlorate of potass into a fine powder in a mortar, and add one grain of flowers of sulphur. Mix them very accurately, by well triturating them in the gentlest possible manner; and then, having collected the mixture to one part of the mortar, press the pestle down upon it suddenly and forcibly......a loud detonation, accompanied by a flash of light, will instantly ensue.

755. *Process* 2.—Let the mixture of the salt and sulphur just described be wrapped in some strong paper or tin-foil, and then struck with a hammer: a still louder report will be produced.

756. *Process* 3.—Let *half* the quantity of a similar mixture be forcibly triturated in a dry mortar......several explosions like the cracking of a whip, accompanied by flashes of purple light, take place.

757. *Process* 4. Four grains of the salt are to be reduced to a fine powder, and then mixed with two grains of finely-pulverized charcoal. To this mixture rather more than one grain of sulphur is to be added; and the whole must be intimately incorporated by mixture, with the least possible friction, on a piece of paper. If this mixture be triturated, it will burst into flame—but not with much noise.

758. *Process* 5.—Mix gently, but intimately, three grains of the salt, with three grains of loaf sugar, both previously reduced to fine powder. Place the mixture on a

plate, and touch it with a thread which has just been dipped in strong sulphuric acid......a sudden and vehement inflammation will be immediately produced.—It will be prudent to fasten the string to the end of a stick.

759. *Process* 6.—Upon one grain of the powdered salt, in a mortar, place half a grain of phosphorus; and then, strike the phosphorus with a pestle .....a violent detonation takes place instantly.—The utmost degree of caution is requisite in this experiment.

760. *Process* 7.—Put into the glass, fig. 17, one part (about 3 grains) of phosphorus, and two parts (6 grains) of the salt; nearly fill the glass with water; and then convey to the bottom of it, by means of the funnel, fig. 10, three or four parts of sulphuric acid.—A violent action ensues, and the phosphorus burns very vividly, with a curious light, under the water.

761. *Process* 8.—Oil may be inflamed on the surface of water, by repeating the preceding experiment, omitting however, the phosphorus, and substituting a little olive or linseed oil.

762. *Process* 9.—If a slip of cotton cloth be dipped in a strong solution of the salt, and afterwards well dried, upon being rubbed in a mortar, it will emit flashes of fire, with explosions similar to the cracking of whips. If the cloth and the mortar be very dry and warm, the trituration causes the cloth to take fire.—Inflammation is also produced by pouring sulphuric acid upon a similar piece of of cloth.

763. *Process* 10.—If a little of the mixture described at *process* 1, be taken on the point of a knife and dropped into a wine-glass containing sulphuric acid, a beautiful column of flame will be produced.

764. Extemporaneous Formation of a Bleaching Liquid.—Add a few grains of chlorate of potass to a spoonful of muriatic or sulphuric acid diluted with half a wine-glassful of water. The liquid thus formed will possess the bleaching property of that described 616.

765. Instantaneous Light-Boxes, sold by Chemists, contain a little phial filled with a liquid, and a number of

small matches: you take a match and dip it into the liquid, upon which it takes fire.—The *liquid* is concentrated sulphuric acid. The bottle containing it is never opened except when it is to be used; for the acid, when exposed to the air, imbibes moisture very rapidly, and is soon spoiled. The *matches* are prepared as follows: the ends of some small slips of light wood are dipped into a strong solution of gum, and afterwards into the mixture of chlorate of potass and sulphur prepared as described 754: the powder is fastened to the wood by the gum, and the matches when dry are fit for use.

766. To prepare Baldwin's Phosphorus, which emits Light in the Dark.—Put some dry nitrate of lime into a crucible, place it in a clear fire, and let it remain in a state of fusion for about ten minutes; then pour it out into a warm iron vessel and it will become solid; break it into pieces, and enclose them in a well-stopped phial. If this phial be exposed for some hours to the direct rays of the sun, and be then taken into a dark place, the substance within it will emit a considerable quantity of light.

767. Homberg's Phosphorus possesses the same property as Baldwin's phosphorus, and is prepared in the same manner—only substituting muriate of lime for nitrate of lime.

768. To obtain Large and Beautiful Artificial Crystals.—This operation requires considerable address, and much patient attention, it is as follows: a solution of the salt to be crystallized is to be slowly evaporated to such a consistency that it shall crystallize upon cooling, which may be known by letting a drop of it fall on a plate of glass. When it is in this state, set it by; and when it is cold, pour into a flat-bottomed vessel the liquid part of the solution off the mass of crystals, which will have formed at the bottom of it. After a few days, solitary crystals will be formed, which will gradually increase in size. Pick out the most regular of these, and put them into another flat-bottomed vessel; and pour over them a fresh solution of the salt evaporated till it crystallizes on cooling. After this, alter the position of every crystal once a day with a glass rod, so that all the faces of it may be alternately ex-

posed to the liquid; for the face on which the crystal rests never receives any increment. By this process the crystals gradually increase in size. When they are so large that their forms can be easily distinguished, take the best of them, and put each into a vessel separately; add a fresh solution of the salt as before directed; and turn every crystal several times a day. By this treatment we may obtain them of almost any size we wish. It is necessary to pour off the liquid from the crystals, and add fresh liquid in its place, very frequently; for the solution, after depositing a certain portion of its salt, becomes weakened, and then attacks the crystals—rounding of their angles in the first place, as an attentive observer may perceive, and infallibly destroying them unless renewed.—The student may endeavour to form regular crystals of *alum* thus, to exercise his dexterity.

769. To Prove that, "Every Salt has a certain Determinate Figure which it assumes upon Crystallization."

Process 1. Dissolve in separate portions of boiling water, equal weights of sulphate of copper and nitrate of potass; pour them together while hot into an evaporating dish, drive off by heat a little of the water, and then suffer the mixture to cool, when the salts will shoot:—the sulphate of copper into *blue* crystals, the nitrate of potass into *white* ones—precisely similar to what they were before they were dissolved.—*Process* 2. Treat, in the same manner, sulphate of iron and muriate of soda: the former salt is separated from the solution (in *green* crystals) by alternate evaporation and cooling; the latter salt can only be obtained (in *white* crystals) by converting all the water into steam.—*Process* 3. Dissolve a quarter of an oz. of each of the following salts in a small quantity of water, in separate glasses,—sulphates of magnesia, iron, copper, soda, alumina and potass (alum),—pour the whole into the Wedgewood's-ware basin, and slowly evaporate a portion of the water. When the liquid has acquired its proper degree of density (the student will be taught by practice to know when this is the case) it must be set by to cool—when every salt will crystallize in its own peculiar manner; having the identical colour, form, taste, and other properties by which it was distinguished previous to its solution: the mixture of the different crystallized salts having a most pleasing, singular, and beautiful appearance.

770. Pleasing Example of Crystallization by Fusion.—Take common red litharge, pour over and stir well with it one third of its weight of strong muriatic acid. Let the mixture become dry, then melt it in a crucible, and pour it into a metallic vessel while in a state of fusion. The mass when cool will be of a beautiful yellow colour, and when broken will exhibit the most regular crystallization that can be conceived.

771. The Mineral Chameleon.—When one part of black oxide of manganese and three parts of nitrate of potass, both reduced to powder, and mixed together, are exposed in a crucible to a strong heat for about an hour, or, as long as any gas continues to be disengaged, a compound of highly oxidised manganese and potass, possessed of some very curious properties, is obtained.—*Experiment* 1.—A few grains of this compound, put into a wine-glassful of water, produces a *green* colour; an increase of the quantity changes the colour to a *blue;* more still to a *purple;* and a yet farther increase produces a beautiful *deep purple.*—*Experiment* 2. Put equal quantities of this substance into two separate wine-glasses, and add to the one *hot,* and to the other *cold,* water. The hot solution will be of a beautiful green colour; the cold one of a deep purple. By using more glasses, and water more or less in quantity, and at different temperatures, a great variety of colours will be produced in this way from the same substance.

772. Examples of Sublimation.—*Process* 1. Put a quantity of roll sulphur, previously reduced to a powder, into the mattrass *a*, fig. 26, then fasten upon *a* the head *b*, and close by a cork the neck *c*. Apply now a gentle heat, and the sulphur will be converted into a vapour, which will be condensed in the head of the vessel in a state of tolerable purity; its purification may be completed by washing it with distilled water.—*Process* 2. Spread a small quantity of grossly-powdered gum benzoin on the bottom of a Wedgewood's-ware basin, invert over it a glass tumbler,

and apply to it a gentle heat by means of the lamp furnace; the gum will melt, and dense fumes will immediately rise from it and deposit themselves in beautiful silky crystals (which are benzoic acid) on the sides of the glass.—*Process* 3. Take a large glass jar, containing at its top a sprig of rosemary or some such shrub, and invert it over a flat thick piece of heated iron on which coarse powder of gum benzoin has just been spread—then, the benzoic acid which rises, as in the preceding experiment, will be deposited on the branches of the shrub, producing a singular and beautiful representation of hoar frost.

773. To obtain pure Gold.—Add to a solution of nitro-muriate of gold, a solution of green sulphate of iron, as long as precipitation ensues: the precipitate is to be well-washed on a filter, (first with diluted muriatic acid, and then with pure water), and dried—it is then pure gold.

774. To form Sulphuret of Iron.—Bring a bar of iron to a white heat, hold it over a pan of water, and touch it with a roll of sulphur. A portion of the metal will instantly combine with the sulphur, and fall, in drops, into the water.

775. Pure Lime is obtained by exposing oyster-shells, marble, or chalk, to the action of a clear kitchen fire, for about an hour. The heat drives off the carbonic acid, and the substance remaining, is pure lime, which must while warm be put into a bottle and be well-secured from the air.

776. Curious Mode of Silvering Ivory.—Immerse a small slip of ivory in a weak solution of nitrate of silver; and let it remain till the solution has given to it a deep yellow colour; then take it out, and immerse it in a tumbler of clear water; and expose it in the water to the rays of the sun. After it has been thus exposed for about three hours, the ivory acquires a black colour; but, the black surface, on being rubbed, soon becomes changed to a brilliant silvery one.

777. Moire Metal, or Crystallized Tin.—Clean a piece of tin from dirt or grease, by well washing it with warm soapy water; and rinse it in clean water. Then, heat the tin to the temperature of bare sufferance to the hand, and pour on it, or apply with a brush or spunge, one

of the following mixtures.—1. Dissolve two ounces of muriate of soda in four ounces of water, and add one ounce of nitric acid.—2. To two ounces of water, add half an ounce of muriatic acid, and one fourth of an ounce of sulphuric acid.—3. Either of the preceding in a greater or less degree of dilution.—When the mixture has been applied, the tin is to be dipped into water slightly acidulated, and afterwards well washed in clean water. This process will cause the tin to assume an appearance of great beauty: an apparent crystallization takes place, somewhat resembling mother of pearl; and curious figures, stars, and rude leaves appear. A transparent varnish (either coloured or colourless) may be laid on now, which will give a fine polish to the work, and produce that brilliant covering so much employed for snuffer-stands, for covering pillars in shop-windows, &c.

Gold-Varnish to be laid on the tin which has been ornamented by undergoing the process just described.—Take of shell-lac two ounces, of arnatto and turmeric of each one ounce, of dragon's blood thirty grains: make an extract with twenty ounces of alcohol in a gentle heat.

778. Sympathetic Inks.—Among the amusing experiments of the science of chemistry, the exhibition of sympathetic ink holds a distinguished place. These liquids, when written with, leave no visible traces behind: the writing only becomes sensible when some known *re-agent* is applied to it.—We shall here mention a few of these "inks" out of the great number which but a slight acquaintance with chemistry will suggest to the student.—Note:—The sympathetic inks may be laid on paper either with a camel hair pencil or a common pen; but, whichever is used, it is necessary that the instrument be perfectly clean—the presence of the smallest conceivable quantity of any foreign body will go nigh to spoil the effect. The best thing to employ is a clean fresh-cut pen.

Process 1.—Write with weak tincture of galls—the characters will be invisible. Moisten the paper with a feather dipped in a weak solution of sulphate of iron—the writing will become *black*.—For an explanation of this phenomenon, see 524.

779. *Process* 2.—Write with a weak solution of prussiate

of potass—the letters will be invisible. Moisten the paper, as in the preceding experiment, with a weak solution of sulphate of iron—the writing will assume a fine *blue* colour.—*Rationale.* Prussiate of iron is formed, see 211, 666.

780. *Process* 3.—Wash paper with a solution of sulphate of iron, and suffer it to dry: when written upon this paper, solution of prussiate of potass produce *blue* letters, and tincture of galls *black* ones; but, upon common paper, they make colourless marks.

781. *Process* 4.—Most acids, diluted, and written with, leave marks which are invisible till the paper is heated, when they become *black;* the heat concentrating the weak acid, and enabling it to char the paper.

782. *Process* 5.—Write with a weak solution of nitrate of silver, and let the writing dry *in the dark*—it will be invisible; fold up the paper so as to keep the writing in the dark—it will continue invisible; but, expose the writing to the light of the sun—it will become *black.*—*Rationale.* The nitrate of silver has the property of being decomposed by light; a black colour being acquired by the metallic oxide.

783. *Process* 6.—Characters written with a solution of equal parts of sulphate of copper and muriate of ammonia, have a *yellow* colour when heated; but, are invisible when cold.

784. *Process* 7.—Write with a weak solution of mnriate of copper—the writing is invisible when cold, but *yellow* when heated.

785. *Process* 8.—Write with a weak solntion of nitro-muriate of gold, and dry the writing in the dark—it will be invisible. Moisten the paper, by means of a feather or bit of spunge, with a solution of muriate of tin—the writing will then assume a *purple* colour.

786. *Process* 9.—Write with a solution of nitrate of bismuth—the writing will be invisible. Immerse the paper in water—the characters will then be legible.—*Rationale.* The water decomposes the salt, and causes the white oxide of bismuth to be precipitated.

787. *Process* 10.—Expose a paper upon which you have

written with nitrate of bismuth, to the vapour of water impregnated with sulphuretted hydrogen—the writing will become *black*. It being the property of bismuth to be thus affected by sulphuretted hydrogen.

788. *Process* 11.—Let a paper upon which you have written with nitrate of bismuth be moistened with solution of prussiate of potass—the writing will assume a *beautiful yellow* colour: a prussiate of bismuth being formed, see 211.

789. *Process* 12.—Write with a solution of sulphate of copper—no writing will be visible. Wash the paper with solution of prussiate of potass—the writing will then get a *reddish-brown* colour: prussiate of copper being formed, see 211.

790. *Process* 13.—Write with a solution of super-acetate of lead—the writing will be invisible. Hold the paper over a saucer containing liquid sulphuretted hydrogen—the writing will become, first black, and then glittering like silver.—*Rationale.* The metallic salt is decomposed by the sulphuretted hydrogen, which robs it of its oxygen, and, consequently, the lead is gradually reduced to its metallic state.

791. *Process* 14.—Upon a fire-screen let there be drawn a representation of winter, with trees destitute of foliage, and ground covered with snow. Let, however, every part of the picture which, if the scene represented summer, would be green, be covered with the sympathetic ink for making which directions are given at 648. Draw for instance, leaves on the trees, and grass on the ground. These marks will not be visible: the picture will still bear the aspect of winter. But, let the firescreen be placed near the fire, *then* the view will exhibit all the verdure of summer. When allowed to cool, the verdure disappears; but it may be again revived, by the same means as before, and that as often as desired—provided, that the paper be not heated beyond a certain point: for, if heated too much, the ink will assume a permanent brown colour.

792. *Process* 15.—Write with a diluted solution of acetate of cobalt (made by dissolving oxide of cobalt in acetic

acid):—the writing will be invisible till the paper is heated, when it becomes *blue*.

793. Preparation of Writing Ink.—*Process* 1. Take two ounces of gall-nuts (in coarse powder); one ounce of logwood (in thin chips); one ounce of sulphate of iron (green vitriol); three-fourths of an ounce of gum-arabic (in powder); one-fourth of an ounce of sulphate of copper (blue vitriol); and one-fourth of an ounce of sugar-candy. Boil the galls and logwood together in three pints of water, till the quantity is reduced to one half; when the liquor must be strained through a flannel into a proper vessel, and the remainder of the ingredients be added to it. The mixture is now to be frequently stirred, till the whole is dissolved: after which, it must be left at rest for 24 hours. The ink may then be decanted from the gross sediment, and must be preserved in a glass, or stone bottle, well corked.—Writing performed with this ink has a beautiful black cast, which it retains, unaltered, for a considerable length of time.—There is an inconvenience attends the use of the sulphate of copper (which some, therefore, dispense with) that requires notice:—upon mending a pen, which is moist with the ink, a film of copper is deposited upon the edge of the penknife, and takes considerably from its keenness. Note:—Ink-holders ought always to be made of *glass*.

794. *Process* 2.—Take four ounces of the best galls; two ounces and a half of sulphate of iron calcined to whiteness; two pints of water; and ten drachms of gum-arabic. The galls, and calcined vitriol, are to be left to macerate for 24 hours, then the gum is to be added, and the mixture is to be preserved in a stone jar, open, or merely covered with paper.

795. Indelible Inks, useful for writing Labels for Bottles containing Acids, &c.—1. Take oil of lavender, 200 grains; gum copal, in powder, 25 grains; and lamp black, 3 grains. Dissolve the copal in the oil of lavender, in a small flask or phial, by the aid of a gentle heat; and then mix the lamp-black with the solution, by trituration in the Wedgewood's-ware mortar. After a repose of some hours, the ink, before use, requires to be shaken, or

must be stirred with an iron wire. If it be found too thick, it may be diluted with a little oil of lavender, or of turpentine.—2. A solution may be made, in like manner, of 120 grains of oil of lavender; 17 grains of copal, and 60 grains of vermillion.—3. Boil one ounce of finely-rasped Brazil-wood, and half an ounce of alum, in twelve ounces of water, till the liquid is reduced to eight ounces; then decant the clear part, and add to it an ounce of calcined manganese mixed with half an ounce of gum arabic.

796. Coloured Inks.—*Red.* Boil an ounce of Brazil-wood (in fine chips) in half a pint of water, for a quarter of an hour; and add to the decoction, 3 drachms of gum-arabic, and as much alum as it will dissolve.—*Blue.* Diffuse Prussian blue or indigo through strong gum-water.—*Yellow.* Dissolve gamboge in gum-water.—*Scarlet.* Dissolve vermillion in gum-water.—Inks of other colours may be made from a strong decoction of the materials used in dyeing, mixed with a little alum and gum-arabic.

797. Ink Powder.—For the use of travellers, who may not find it convenient to carry liquid ink with them, the materials used for producing good ink—see 793, 794—may be finely powdered, and intimately blended together; by which means, an ink powder is made, from which, at any time, good ink may be extemporaneously prepared, by mere mixture with water.

798. To Remove Ink Stains from Books, Linen, &c.—Apply to the spot, muriatic acid, diluted with five or six times its weight of water, and, after a minute or two, wash it off; repeating the application as often as may be found necessary. Strong solutions of oxalic, citric, and tartaric acids, also effect the purpose, and, being less likely than the muriatic acid to injure the fabric they are applied to, are preferable.

799. Permanent Ink for Marking Linen.—Dissolve a drachm of lunar caustic (fused nitrate of silver) in thrice its weight of distilled (or rain) water, and add about half a drachm of gum-arabic. This forms the *ink*, with which you must write, or rather *paint*, with a clean pen, upon the linen prepared as follows: dissolve half an ounce of sub-carbonate of soda in an ounce of distilled water, and add

20 grains of gum-arabic; this forms the *mordant*. Well moisten, with the mordant, the part of the linen that is to be written on, dry it well by a gentle heat, and then apply the ink in the manner above directed, to the place that has been moistened. The writing, when exposed to the sun, becomes black.

800. Ink for Printing on Linen with Types.—Dissolve one part of asphaltum in four parts of oil of turpentine, and add lamp-black, or black-lead, in fine powder, in sufficient quantity to render the ink of a proper consistence for printing with types.

801. Curious effect of Colour with respect to the Absorption and Reflection of Heat.—Take 6 pieces of tin plate, each one inch square—paint (on one side only) 1 black, 1 blue, 1 green, 1 red, 1 yellow, and let the other remain bright. On the backs of these pieces of metal, lay a thin coat of cerate, composed of oil and wax, which easily melts. Place them, thus prepared, on a board painted white, and expose the coloured surfaces of the metal to the rays of the sun. The heat will melt the cerate, and (if the board rests in a proper position) it will run down—from the black, the blue, the green, the red, the yellow, pieces—while the bright one remains nearly unaffected.—This experiment shows that light-coloured surface reflect heat, and dark ones absorb it. Hence we learn, that, if we wish to be warmed by the sun, we should clothe ourselves in black; and that, in the summer, light-coloured dresses are preferable.

802. Very singular property of Camphor.—If a small piece of camphor is placed on the surface of water contained in a basin, it immediately begins to move round and round with considerable rapidity. It is necessary that the water be pure, for, if dust or grease be present, the camphor will not move, or, if, while its rotatory motion is proceeding, a single drop of grease be let fall into the water, the camphor will instantly start away from it to the sides of the basin, and its motion will be put a stop to.—Nothing satisfactory has yet been advanced in explanation of this phenomenon.

803. To make Pewter; melt, in a crucible, one part of lead, or bismuth, with about twenty parts of tin.

804. An Example of the mode of Analyzing a Metallic Alloy.—Suppose the alloy to contain silver, zinc, lead, and bismuth.—*Process* 1. Let it be dissolved with the aid of heat, in an excess of nitric acid.—2. Evaporate the solution to dryness.—3. Pour water on the residuum, which, of course, contains *nitrates* of the different metals—solutions of nitrate of silver, zinc, and lead, will be obtained; the nitrate of bismuth will be decomposed by the water, and oxide of bismuth (for every 100 grains which reckon 90 grains of metallic bismuth) will be left at the bottom.—4. Into a hot and pretty dilute solution of the remaining salts, pour muriatic acid—muriate of silver (containing 83 grains of metal in every 100 grains of the salt) will be precipitated.—5. Add to the solution, having separated the product of the last process by filtration, sulphate of soda—this will throw down sulphate of lead (which contains 69 grains *per cent.* of the metal).—6. Finally, add carbonate of potass to precipitate the zinc. *Note:*—the papers through which the mixture is filtered, are to be carefully weighed before they are used; and are to be weighed again, when perfectly dry, after the process, with the precipitates upon them. The number of grains shows the weight of the precipitates.

805. Lamp without Flame.—Take platinum wire about 1-100th of an inch in thickness. Coil it up, and stick the coil loosely on the wick of a spirit-lamp. The cotton of the lamp must be very straight and not pressed by the wire. There should be about 16 spiral turns, one-half of which should surround the wick, and the rest rise above it. Having lighted the lamp for an instant, on blowing it out, the wire will become brightly ignited, and will continue to glow as long as any alcohol remains.

806. A wire instantly made Red-hot by being placed in contact with a Vapour.—Let a few drops of ether be thrown into a cold glass, or a few of alcohol into a warm one; let a few coils of platinum wire, of the 1-60th or 1-70th of an inch in thickness, be heated to redness by a candle, then, when it has ceased to be red-hot, let it be held in the glass over the ether: in some parts of the glass, it will become glowing, almost white-hot, and will continue

so, as long as a sufficient quantity of vapour and air remains in the glass.

807. Curious Instance of Combustion resulting from Intense Chemical Action.—Coarsely powder a few crystals of nitrate of copper, lay them on a piece of tin foil, add enough water to make them into a kind of paste, and then quickly fold up the tin foil, doubling the sides and corners well together, so as to exclude air: in a short time, nitrous gas will force its way out of the packet, and the tin foil will be set on fire.

808. Exhibition of the effects produced by Galvanic Action.—*Process* 1. Place a piece of zinc upon the tongue, and a piece of silver (as a half-crown) under it; and bring the extremities of the pieces into contact; when a curious metallic taste will be distinctly perceived.

809. *Process* 2. Place a piece of wet tin-foil over one of the eyes, and hold a piece of zinc between the teeth; connect these metals in a dark place by means of a teaspoon—instantly a flash of light will be perceived.

810. *Process* 3. If a rod of zinc, and a rod of silver, are introduced as far back as possible into the roof of the mouth, and the ends brought into contact, the sensation produced will be very powerful.

811. *Process* 4. A Voltaic Pile, constructed as directed, 435, affords a constant current of the galvanic fluid, for many hours, through any conducting body which may be employed to connect its two ends. If the hands be moistened, and one applied to each end of the pile, or if a rod of metal be held in each hand, and a communication be made by means of them, a shock will be received; the intensity of which is according to the number of pieces that compose the pile: thus, zinc, copper, and cloth, repeated 20 times, forms a pile that gives a shock perceptible to the wrists, and a pile five times as high, gives a tremulous but severe and continued sensation extending to the shoulders.

812. *Process* 5. When a wire communicating with the top of a small pile is held between the teeth, so as to rest upon the tongue (the hands at the same time touching the bottom of the pile), the lips, and the tongue, will become con-

vulsed, a flash will appear to the eye, and a very pungent taste will be perceived in the mouth.

813. *Process* 6. Put distilled water into a small glass tube (of a diameter of about one-seventh of an inch), and connect the tube, by means of two copper wires, to the Voltaic pile, in the manner described, 437. (The pile, for this experiment, must be formed of at least 50 or 60 sets of plates). After some time, the wire connected with the zinc or positive end of the pile, will be oxidised at the end in the tube; while from the end of the other (the negative) wire in the tube, a stream of small bubbles of gas will arise. This gas is hydrogen; as may be proved by pulling out the cork, and instantly applying an ignited body to the tube, by which the gas will be inflamed. As the gas that is formed in the tube occupies more space than the water that is decomposed, it is necessary to make room in it by allowing some of the water to escape; this is done by cutting a small slit in the cork fastened in the bottom of the tube.—If two wires of gold or platinum (which are not oxidable) be used instead of the copper wires, a stream of gas then issues from each; and collects at the top of the tube; forming a mixture of hydrogen and oxygen gas, which explodes on the approach of an ignited body.—The gases may be obtained separately, by passing each of the gold wires down a leg of a glass syphon, making them nearly meet at the bottom, and closing the openings at top by means of corks as before. The gas that will be formed will rise up the two legs of the syphon—the hydrogen up the leg containing the negative wire—the oxygen up the leg containing the positive wire—and it will be seen that the gases are formed from the decomposition of the water precisely in the proportions that they are required to compose it, namely, two volumes of hydrogen to one of oxygen. In this case, the water that must be suffered to escape to make room in the tube, must pass through a small hole ground iu the bended part of the syphon, near where the two wires are opposed to each other.

814. *Process* 7. Fill the tube *c*, fig 40, with a solution of acetate of lead, and let the galvanic influence be passed through the tube by copper wires, in the manner described

in the preceding process: no gas will be perceived, for the hydrogen arising from the decomposition of the water reduces the oxide of lead held in solution by the acetic acid, and uniting to its oxygen re-forms water; the lead, in a brilliant metallic state, being precipitated on the negative wire, first in the form of beautiful needles, and then like fern.

815. *Process* 8. Lay a live flounder upon a wetted plate of copper, and lay on the top of it, a piece of zinc; then, by means of a bended wire, make a communication between the pieces of metal placed on each side of the fish: instantly, the animal (though previously lyeing perfectly quiet) will be violently convulsed.

816. *Process* 9. If a piece of zinc and a piece of silver have each one extremity immersed in the same vessel, containing sulphuric or muriatic acid largely diluted with water, the zinc is dissolved and yields hydrogen gas by decomposition of the water; the silver not being acted upon, has no power of decomposing the water; but whenever the zinc and silver are made to touch, or any metallic communication is made between them, hydrogen gas is also formed at the surface of the silver.

817. *Process* 10. Experiments analogous to the former, and equally simple, may also be made with metallic solutions. Take a solution of sulphate of copper; immerse a piece of silver in it—it will come out unchanged; immerse a piece of polished iron it—it will receive a coat of copper (see 662): bring the iron and silver into contact, and immerse them in the solution together—then, both will be coated with copper.

818. Sketch of the Science of Galvanism—explanatory of the preceding experiments.—1. It was accidentally discovered by Galvani, an Italian, that if the crural nerve and the muscles of the leg of a frog be laid bare, and we place a piece of zinc upon the nerve, and a piece of copper upon the muscle, and make the two metals, while so placed, touch each other, the leg of the frog is immediately thrown into violent convulsions.—2. Volta, a friend of Galvani's, invented the *pile* we have described; and showed that shocks like those produced by electricity

could be received from it.—3. Shortly after, it was found that water, and many other substances, could be decomposed by the galvanic energy.—4. It was next discovered, that, when compound bodies are decomposed, oxygen and acids accumulate round the positive pole; while hydrogen, alkalies, earths, and metals, accumulate round the negative pole. Hence it was deduced, that chemical affinity is identical with electrical attraction; and, that the reason that oxygen combines with hydrogen, and acids with alkalies, earths, and metals, is that they are in opposite states of electricity.—5. Galvanic electricity, when properly excited and directed, is sufficiently powerful to decompose any compound whatever. And even pure gold may be burned by being made to form part of a galvanic circuit.

819. Illustrations of the Art of Calico-Printing. —*Process* 1. *To produce a white pattern on a black ground.* Let a piece of white calico be dipped in a cold solution of sulphate of iron, and dried. Then imprint any figures upon it with a strong solution of colourless citric acid, and let this dry also. If the piece be then well washed in warm water, and afterwards boiled in a decoction of logwood, the ground will be dyed either a slate or black colour, according to the strength of the metallic solution, while the printed figures will remain beautifully white.

820. *Process* 2. To produce a Scarlet pattern on a Black ground.—Dip a piece of white calico in a strong solution of acetate of iron (which may be made by boiling sulphate of iron with acetate of lead); dry it by the fire and lay it aside for 3 or 4 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 logwood; and, lastly, rinse it in water, and let it dry. Now, any figures printed upon it with a *colourless* solution of muriate of tin, will acquire a beautiful scarlet colour,—though the ground remains black.

821. *Process* 3. *Of dyeing different colours with the same liquor.* Dissolve indigo in sulphuric acid, and add to the solution an equal quantity of solution of carbonate of potass.—If a piece of *white* cloth be dipped in this mixture, it will be changed to *blue*: in the same way, *yellow*

may be changed to *green;* and *red* to *purple;* and a piece of *blue* litmus paper will become *red.*

822. To obtain Metallic Zinc from an Ore.—Rub together in a mortar 1 ounce of lapis calaminaris (which is an oxy-carbonate of zinc mixed with earths, &c.), and rather more than $\frac{1}{2}$ the quantity of powdered charcoal, mixed with a little quick-lime; press a portion of this mixture into the bowl of a large tobacco-pipe, and submit it to the action of a strong clear fire; after some time, the zinc will be reduced, and will be found at the bottom of the vessel.

823. To Analyse Galena, an Ore of Lead:—A very common ore of lead is *galena,* which is a compound of lead and sulphur. It is of a blue colour, has a brilliant metallic lustre, and is easily broken. Before the blow-pipe it decripitates, melts with a sulphureous smell, and yields a globule of lead.—Let a quantity of this mineral (say 200 grains) be pounded, and put into nitric acid, diluted with an equal weight of water. Nitrate of lead will be formed, and the sulphur will remain undissolved. Filter the solution, and crystallize the salt by evaporation. Or, add to the solution, concentrated sulphuric acid: a white precipitate of sulphate of lead will be thrown down: weigh this, and from the weight deduct 70 per cent.; the remainder shows the quantity of lead.

824. Application of Chemistry to Agriculture.—Analysis of Soils.—Among the substances that compose *soils,* the following are the principal: mixtures of the *earths* (see 165); animal and vegetable matter in a decomposing state; certain saline bodies; and oxide of iron; together with water. Now, in order that a soil may answer a certain purpose, these bodies should be present in particular proportions, and united in a particular manner; and the end of analytical experiments performed with soils, is to determine whether any substance is either super-abundant or wanting.

825. The earths commonly found in soils are principally silica, or the earth of flints; alumina, or the pure matter of clay; lime, or calcareous earth; and magnesia; for the characters of which see articles 169, 170, 171, 172. Silica composes a considerable part of hard gravelly soils, hard

sandy soils, and hard stony lands. Alumina abounds most in clayey soils, and clayey loams; but even in the smallest particles of these soils it is generally united witb silica and oxide of iron. Lime always exists in soils in a state of combination, and chiefly with carbonic acid, when it is called carbonate of lime. This carbonate in its hardest state is marble; in its softest, cbalk. Lime united with sulphuric acid is sulphate of lime, or gypsum; witb phosphoric acid, phosphate of lime, or tbe earth of bones. Carbonate of lime, mixed with other substances, composes chalky soils and marls, and is found in soft sandy soils. Magnesia is rarely found in soils: when it is, it is combined with carbonic acid, or with silica and alumina. Decomposing animal matter exists in different states, contains much carbonaceous substance, volatile alkali, inflammable aëriform products, and carbonic acid. It is found chiefly in lands lately manured. Decomposing vegetable matter usually contains still more carbonaceous substance, and principally differs from the preceding, in not producing volatile alkali. It forms a great proportion of all peats, abounds in rich mould, and is found in larger or smaller quantities in all lands. Tbe saline compounds are few, and in small quantity: they are chiefly muriate of soda, (common salt), sulphate of magnesia, muriate and sulphate of potash, nitrate of lime, and the mild alkalies. Oxide of iron, which is the same with the rust produced by exposing iron to air and water, is found in all soils, but most abundantly in red and yellow clays, and red and yellow siliceous sands.

Process 1. When the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places; the total quantity submitted to analyses may be 400 grains. For weighing the various products of analysis, a pair of scales, capable of holding a quarter of a pound of common soil, and turning with a grain when loaded, must be provided. Soil, when collected, if it cannot be immediately examined, should be preserved in phials quite filled witb it, and closed with ground glass stopples. It should be collected in dry weather, and exposed to the air till it feels dry. The first step to be taken, is an examination of the physical properties of the soil, because *they*, to a certain extent, denote its composition, and therefore serve as guides in directing the experiments: thus, it is of importance that the *specific gravity* of it should be known, as it affords an idea of the quantity of animal and vegetable matter it contains, these substances being always most abundant in the lighter soils; thus, also, a roughness to the tough, and a capability of scratching glass when rubbed upon it, denote siliceous soils; if a soil adheres strongly to the tongue, and emits a strong earthy smell when breathed upon, it is aluminous; and if it is soft, and possesses little adhesiveness, it is calcareous.

826. *Process* 2. The next step is to free the soil as much as possible from water, without, in any other respect, affecting its composition. This is done by heating the soil for ten or twelve minutes in the Wedgewood's-ware basin, fig. 4, by means of the lamp-furnace; the proper degree of heat being ascertained by keeping a piece of wood in contact with the bottom of the basin: the process must be stopped, as soon as the wood begins to be charred. The loss of weight in this process must be carefully noted: if it amount to 50 grains in 400 of the soil, then clay, or aluminous earth will be abundant; if it amount to but about 10 or 20 grains in 400, the soil is to be considered as chiefly siliceous.

827. *Process* 3. Now, gently bruise the soil in the Wedgewood's-ware mortar, and separate from it, (by means of a wire sieve, coarse enough to let a pepper corn pass through) the large vegetable fibres, and loose stones; note down separately the weights of these substances, and let the nature of the latter be ascertained. If the stones or gravel be calcareous, they will effervesce with acids; if siliceous, they will scratch glass; if aluminous, they will be soft, easily scratch glass, and incapable of effervescing with acids.

828. *Process* 4. Mix the soil well with water; let it settle for a minute or two, during which time, the coarse sand will sink to the bottom; then, pour off the water in which the fine part of the soil remains suspended through a filter. Preserve the water; it will contain the soluble matter of the soil. Dry and weigh the coarse sand, and

also, what remains on the filter; and note down their respective quantities.

829. *Process 5.* The coarse sand thus separated is always siliceous, or calcareous sand, or a mixture of the two; its nature may be detected in the same way as that of the stones and gravel, (process 3). If it consist wholly of carbonate of lime, it will dissolve rapidly, with effervescence, in diluted muriatic acid (the experiment may be made in a glass tumbler); but if it consist partly of this and partly of siliceous matter, a residuum will be left after the acid has ceased to act upon it, the acid being added till the mixture has a sour taste, and has ceased to effervesce. This residuum is the siliceous part; which being washed (by being placed in a filtering paper, and having rain water poured over it), dried, and heated strongly in a crucible, shows, by the difference of its weight from that of the whole, the quantity of the calcareous sand.

830. *Process 6.* The purely divided matter of the soil (separated by *process* 4) sometimes contains the four usual earths of soils, as well as animal and vegetable matter; and it is the most difficult part of *the analysis* to ascertain with accuracy the proportions of these. Put the earthy matter into the evaporating basin, fig. 4, and add twice its weight (measured as directed 404) of a mixture of one part of muriatic acid with two parts of water. Stir the mixture often with a glass rod, and suffer it to remain for an hour and a-half before it is examined. During this time, the acid will have dissolved (what was present) of the carbonate of lime, or of magnesia; and, sometimes too, a litttle oxide of iron. Filter the mixture; wash the solid matter; dry it at a moderate heat, and weigh it; add the washings to the solution. The weight lost by the solid matter denotes the quantity of it dissolved by the muriatic acid. The solution must be made sour to the taste (if not so already) by the addition of fresh acid. Into this solution, drop a solution of prussiate of potass: if a blue colour is produced, continue to drop it in, till the production of a blue precipitate ceases. Collect the precipitate on a filter, in the same manner as the other precipitates, and heat it red; the result will be oxide of iron, which must be weighed. Into the

remaining solution, drop solution of carbonate of potass till effervescence entirely ceases, and till the solution has a strongly alkaline taste. Collect the precipitate by filtration, dry it at a heat below redness, and weigh it—it is carbonate of lime. Boil the filtered fluid (in a Florence flask) for a quarter of an hour; when the magnesia (if any be present) will be precipitated, combined with carbonic acid: proceed with this as with the carbonate of lime.

831. *Process* 7. To ascertain the quantity of insoluble animal and vegetable matter contained in the solid matter separated in the preceding process, from the muriatic solution, heat it in a crucible, over a common fire, at a strong red heat, till the mass retains no blackness, stirring it frequently meanwhile with a metallic wire. The loss of weight shows the quantity of animal and vegetable matter there was, but not the proportions of each. The presence of animal matter is indicated by a smell of burnt feathers emitted during the process; and a copious blue flame generally denotes a considerable proportion of vegetable matter.

832. *Process* 8. What remains now is a mixture of silica, alumina, and oxide of iron. To separate these, boil them, for 2 or 3 hours, in sulphuric acid diluted with four times its weight of water, allowing about 6 grains of acid for every 5 grains of the residuum. At the end of this time, whatever remains undissolved is silica, which may be separated, washed, dried, and weighed, in the usual manner. Carbonate of ammonia being added to the solution in quantity more than sufficient to saturate the acid, the alumina will be precipitated, and the oxide of iron, if any, may be obtained by boiling away the remaining liquid.

833. *Process* 9. Let the filtered liquid of *process* 4, be now evaporated to dryness, at a heat below boiling: the nature of the residuum (if any) may be ascertained as follows: if it be of a brown colour, and inflammable, it is vegetable extract; if, when heated, its smell be strong and fetid, it is animal mucilaginous, or gelatinous matter. If it be white and transparent, it is saline. Nitrate of potass or of lime in this saline matter is indicated by its sparkling when thrown on burning coals: sulphate of magnesia may be detected by its bitter taste: and sulphate of potass produces

no alteration in a solution of carbonate of ammonia, but gives a precipitate with a solution of muriate of barytes.

834. *Process* 10. A particular operation is required to detect sulphate of lime (or gypsum) and phosphate of lime in a soil. A given weight (400 grains) of the entire soil must be mixed with one-third as much powdered charcoal, and kept at a red heat in a crucible for half an hour. The mixture must then be boiled a quarter of an hour in half a-pint of water, and the solution, being filtered, exposed some days to the open air. A white precipitate will form in the fluid, which, being weighed, gives the proportion of sulphate of lime existing in the soil.—To separate the phosphate of lime, add to the soil, after the process for gypsum, muriatic acid, more than sufficient to saturate all the soluble earths; form a solution by digestion; then, evaporate the solution to dryness, and pour water upon the solid matter. This will dissolve the muriates, and leave the phosphate of lime untouched.

835. When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid, *Process* 6, may be omitted: in examining peat soils, he will have to attend principally to the operation by fire and air, *Process* 7: and in the analysis of chalks and loams, he will often be able to omit the experiment with sulphuric acid, *Process* 8.

836. The examination of a soil being completed, the products are to be classed, and their quantities added together; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. When, however, products are obtained by *process* 10, a sum equal to their weights must be deducted from the weight of the carbonate of lime obtained by precipitation in *process* 6. In arranging the products, the form should be in the order of the experiments by which they are obtained. Thus, 400 grains of a good siliceous sandy soil may be supposed to contain,

			grains.
Of water of absorption, - - - - - -			18.
Of loose stones and gravel, chiefly siliceous, - -			42.
Of undecompounded vegetable fibres, - -			10.
Of siliceous sand, - - - - - -			200.
Of minutely-divided matter, consists of			
	Carbonate of lime, - - -	25.	
	Carbonate of Magnesia, - - -	4.	
	Matter destructible by heat, principally vegetable, - - - - -	10.	
	Silica, - - - - - - -	40.	
	Alumina, - - - - - -	32.	
	Oxide of iron, - - - -	4.	
	Soluble matter, principally sulphate of potass and vegetable extract, - -	5.	
		— 120.	
Of sulphate of lime, - - - - - - -			3.
Of phosphate of lime, - - - - - -			2.
	Amount of all the products, - - -		395.
	Loss, - - - - - - -		5.
			400.

837. In this instance the loss is supposed small, but, in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within 30 for 400 grains, there is no reason to suspect any want of due precision in the processes.

838. In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it than that of attempting original investigations. In pursuing his experiments, he will be continually obliged

to learn from books the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

839. Analysis of Marls.—The ingredients of marls, on which their fitness for agricultural purposes depends, is carbonate of lime. To find the composition of a marl, pour a few ounces of diluted muriatic acid into a Florence flask, place the flask in a scale, and counterpoise it. Then reduce some dry marl to powder, take a few ounces of this powder, and drop it carefully and gradually into the diluted acid, until an addition ceases to cause effervescence. Let the remainder of the quantity of marl taken be weighed, by which the quantity projected will be known. Let the balance be then restored. The difference of weight between the quantity projected, and that requisite to restore the balance, will show the weight of air lost during effervescence. This air is carbonic acid gas. For every 45 grains of which that escape, reckon 100 grains of carbonate of lime as present in the projected quantity of marl. If the loss (by the escape of gas) amount to 13 *per cent* of the quantity of marl projected, or from 13 to 32 *per cent*, the marl assayed is rich in calcareous earths. Clayey and sandy marls lose only 8 or 10 *per cent* by this treatment.—The presence of much argillaceous earth may be judged by drying the marl after being washed by muriatic acid, when it will harden and form a brick. To determine, with still greater precision, the quantity of calcareous earth in a marl, let the muriatic solution be treated with carbonate of potass, as described, 830. Note:—In some of the processes instituted to determine the quantity of carbonic acid discharged by another acid, errors arose, in consequence of a portion of water being thrown from the vessel along with the gas, by the violence of the effervescence. To remedy this inconvenience, the instrument described at 475 was contrived. A given quantity of any matter to be examined—as carbonate of potass or of lime—being introduced into a bottle, and weighed, and a given weight of diluted acid being added, the cork affixed to the bottom of the bended tube is *instantly* inserted in the neck of the bottle.

Any water therefore that rises with the gas, is condensed in the worm, and runs down again into the vessel; nothing but gas escaping.

840. How to Improve Soils.—Having given an abstract of Sir Humphry Davy's method of analyzing soils, we subjoin the rules he has laid down for improving them. In cases where a barren soil is examined with a view to its improvement, it ought if possible to be compared with an extremely fertile soil, situated in a similar place: the difference given by their analysis will indicate the means of improvement. If, for instance, the fertile soil contain much more sand than the barren one, then sand is the material which the barren soil is in need of; and so of other kinds of matter. In the application of clay, marble, chalk, &c., to lands, there are no particular chemical principles to be observed; but when quicklime is used, great care must be taken that it is not obtained from the magnesian limestone, for such lime is exceedingly injurious to land. The magnesia limestone may be distinguished from the common limestone by the slowness of its solution in acids —the softest kind of it being much longer in dissolving than marble. When the analytical comparison indicates an excess of vegetable matter as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or by the agency of newly-made quicklime. And a defect of animal and vegetable matter, must be supplied by suitable manure.

841. Fluxes are substances employed to assist the fusion of minerals. *Crude flux* is a mixture of nitre and tartar, which is put into the crucible with mineral intended to be fused. *White flux* is formed by projecting a mixture of equal parts of nitre and tartar, by moderate portions at a time, into an ignited crucible. It is potass in a state of tolerable purity. *Black flux* differs from white flux (both being made in the same manner) in the proportion of its ingredients. In this, the weight of the tartar is double that of the nitre. *Microcosmic Salt* is procured, by mixing equal part of phosphate of soda and phosphate of ammonia in solution, and then crystallizing. A slight excess of ammonia is useful.

842. Lutes, are substances applied to the junctures of vessels used in distillation, to prevent the escape of vapours. In fig. 20, the adopter *b* is represented as *luted* to the necks of the retort and receiver—*a* and *c*. When vapours of watery liquors, and such others as are not corrosive, are to be contained, it is sufficient to surround the joining of the receiver to the retort with slips of wet bladder, or of linen, or paper, covered with flour paste, or mucilage of gum arabic. When more penetrating and dissolving vapours are to be contained, a lute is to be employed of quicklime slacked in the air, and beaten into a liquid paste with white of eggs. This must be applied on strips of linen; it is very convenient, as it easily dries, and becomes firm. This lute is very useful for joining broken china-ware.—For containing the vapour of acid, or highly-corrosive substances, the *fat-lute* is made use of. This is formed by beating perfectly dry and finely-sifted tobacco-pipe clay, with painters' drying oil, in a mortar, to such a consistence that it may be moulded by the hand. To use it, it is rolled into cylinders of a convenient size, which are applied, by flattening them, to the joinings of the vessels, which must be quite dry, as the least moisture prevents the lute from adhering. The lute when applied is to be covered with slips of linen spread with the second-mentioned lute; which slips are to be fastened with pack-thread.

843. To make Patent Cement.—A mixture of lime, clay, and oxide of iron, separately calcined, and reduced to fine powder, are to be intimately mixed. It must be kept in close vessels, and mixed with the requisite quantity of water when used. This cement is useful for coating the joinings of the wood of which the pneumatic trough is composed, in order to render it water-tight; and for other purposes of a like nature.

844. To procure Boracic Acid.—Dissolve borate of soda (borax) in hot water, and filter the solution; then add sulphuric acid by little and little, till the liquor has a sensibly acid taste. Lay it aside to cool, and a great number of small laminated crystals (scales) will be gradually formed. These are the boracic acid. They are to be purified by washing with cold water, which carries off any ex-

traneous soluble body, but leaves the acid, which is very sparingly soluble, almost untouched. When the crystals have been washed, they are to be drained upon brown paper.

845. Easy method of Breaking Glass to any required Figure.—Make a small notch, by means of a file, on the edge of a piece of glass; then, make the end of a tobacco-pipe, or of a rod of iron of the same size, red-hot in the fire: apply the hot iron to the notch, and draw it slowly along the surface of the glass in any direction you please; a crack will be made in the glass, and will follow the direction of the iron. Cylindrical glass vessels, such as flasks, may be cut in the middle, by wrapping round them a worsted thread dipped in spirit of turpentine, and setting it on fire when fastened on the glass.

REFERENCES TO TESTS

FOR THE PRESENCE OF THE FOLLOWING SUBSTANCES.

APPENDIX.

TABLE OF CHEMICAL DECOMPOSITIONS.

Alkalies.	Barytes and Strontia.	Lime.	Magnesia.
Sulphuric acid	Sulphuric acid	Oxalic acid,	Oxalic acid,
Nitric,	Oxalic,	Sulphuric,	Sulphuric,
Muriatic,	Nitric,	Tartaric,	Nitric,
Oxalic,	Muriatic,	Nitric,	Muriatic,
Tartaric,	Tartaric,	Muriatic,	Tartaric,
Carbonic.	Carbonic.	Carbonic.	Carbonic.
Sulphuric Acid.	**Nitric Acid.**	**Muriatic Acid.**	**Carbonic Acid.**
Barytes,	Barytes,	Barytes,	Barytes,
Strontia,	Potass,	Potass,	Strontia,
Potass,	Soda,	Soda,	Lime,
Soda,	Storntia,	Strontia,	Potass,
Lime,	Lime,	Lime,	Soda,
Magnesia,	Magnesia,	Ammonia,	Magnesia,
Ammonia.	Ammonia.	Magnesia.	Ammonia.
Oxalic and Tartaric Acids.	**Acids with Oxygen.** (See 662.)	**Oxide of Silver.**	**Oxide of Iron.**
Lime,	Zinc,	Gallic acid,	Gallic acid,
Barytes,	Iron,	Muriatic,	Sulphuric,
Strontia,	Tin,	Oxalic,	Muriatic,
Magnesia,	Lead,	Sulphuric,	Nitric,
Potass,	Copper,	Nitric,	Acetic,
Soda,	Mercury,	Prussic.	Prussic,
Ammonia.	Silver.	Carbonic.	Carbonic.

Explanation: This table shows what would result from the mutual action of two chemical agents, if placed in contact. Thus the column headed *sulphuric acid* is designed to show, that barytes has a stronger affinity than any other body for that acid, and will detach it from any of the succeding substances in the list; and that strontia will separate it from potass; and so on of the rest. This may be verified by actual experiment.—When, therefore, any question regarding decomposition occurs, if, for instance, we wish to know, whether potass will decompose sulphate of magnesia, instead of putting the bodies together to try the experiment, we refer to the table, in order to save trouble; and there, under the head *sulphuric acid*, we find it stated, that potass has a stronger affinity for that acid than magnesia, and, therefore, that it *will* decompose the above-mentioned salt.

TABLE OF FREEZING MIXTURES.

Mixtures.		Thermometer sinks.
Muriate of Ammonia, Nitrate of Potass, Water,	5 parts 5 16	From 50° to 10°
Nitrate of Ammonia, Water,	1 part 1	From 50° to 4°
Sulphate of Soda, Diluted Sulphuric Acid,	5 parts 4	From 58° to 30°
Snow, Common Salt,	1 part 1	From 32° to 0°
Muriate of Lime, Snow,	3 parts 2	From 32° to—50°
Snow, Diluted Sulphuric Acid, Diluted Nitric Acid,	2 parts 1 1	From—10° to—50°
Snow, or pounded Ice, Common Salt, Nitrate of Ammonia,	12 parts 5 5	From—18° to—25°
Muriate of Lime, Snow,	3 parts 1	From—40° to—73°
Diluted Sulphuric Acid, Snow,	10 parts 8	From—68° to—91°

NOTE:—The principle upon which the action of *freezing mixtures* depends is mentioned at 510. In order to produce the effects described in the above table, several things must be attended to. The salts employed must be fresh crystallized, and should contain as much water of crystallization as possible; they should also be quite dry, and reduced to fine powder immediately before being used. The vessel in which the freezing mixture is made should be very thin: it may be made of glass, or what is better, of tin. The materials should be mixed as quickly as possible, and must be in sufficient quantity to fill the vessel.—When great cold is to be produced, the materials for the mixture must first, separately, be reduced to the temperature marked in the table, by being placed in some of the other freezing mixtures; and they are then to be mixed together in a vessel placed in a similar freezing mixture.

Mercury freezes at—39° so that, by the aid of some of the mixtures described in the above table, put together in the manner we have just directed, the interesting experiment of the congelation of this singular metal may be performed. The readiest method of exposing the mercury to the action of the mixture, is to place a little of it, on a watch glass, or concave piece of tin, supported in the middle of a pretty large mass of the freezing mixture.

For procuring moderate refrigeration, the most convenient mixture is the *first* in the above table; because, the water of solution being afterwards removed by evaporation, the pulverized salts are equally efficacious as at first.

LIST OF CHEMICAL PREPARATIONS,

And other Miscellaneous Articles which the student should be provided with, to enable him to perform the experiments.— It is necessary, for experiments of research, where particular nicety is required, to be furnished with re-agents, &c., in the very greatest possible degree of purity; but, for ordinary purposes—for the performance of such experiments as the student finds either necessary or agreeable—the different substances may be made use of in the degree of purity at which they are sold by respectable druggists, and at Apothecaries' Hall. In the experiments in this book, for which *pure* preparations are requisite, directions are given for purifying the preparations of *commerce*.

ACIDS.—Sulphuric, 4 oz. per oz. 0½*d*.—Muriatic, 4 oz. per oz. 1*d*.—Nitric, 4 oz. per oz. 3*d*.—Oxalic, ½ oz. per oz. 6*d*.—Tartaric, 1 oz. 5*d*.—The sulphuric, muriatic, and nitric, must be kept in bottles with glass-stopples.—*Rule:* always wipe the neck of the bottle from which a strong acid has been poured, before replacing the stopple: this will keep you from burning your fingers or clothes.

ALKALIES.—Potass (Caustic) 1 oz. 8*d*. This is obtained in small sticks resembling slate pencils, which must be kept in a phial well secured from air.—Liquid Ammonia 2 oz. per oz. 2*d*. To be kept in a phial with a glass-stopple.

METALS.—Iron filings, and thick polished wire.—Copper clippings—get some slips of thin copperplate from a coppersmith, which clean bright with pumice stone and water, and clip into very small pieces with strong old scissars. Cut some of the same copper slips into pieces ⅓ of an inch wide, and three inches long, and finely polish them, these are to be used in precipitating silver, &c. from solution.—Zinc, in lumps, may be bought of brass-founders for 9*d* a-pound. If you cast plates for a galvanic pile, you will want two pounds or so, of this. Zinc, granulated, may be bought at chemists, at 1*s*. per pound. Half a pound will be needed for making hydrogen gas.—Gold leaf, a small quantity from a gold-beater.—Granulated Tin, (called by Dyers *dropt* tin), 1 oz. 1*d*.—Tin foil, a square foot, 3*d*.—Mercury, 1 oz. 6*d*. To be kept corked in a phial.—Bismuth, 1 oz. 6*d*.—Antimony, 1 oz. 6*d*.—Cobalt, 1 drachm 3*d*.

SALTS.—Acetate of lead, 1 oz. 4*d*.—Borax, 1 oz. 2*d*.—Carbonate of Ammonia, 3 oz. per oz. 2*d*.—Carbonate of Barytes (Native), and Carbonate of Strontia (Native), are to be had (in small pieces) of those who deal in minerals.—Carbonate of magnesia (common magnesia) 1 oz. 3*d*.—Carbonate (super-carbonate of the druggists) of Potass 2 oz. per oz. 3*d*.—Sub-carbonate of potass (the potash of the dry-salters, of whom it may be bought) 4 oz. per oz. 0½d. This must be purified before use, and must be kept from air. in a stone-jar.—Carbonate (super-carbonate of the druggists) of soda 1 oz. 6*d*.—Sub-carbonate of soda (the *soda* of the dry-salters) 4 oz. per oz. 0½*d*. The salts of soda, like those of potass, must be kept from air.—Fluate of Lime (fluor spar) to be had of dealers in minerals.—Muriate of Ammonia, 2 oz. per oz. 2*d*.—Nitrate of Potass (saltpetre) 4 oz. per oz. 0½*d*.—Prussiate of Potass, 1 drachm, 3*d*.—Sulphate of Alumina and Potass (Alum), 4 oz. per oz. 0½*d*.—Sulphate of Copper (Blue Vitriol) 1 oz. 2*d*.—Sulphate of Iron (green Vitriol), 4 oz. per oz. 0½*d*.—Sulphate of Magnesia 2 oz. per oz. 1*d*.—Sulphate of Soda, 2 oz. per oz. 0½*d*,—Cream of Tartar, 1 oz. 1½*d*.

Miscellaneous Articles.—Alcohol, 4 oz. per oz. 2*d*.—Olive Oil, 1 oz. 2*d*.—Oil of Turpentine, 2 oz. per oz. 1*d*.—Phosphorus, ¼ oz. per oz. 6*s*.—The manner in which this is preserved, is mentioned at 700.—Roll sulphur, flowers of sulphur, chalk, pipe-clay, red-lead, of each a penny worth. Pieces of white marble.—Sulphuric Ether, ½ oz. 6*d*. To be kept in a well-closed phial, in a cool place.—Turmeric, ½ oz. 1½*d*.—Litmus, ½ oz. 3*d*.—Nut-galls, ¼ oz. 1½*d*,—Oxide of Manganese, a-pound 6*d*. or 8*d*.:—This is to furnish oxygen.—Sulphuret of Antimony 1 oz. 3*d*.—Gum benzoin, ½ oz. 1½d.—Some Charcoal, newly-made.

SMALL ARTICLES OF APPARATUS.

An iron ladle.—A deep iron pan holding about a quart: to be filled with sand—this is to serve for a *sand-bath*.—A magnifier.—An artificial magnet.—Glass rods, and clean straws, for stirring mixtures in glasses.—A collection of glass tubes:—see 454.—Corks of all sizes; and a considerable number of spare phials should be constantly at hand, to receive the products of experiments.—About a dozen from 2 to 4 ounce phials, with ground glass-stopples, should be provided to hold corrosive liquids.—Bottles with wide mouths, or jars with tin covers, such as are seen on the shelves of apothecaries' shops, should be provided, to hold salts and substances that require to be kept from the air.—A number of small wooden and pasteboard boxes will also be found convenient.

TABLE OF SPECIFIC GRAVITIES.

Metals.

Water (the Standard),	1.00
Platinum, - - -	21.50
Gold, - - - -	19.30
Standard Gold, -	17.50
Mercury, - - -	13.50
Lead, - - - -	11.35
Silver, - - - -	10.50
Bismuth, - - -	9.80
Copper, - - - -	8.90
Brass, - - - -	8.50
Arsenic, - - - -	8.35
Nickel, - - - -	2.55
Cobalt, - - - -	8.00
Iron, - - - -	7.78
Tin, - - - - -	7.30
Zinc, - - - -	7.00
Manganese, - - -	6.85
Antimony, - - -	6.70
Sodium, - - - -	0.97
Potassium, - - -	0.86

Gases.

Air (the Standard),	1.00
Iodine (Vapour of),	8.77
Chlorine, - - - -	2.50
Nitrous Oxide, -	1.53
Muriatic Acid, -	1.29
Sulph. Hydrogen, -	1.19
Oxygen, - - - -	1.12
Nitric Oxide, - -	1.04
Carb. Hydrogen, -	0.99
Carbonic Oxide, -	0.98
Nitrogen, - - -	0.97
Phos. Hydrogen, -	0.89
Water (Vapour of),	0.62
Ammonia, - - -	0.60
Hydrogen, - - -	0.07

Liquids.

Water, - - - -	1.00
Sulphuric Acid, -	1.90
Nitric Acid, - - -	1.50
Carburet of sulphur,	1.27
Muriatic Acid, -	1.21
Sea Water, - - -	1.03
Linseed Oil, - -	0.94
Olive Oil, - - -	0.92
Ammonia, - - -	0.88
Oil of Turpentine, -	0.87
Alcohol (Com.), -	0.84
Alcohol (Pure), -	0.79
Naphtha, - - -	0.72
Sulphuric Ether, -	0.71

Solids.

Water (the Standard),	1.00
Barytes, - - - -	4.20
Strontia, - - -	3.70
Carbon (Diamond) -	3.50
Flint Glass, - -	3.29
Fluor Spar, - - -	3.18
Carbon. of lime, as marble, chalk, &c.	fr. 2.70 to 1.38
Rock Crystal, - -	2.65
Silica, - - - -	2.60
Potass, - - - -	2.50
Lime, - - - - -	2.30
Magnesia, - - -	2.30
Alumina, - - -	2.00
Sulphur, - - -	1.99
Phosphorus, - - -	1.77
Camphor, - - -	0.99
Oak (Dry), - - -	0.92
Pumice-Stone, -	0.91
Fir (Dry), - - -	0.55
Cork, - - - -	0.24

INDEX AND GLOSSARY.

The Figures refer to the Paragraphs of the Work.

FINIS.

New and Interesting Works

PUBLISHED BY

RICHARD GRIFFIN & CO.

HUTCHESON-STREET, GLASGOW,

And Sold by

E. WEST & Co. EDINBURGH; R. B. LUSK & Co. INVERNESS; M. JELLET. BELFAST; and T. TEGG, LONDON;

And may be had of

Every Bookseller in the United Kingdom.

Ure's Dictionary of Chemistry.

Second Edition.

A Dictionary of Chemistry, on the Basis of Mr. Nicholson's, in which the Principles of the Science are investigated anew, and its applications to the Phenomena of Nature, Medicine, Mineralogy, Agriculture, and Manufactures, detailed, by AND. URE, M. D. F. R. S. Professor of the Andersonian Institution, Member of the Geological Society, &c. &c. With an Introductory Dissertation, containing instructions for converting the Alphabetical arrangement into a Systematic Order of Study. One large volume, 8vo, closely printed, with engravings.—Price One Guinea, in boards.

*** No less than four sheets of letterpress are now added, as well as two new plates. Among the various new articles are the following: Several newly-discovered Acids, Chlorides of Carbon, Electro-Magnetism, Geology, Chloride of Lime, or Bleaching Powder, Quack Medicines, Salts (General Table of), Soap. Many insertions are made in the articles in the former edition.

Encomiums on the First Edition of this Work.

"We have no hesitation in affirming that it contains greater power of original research than any other body of Chemical knowledge extant."—*Philosophical Magazine.*

"The Work is, in our opinion, unrivalled."—*Johnson's Med. Journal.*

"We confidently recommend this Work to Medical Students, Manufacturers, Agriculturists, and Mineralogists, as the most useful work in Chemistry they can possess."—*Eclectic Review.*

"It is a Work which displays considerable diligence, and equal knowledge of the subject on which it treats, and will prove a valuable addition to the Student's Library."—*Brand's Journal of Science.*

Innes on the Muscles.

With Notes by R. Hunter.

A Description of the Muscles, with their several uses, and the Synonyma of the best Authors, by JOHN INNES. A new edition, with Notes Practical and Explanatory, by Robert Hunter, Lecturer on Anatomy and Surgery, and Member of the Faculty of Physicians, Glasgow. Illustrated with eighteen new Engravings of the Muscles, by W. H. Lizars. Price 6*s*. boards.

"Mr. Hunter, whom we regard as a promising young Anatomist, has greatly improved Innes's useful work, by the introduction of many judicious Explanatory Notes, from which not only Students in the Dissecting-room, but the practical Surgeon, may derive much profitable instruction. The plates by Lizars are new, and well executed; they exhibit, with much precision, the particular and relative distribution of parts. We are not acquainted with another Manual of Myology which contains so much valuable information at so low a price."—*London Medical Repository* for Dec. 1822.

THE YOUNG MAN'S BOOK OF KNOWLEDGE,

Containing a Familiar View of the Importance of Religion, the Works of Nature, Logic, Eloquence, the Passions, Matter and Motion, Magnetism, Mechanical Powers, Hydrostatics, Hydraulics, Optics, Acoustics, Electricity, Galvanism, Geometry, Geography, Astronomy, History, Chronology, &c. &c. By THOMAS TEGG, Editor of the "Chronology, or Historian's Companion." Twelfth edition, with a Treatise on Short-Hand, and a General Index. In 1 vol. 12mo, with Engravings. Price 4*s*. extra boards.

"This is a book from which he who knows little may learn a great deal, and he who knows much will find knowledge recalled to mind in a manner highly pleasing."—*Evang. Mag.*

THE BOOK OF NATURE LAID OPEN,

In a Popular Survey of the Phenomena and Constitution of the Universe, and the Appearances of Nature during each month in the year. By the Rev. W. HUTTON, A. M. In 1 vol. 12mo, with Engraving. Fourth edition. Price 3*s*. 6*d*. extra boards.

"The Author has certainly evinced graat taste and judgment in its execution. His selection of materials is a proof of the former, while his skill in disposing and arranging them evinces the latter. If this interesting volume could but get into the hands of our youth of both sexes, whose minds are vitiated, or are in danger of being vitiated, by Novels and Romances, what important effects might it not, in process of time, operate upon them."—*New Evang. Mag.* Dec. 1820.

Scientific Amusements in Philosophy and Mathematics,

Including Arithmetic, Acoustics, Electricity, Magnetism, Optics, Pneumatics; together with amusing secrets in various branches of science; the whole calculated to form an agreeable and improving exercise for the mind. Edited by the Rev. W. ENFIELD, M. A. In 1 vol. 12mo. With a beautiful Frontispiece. Price 3s. 6d. extra boards.

"This is a book from which much amusement may be obtained: but so judiciously is it constructed, that it is impossible to gain amusement without gaining instruction also."

NATURAL THEOLOGY;

Or, a Demonstration of the Being and Attributes of God, from His Works of Creation. By W. ENFIELD, M. A., Author of the New Encyclopedia, Scientific Amusements, &c. Sixth edition. Enlarged, and embellished with 26 Engravings. Price 2*s*. 6*d*. boards.

"The object of this work is to impress the youthful mind with a deep and abiding sense of the existence and attributes of God, as the surest shield against the allurements that would lead the rising generation from the path of duty; and also to awaken them to a veneration of that Being who hath called them into existence."

THE YOUNG ARTIST'S ASSISTANT;

Or, Elements of the Fine Arts; containing the Principles of Drawing, Painting in General, Crayon Painting, Oil Painting, Portrait Painting, Miniature Painting, Designing, Colouring, Engraving, &c. &c. By WILLIAM ENFIELD, M. A. Author of Scientific Amusements, Natural Theology, &c. The second edition, with six Engravings. Price 4*s*. 6*d*. boards.

THE BOOK OF UTILITY;

Or, Repository of Useful Information, connected with the Moral, Intellectual, and Physical condition of Man, and containing also many Notable Things in the Arts, Sciences, and History, particularly calculated to direct the attention of youth to subjects of real utility and importance. By THOMAS TEGG, Editor of the Young Man's Book of Knowledge. Embellished with a beautiful Frontispiece, from a Painting by Stothard. Price 4*s*.

"To families, it is presumed, this Book will be found singularly advantageous. On each subject the information, though compressed, is accurate, and it may be affirmed there are few individuals who may not find a reference to these pages useful and expedient."

ORIGINAL TALES FROM MY LANDLORD,
From Modern Records and Living Characters; for Young People. By WILLIAM GARDINER, Author of the Exile of Scotland, &c. With Engravings. Price 2*s*. half-bound.

SANDFORD AND MERTON;
Intended for the use of Children. By THOMAS DAY, Esq. With a beautiful Frontispiece. Price 2*s*. 6*d*. in boards.

JANE SEATON;
Or, THE CORNELIAN CROSS, a Moral Tale for Youth. By a LADY. With an elegant Frontispiece, by Lizars. Price 2*s*. boards.

THE GENTLE SHEPHERD,
A Pastoral Comedy. By ALLAN RAMSAY. With Notes, and an Original Memoir of the Author. Embellished with a beautiful Frontispiece, by Lizars, fine paper, hot-pressed. Price 1*s*. 6*d*. boards.

SALMAGUNDI.
By the Author of "The Sketch Book, Bracebridge Hall," &c.
Salmagundi; or, the Whim Whams and Opinions of Launcelot Langstaff, Esq. and Others. In a neat Pocket Volume. Price 4*s*. in boards.

"With baked, and broiled, and stewed, and toasted,
And fried, and boiled, and smoked, and roasted,
We treat the town."

HUMOROUS HISTORY OF NEW-YORK.
From the Creation of the World till the End of the Dutch Dynasty, by DIEDRICH KNICKERBOCKER, Author of the Sketch Book, Salmagundi, &c. A new edition. crown 8vo. Printed on fine yellow laid paper, hot-pressed, Price 8*s*.

BRITISH ESSAYISTS;
Containing the Tatler, Spectator, Guardian, Rambler, Adventurer, Idler, World, Connoisseur, Mirror, Lounger, Ob-

server, Knox's Essays, Knox's Winter Evenings; with Prefaces, Biographical, Historical, and Critical, by James Ferguson, Esq. Author of "The New Biographical Dictionary. 40 vols. royal 18mo. Price £9 in boards. The greatest care has been taken, and no expense spared, to render this edition worthy the patronage of the public. The Text has been carefully corrected throughout, and the Mottos, Greek and Latin, with their Translations, revised.

The National Melodies of Great Britain and Ireland.

Part I. of the National Melodies of Great Britain and Ireland, with Notes, Historical and Explanatory. Embellished with an Elegant Engraving, price 2*s*. 6*d*. *General Plan of the Work.*—The Work will not exceed Ten Parts, forming Five handsome Pocket Volumes, and will be divided in the following order: *First Series*—Jacobite Melodies, with an Appendix of Whig Songs. Two Parts. *Second Series*—Legendary Tales, Ballads, &c. of Great Britain. Four Parts. *Third Series*—Scots, English, and Irish Songs, not properly belonging to the other division of the Work. Four Parts. Each Series may be had separately. Each Part of the Work will contain at least 144 pages, with an Elegant Engraving. Price 2*s*. 6*d*.

THE LITERARY CORONAL FOR 1823.

The Literary Coronal for 1823; an Agreeable Melange of Polite Literature, carefully selected from New and Esteemed Publications, with many Original Pieces. In a neat Pocket Volume, containing 400 pages, and embellished with a beautiful Frontispiece and Vignette. Price 4*s*. 6*d*. in boards.—Also, just re-printed,

The LITERARY CORONAL for 1822. Price 4*s*. 6*d*. bds.

HYMNS AND ANTHEMS,

For the Use of the Episcopal Chapel, Glasgow.

A new edition, revised and corrected, with a New Index. Handsomely printed on fine paper, hotpressed. Price 3*s*. bound.

THE BEAUTIES OF SCOTTISH POETS,

Ancient and Modern, with Biographical Sketches of the Au-

·hors, and Notes, Illustrative and Explanatory; and embellished with beautiful Engravings. Price 5*s*. 6*d*. in boards. A few copies are printed on royal paper. Price 8*s*. boards. The above volume contains—LIFE OF JAMES I.—Christis Kirk on the Grene, Peeblis to the Play.—LIFE OF MICHAEL BRUCE—Elegy to Spring, Sir James the Ross, Lochleven.—LIFE OF W. DUNBAR—The Thistle and the Rose, Fenyet Freir of Tungland, Goldin Terge, Freirs of Berwik.—LIFE OF H. MACNEIL—Scotland's Scaith, or The History of Will and Jean, Waes o' War, The Harp, Links of Forth.—THE GABERLUNZIE-MAN.—LIFE OF ALLAN RAMSAY—The Gentle Shepherd, The Vision.—LIFE OF ROBERT BLAIR—The Grave.

THE CIRCLE OF ANECDOTE AND WIT.

By George Coleman, Esq. The second edition, with a Frontispiece and Vignette. Price 4*s*. boards.

"To interest and inform, to enliven the social, and beguile the solitary hours, has been the object of the editor in this compilation. Every region of literature favourable to this purpose has been explored, and nothing valuable, whether instructive or entertaining, has been neglected, or carelessly set aside."

MRS. HOLLAND'S ECONOMICAL COOK.

Fourth Edition Enlarged.

The Complete Economical Cook and Frugal Housewife: Containing approved Directions for Purchasing, Preserving, and Cooking; also Dressing and Carving; Preparing Soups, Gravies, Sauces, Made Dishes, Potting, Pickling, &c. With Directions for Pastry and Confectionary. Likewise, THE ART OF MAKING BRITISH WINES, Brewing, Baking, Gardening, &c. By Mrs. Mary Holland, Professed Cook. Fourth edition, considerably amended and enlarged; the result of thirty years' experience. Illustrated with Engravings. Price 4*s*. boards.

"This little Manual, in plain language, developes the arcana of the culinary art, and will form a valuable appendage to the Kitchen Library."—*Gentleman's Mag.*

"The information contained in this work lies in a small compass, and may be obtained at a cheap rate.—*Monthly Mag.*

"We need not tantalize ourselves with examining more than is necessary, to ascertain that the work before us is both cheap and useful."—*European Mag.*

WHITTINGHAM'S DIAMOND SHAKSPEARE.

The Dramatic Works of Shakspeare, with a copious

Glossary, in 1 Vol. 12mo. being the smallest, neatest, and cheapest edition of Shakspeare's Dramas ever published; and, when properly bound, will not exceed one inch in thickness. Price £1 1*s.*

A Tour of Modern, and Peep into Antient Glasgow,

With an Historical Introduction, and a Statistical Appendix. By the Rev. W. M. WADE, author of "Walks in Oxford," &c. Closely printed, in a neat pocket volume, with a map of the City, price 4s. 6d. boards.

"The chief object of the Author, in producing this work, has been to supply the *Inhabitants* of Glasgow with a view of their City, as it was and is, and *strangers* with a neat and portable Guide through the Commercial Capital of Scotland. Both classes of readers will find that the "*Tour of Modern and Peep into Ancient Glasgow,*" leaves untouched, few, if any, of the points on which an enlightened curiosity would naturally seek for information."

The Topographical Picture of Glasgow,

In its Ancient and Modern State; with Sketches of a Tour to the LAKES and ROMANTIC SCENERY of the Shires of Dumbarton, Argyll, and Perth, and to the Falls of Clyde. The third edition, enlarged, and embellished with three views, a map of the City, and a Chart of the Clyde. Price 7s. in extra boards.

MAWE'S EVERY MAN HIS OWN GARDENER.

The Complete Gardener; being a Gardener's Calendar, and General Directory, much more complete than any other published, containing not only an account of what work is necessary to be done in the Kitchen and Fruit Gardens, Pleasure Grounds, Flower Gardens, Shrubbery, Nursery, Greenhouse, and Pot-house, for every month in the year, but also ample directions for performing the said work. Price 8*s.* in boards.

MORRISON'S BOOK-KEEPING.

A Complete System of Practical Book-Keeping, applicable to all kinds of Business; exemplified in Four Sets of Books, of Individual and Partnership Concerns, arranged by Single Entry, Double Entry in Present Practice, and a New Method, which obtains the same result by *Two* Entries, as the Present Practice by Four; with a Comparison of these Methods. And an Appendix, containing Queries and Answers on Merchants' Accounts, on the Principles and Practice of Book-keeping, and on the Nature and Negotiation of Inland and Foreign Bills of Exchange. To which are added, A Series of Letters connected with the Sets; and an explanation of Commercial Terms. With Engraved Forms of the various Accounts which occur in business. By C. MORRISON, Accountant. Third edition, with Valuable Improvements. One volume 8vo, price 8s. half-bound, calf.

CHEMICAL RECREATIONS:

A Series of Amusing and Instructive EXPERIMENTS, which may be performed safely, easily, and at little expense. To which are prefixed, FIRST LINES of CHEMISTRY; in which the principal facts of the Science, as stated by the most celebrated experimentalists, are familiarly explained. With a minute description of a *cheap and simple apparatus*, illustrated by seventy engraved figures of the different parts of it. In a neat closely-printed pocket volume. Price 3*s*. in boards.

"Nothing can conduce to the attainment of more useful knowledge, or rational amusement, than the study of the science of Chemistry. We are taught by it, to account, in a satisfactory manner, for many of the most curious phenomena of nature; and it is the science upon which depend the comforts, and even the very existence, of civilized life. The best way to study Chemistry, is to make experiments; because the science is entirely founded on them: in "Chemical Recreations" a great number of highly interesting experiments are fully explained.

THE PLEASURES OF IMAGINATION,

A Poem. By Mark Akenside, M. D. A new Edition. With Explanatory Notes, and a Life of the Author. With a beautiful Frontispiece. Price 4*s*. boards.

Rev. W. Hutton's Wonders of Nature & Art.

The Wonders of Nature and Art, containing an Account of the most remarkable and curious Animals, and Mineral and Vegetable Productions in the World; also the Manufactures, Buildings, and Wonderful Inventions of Men. Compiled from Works of established celebrity by the Rev. W. HUTTON, M. A. Author of the Book of Nature laid open." In a handsome volume, duodecimo. With an Elegant Frontispiece. Price 4*s*. in extra boards.

Hutton's Abridgement of Buffon's Natural History.

On the 1st of June, was published, handsomely printed in 8vo. and embellished with Two Engravings, by the first Artists, from original designs by Corbould, No. I. Price Sixpence, of Buffon's Natural History Abridged; including the History of the Elements, the Earth, Mountains, Rivers, Seas, Winds, Whirlwinds, Waterspouts, Volcanos, Earthquakes, Man, Quadrupeds, Birds, Fishes, Lizards, Serpents, Insects, and Vegetables. A New Edition, edited by the Rev. W. HUTTON, Author of the "Book of Nature laid open." Please to give orders for Hutton's Abridgement of Buffon.

CONDITIONS.

This Work will be published Weekly, each Number containing two elegant Engravings, for Sixpence; a few Copies, with proof impressions of the plates, Eightpence; or coloured after Nature, One Shilling; to be fully completed in Fifty Numbers, with One Hundred Engravings.

This Work is confidently presented to the Public as the cheapest periodical publication in the world; and a guarantee will be given in the first Number, to continue it to the end in the same style, or the money will be returned. Gentlemen, Booksellers, &c. are requested to be early in their orders to ensure good impressions of the plates, which alone are worth three times the price of the Number.

DR. WATTS' MISCELLANEOUS THOUGHTS.

Miscellaneous Thoughts, in Prose and Verse, on Natural, Moral, and Divine Subjects. Including Advice to Young Men on entering into the World. By I. Watts, D. D. A new edition, carefully revised and corrected; embellished with a beautiful Frontispiece. Price 3s. 6d. in boards.

The Leisure of a Lady

Employed in Extracting from the Best Authors, Pieces in Prose and Verse, for the Amusement and Instruction of her Own Children. Second Edition. With an elegant frontispiece. Price 2s. 6d. half-bound.

REV. WILLIAM GURNEY'S
Diamond Dictionary of the Holy Bible.

The Pocket Dictionary of the Holy Bible, containing an Historical and Geographical Account of the Persons and Places, and an Explanation of the various Terms, Doctrines, Institutions, Laws, Figures, &c. in the Sacred Oracles.

Selected and arranged from Calmet, Brown, Newton, Hurd, and other writers, by the Rev. W. GURNEY, Rector of St. Clement's Danes, London. Beautifully printed. Price 5*s.* 6*d.* in boards.

Beauties of Ancient English Poetry.

To which is prefixed an Essay on the Character and Occupation of the English Minstrels. In a neat pocket volume, Price 2*s.* 6*d.* in boards.

Whittingham's Cabinet Library,

IN A NEAT POCKET SIZE, WITH EMBELLISHMENTS, AFTER CORBOULD, WESTALL, STOTHARD, ETC.

1.

THE POETICAL WORKS OF OLIVER GOLDSMITH. With a Sketch of his Life and Writings. Price 2*s.*

2.

THE HISTORY OF RASSELAS, PRINCE OF ABYSSINIA. A Tale. By Dr. JOHNSON. Price 2*s.* 6*d.*

3.

THE SEARCH AFTER HAPPINESS. A Pastoral Drama. By HANNAH MORE. Price 1*s.* Sewed.

4.

ELIZABETH; or, THE EXILES OF SIBERIA. By MADAME COTTIN. Price 2*s.*

5.

THE SEASONS. By JAMES THOMSON. Price 2*s.* 6*d.*

6.

PAUL AND VIRGINIA. Translated from the French of J. BERNARDIN H. DE SAINT PIERRE. Price 2*s.*

7.

SACRED DRAMAS. Chiefly intended for Young Persons. The Subjects taken from the Scriptures. By HANNAH MORE. Price 2*s.* 6*d.*

8.

THOUGHTS IN PRISON. In Five Parts, viz. The Imprisonment, the Retrospect, Public Punishment, The Trial, Futurity. By Dr. WILLIAM DODD. To which are added, his Last Prayer, the Convict's Address to his unhappy Brethren, and other Miscellaneous Pieces. With some Account of the Author. Price 2*s.*

9, 10.

THE BEAUTIES OF SHAKSPEARE, regularly selected from each Play. With a general Index, digesting them under proper Heads. By Dr. DODD. Price 4*s.* 6*d.*

11.

REFLECTIONS ON DEATH. By Dr. DODD. Price 2*s.*

12, 13.

EMBLEMS, DIVINE AND MORAL. By FRANCIS QUARLES. Price 4*s.* 6*d.*

14, 15.

POEMS. By the late WILLIAM COWPER, Esq. In Two Volumes. Price 6*s.*

16.

THE LETTERS OF JUNIUS. Price 4*s.* 6*d.*

17, 18.

HUDIBRAS. By SAMUEL BUTLER. In Two Volumes. Price 6*s.*

19.

THE VICAR OF WAKEFIELD. By DR. GOLDSMITH. Price 3*s.* 6*d.*

20, 21.

THE ILIAD OF HOMER. Translated by ALEXANDER POPE. In Two Volumes. Price 7*s.*

22, 23.

LETTERS FROM A CITIZEN OF THE WORLD TO HIS FRIENDS IN THE EAST. By Dr. GOLDSMITH. In Two Volumes. Price 7*s.*

24.

LORD CHESTERFIELD'S ADVICE TO HIS SON, on Men and Manners; in which the principles of Politeness, and the Art of acquiring a knowledge of the World, are laid down in an easy and familiar manner. Price 1*s.* 6*d.*

25, 26.

THE ODYSSEY OF HOMER. Translated by ALEXANDER POPE. In Two Volumes. Price 6*s.*

27, 28.

A NARRATIVE OF THE VOYAGES ROUND THE WORLD, PERFORMED BY CAPTAIN JAMES COOK. With an account of his Life, during the previous and intervening periods. By Dr. A. Kippis. In Two Volumes. Price 6*s*.

29.

ESSAYS ON VARIOUS SUBJECTS. Principally designed for Young Ladies. By Hannah More. Price 1*s*. 6*d*.

30.

THE SHIPWRECK; and other POEMS. By William Falconer. Price 2*s*.

31.

A SENTIMENTAL JOURNEY THROUGH FRANCE and ITALY. By Laurence Sterne. Price 2*s*.

32, 33

THE POETICAL WORKS OF ROBERT BURNS. In Two Vols. 6*s*.

34.

THE BEAUTIES of STURM'S REFLECTIONS. Selected by William Jones. Price 2*s*.

35, 36.

THE LIFE AND ADVENTURES OF ROBINSON CRUSOE. With an Account of his Travels. Written by Himself. In Two Volumes. Price 7*s*.

37.

ESSAYS, Moral, Economical, and Political. By Francis Lord Bacon. Price 2*s*. 6*d*.

38.

AN ESSAY ON MAN; and other POEMS. By Alexander Pope. Price 2*s*. 6*d*.

39.

THE SORROWS OF WERTER. From the German. Price 2*s*. 6*d*.

40.

THE VOCAL LYRE. A Collection of Popular National Songs. Price 2*s*. 6*d*.

41.

THE OLD ENGLISH BARON. A Gothic Story. By Clara Reeve. Price 2*s*. 6*d*.

42.

THE CASTLE OF OTRANTO. A Gothic Story. By Horace Walpole. Price 2*s*. 6*d*.

R. Malcolm, Printer, Glasgow.

Preparing for Publication,

THE

BOOK OF SCIENCE

LAID OPEN:

A SERIES OF POPULAR ESSAYS

ON

ELECTRICITY, GALVANISM, PNEUMATICS, HYDROSTATICS, OPTICS, MAGNETISM, MECHANICS,

AND OTHER BRANCHES OF

NATURAL PHILOSOPHY.

WITH

Rules for Performing Experiments:

ILLUSTRATED BY PLATES.

BY THE AUTHOR OF

"CHEMICAL RECREATIONS,"

To which Work the above will form a Companion.

PRINTED FOR
RICHARD GRIFFIN AND CO. GLASGOW;
AND THOMAS TEGG, LONDON.

[illegible]3.