# A SYLLABUS

OF

# A COURSE OF LECTURES

ON

# CHEMISTRY,

DELIVERED AT THE

ROYAL INSTITUTION OF GREAT BRITAIN,

BY MR. DAVY,

ON THURSDAYS AND SATURDAYS AT 2,

AND ON TUESDAYS AT 8 O'CLOCK, P. M.

The Morning Lectures are read on General Chemistry, and the Evening Lectures on the Connexion of Chemistry with the Arts.

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1802.

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# ADVERTISEMENT.

It is generally admitted that the best method of teaching the sciences is to begin with simple facts, and gradually to proceed from them to the more complicated phenomena.

In the following pages, which contain the outlines of a course of lectures on chemistry, an attempt has been made to employ such a method. Hence the abstruse doctrines concerning the imponderable fluids have been separated from the history of simple chemical action; and the applications of the science from the science itself.

The classification of substances adopted is founded rather upon facts than analogies; and in consequence, certain bodies have been placed amongst the simple principles, which, from their resemblance to other bodies of known composition, have been generally arranged in the class of compounds.

This is an imperfection, but on the principles assumed it could not easily be avoided. And it will be fortunate for the Author if a discerning public should not discover many more important imperfections.

HUMPHRY DAVY.

Royal Institution,
January 5, 1802.

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# SYLLABUS

# OF A COURSE OF LECTURES.

## PART I.

## THE CHEMISTRY OF PONDERABLE SUBSTANCES.

### DIVISION I.

### OF THE CHEMICAL POWERS, AND THE MODES OF THEIR APPLICATION.

#### 1. *Of the general Logic of Science.*

The sciences are classes of different facts associated together by analogy.

The theories which represent them are connected propositions, in which, by means of that faculty of the mind named abstraction, one term is made to represent a number of other terms, which themselves stand for ideas.

By means of artificial arrangements or theories, the business of thinking is materially expedited; and the power of calculating concerning new relations of facts, rendered simple and easy.

#### 2. *Of the Nature of Chemistry.*

Chemistry is that part of the science of nature which relates to those intimate actions of bodies upon each other, by which their appearances are altered and their individuality destroyed.

The knowledge of those actions is derived from our sensations; and the facts that represent them are classed according to the corpuscular theory.

### 3. *Of the Corpuscular Theory.*

The different bodies in nature are composed of particles or minute parts, individually imperceptible to the senses. When these particles are similar, the bodies they constitute are denominated simple, and when they are dissimilar, compound.

The chemical phenomena result from the different arrangements of the particles of bodies: and the powers that produce these arrangements are repulsion or the agency of heat, and attraction.

By repulsion, the particles of bodies tend to separate from each other.

By attraction, they tend to come in contact with each other.

### 4. *Of the Power of Repulsion or Caloric.*

The expanding power, or the power of repulsion, is capable of being communicated by the particles of one body to those of other bodies; and the laws of its communication constitute the laws of temperature. See Part II. Div. I.

It acts in uniform opposition to attraction; and the peculiar forms of aggregation in bodies depend upon the different agencies of these powers.

Bodies exist either in the solid, fluid, or aëriform states; and, according as they are made to receive, or communicate, the power of repulsion, they expand or contract. Solids, on a certain increase of the repulsive power of their particles, become fluids, and fluids, gases. Likewise, by a diminution of repulsive power, gases become fluids, and fluids, solids.

The cause of the phenomena of repulsion has been lately generally named caloric; and it is, by a number of philosophers, supposed to be a peculiar ethereal substance.

### 5. *Of Attraction.*

Attraction either acts upon similar particles, and then it is denominated the attraction of aggregation, or upon dissimilar particles, when it is named the attraction of composition, or chemical affinity.

The most important general facts relating to the attraction of composition may be classed in six propositions.

1. The attraction of composition is capable of uniting a number of dissimilar particles.

2. The particles of different simple bodies have different affinities for each other.

3. The agency of the attraction of composition on the particles of bodies, is inversely as that of the attraction of aggregation.

4. The force of the attraction of composition is influenced by the numbers of the combining particles; i. e. by the masses of the acting bodies.

5. The forces of the attraction of composition in different substances, are diminished in different ratios, by the agency of caloric or the power of repulsion.

6. In all cases of combination, the volume of the combining bodies is either diminished, or increased; and, in general, in consequence, they gain a power of increasing, or diminishing, respectively the volumes of the bodies in contact with them; or, in common language, caloric is either given out, or absorbed during chemical combination.

### 6. *Of Chemical Operations.*

Though the powers of attraction and repulsion are parts of an arbitrary system, yet the laws by which they are supposed to act are simple expressions of facts. Guided by those laws, the chemist is capable of imitating the operations of nature, and of producing new operations, so as to exhibit certain substances or principles apparently sim ple, and to ascertain their combinations.

The methods by which these purposes are effected, are synthesis and analysis.

By synthesis, compound substances are formed by the artificial union of different principles.

By analysis, compound substances are resolved into their constituent principles.

### 7. *Of the Instruments of Experiment*

To effect chemical compositions and decompositions, nothing more is required than to bring the particles of the bodies, which are the subjects of experiment, into the sphere of their mutual attractions.

Towards this end, the mechanical division of them into small parts is employed; and likewise, in certain cases, the agency of caloric.

The vessels in which bodies are operated upon, must be composed of substances for which they have no affinity.

The most important instruments in the chemical apparatus, are, furnaces, lamps, crucibles; mercurial and water pneumatic troughs, and gasometers; graduated glass jars, retorts, receivers; the balance, the air pump, the electrical machine, the barometer, and the thermometer.

## DIVISION II.

### OF UNDECOMPOUNDED SUBSTANCES OR SIMPLE PRINCIPLES.

### 1. *Of the Classification of Undecompounded Substances.*

Though the corpuscular theory supposes the existence of bodies composed of similar particles; yet we are not certain that any such bodies have been yet examined. The simple principles of the chemists are substances which have not been hitherto composed or decomposed by art;

and they are elements, only in relation to other known substances.

As they are the *sensible* agents of chemistry, before we can examine the nature of compound bodies, or particular phenomena of composition or decomposition, it is necessary that we should be acquainted with their characteristic properties, and with certain of the modes in which they are procured.

Fortytwo simple principles are at present acknowledged —Considered with regard to the similarity of some of their physical properties, they may be divided into six classes: I. Permanent gasses possessed of no acid properties. II. Solid inflammable bodies having no metallic properties. III. Metals. IV. Earths. V. The fixed alkaline substances. VI. The undecompounded acids.

## 2. *First Class.*

The first class of simple substances contains only three bodies—oxygene, hydrogene, and nitrogene. They are permanent gases at all known temperatures. They have no taste, smell, or colour, and are very little absorbable by water.

1. Oxygene gas constitutes $\frac{1}{5}$ part of the air of the atmosphere. It is produced pure from oxygenated muriate of potash by heat. It eminently supports combustion. The cubic inch weighs .34 pts. of a gr.

2. Hydrogene gas is procured when water is made to act on ignited zinc or iron. It burns when intensely heated in contact with oxygene; and is the lightest of the known gases, weighing, in the cubic inch, only .024 pts. of a gr.

3. Nitrogene gas constitutes about $\frac{4}{5}$ of the atmosphere. It is evolved during the action of nitric acid on animal substances. It is not inflammable; it does not support combustion. A cubic inch of it weighs about .3 pts. of a gr.

## 3. *Second Class.*

Phosphorus, sulphur, and carbon, compose the second class of simple principles. These bodies do not differ considerably in their specific gravities, and are nonconductors of electricity, and insoluble in water.

1. PHOSPHORUS is obtained from phosphoric acid by means of ignited charcoal. It is transparent. Its colour is light yellow; and its specific gravity is to that of water as 2.033 to 1. It becomes liquid at the temperature of 99° Fahrenheit, and aëriform at that of 554°. It burns with a feeble blue flame in the atmosphere at, or even below, 50°, and with an intensely vivid light at 122°.

2. SULPHUR is found abundantly in nature, and it may be procured in a very pure form from sulphuret of potash by means of muriatic acid. It is of a bright yellow colour. It melts at a heat a little above that of boiling water, and becomes aëriform at 600° Fahrenheit. At a temperature scarcely above that of its fusion it burns with a feeble blue flame, and at the heat of ignition with an intensely vivid flame. Its specific gravity is about 2.

CARBON is found pure in nature, in the form of diamond; but it has not yet been produced from any of its compounds. It is, perhaps, the hardest known body; it is extremely transparent. It burns at a very high temperature; and, after becoming black and opaque, is converted into gas. Its specific gravity is about 3.5.

## 4. *Third Class.*

The metals at present known amount to twenty one. They are platina, gold, silver, mercury, copper, tin, lead, iron, zinc, antimony, bismuth, arsenic, cobalt, nickel, manganese, tungsten, uranium, molybdena, titanium, tellurium, chrome.

The metals are possessed of specific gravities superior to those of all other simple substances. They are opaque, brilliant in their appearance, insoluble in water, and conductors of electricity.

1. PLATINA is procured by intensely heating the oxide of platina produced by nitromuriatic acid, with charcoal. It is of a light grey colour, It is malleable, and is the hardest

of the metals after iron. It becomes fluid at a very high degree of heat. It does not burn in the atmosphere. Its specific gravity is 22.5, so that it is the heaviest body in nature.

2. GOLD is found pure in different parts of the globe. It is of a bright yellow colour. It fuses when ignited to whiteness. It is the most malleable and ductile of the metals. Its specific gravity is 19.3.

3. SILVER is found in nature pure, and combined with different substances. It is the whitest of the metals. Its malleability and ductility are less than those of gold. Its specific gravity is about 10.51. It is fused more readily than gold.

4. MERCURY is found pure; likewise it is procured from cinnabar. It is the only metal which is fluid at the common temperatures of the atmosphere: it does not become solid, except at 40° below 0°; at 600° it boils. Its colour is analogous to that of silver. Its specific gravity is 13.568.

5. COPPER is found native; likewise it is extracted from sulphuret of copper. It is of a light red colour. Its specific gravity is 8.584. It melts at the white heat. It is malleable and ductile.

6. TIN is procured when the oxide of tin is heated to whiteness with charcoal. It is of a white colour, but little duller than that of silver. It melts long before it becomes ignited, i. e. at about 410° Fahrenheit. It is very malleable, but imperfectly ductile. Its specific gravity is 7.299.

7. LEAD is generally obtained by separation from the sulphuret of lead by heat. It is of a bluish-white colour, and soon loses its metallic lustre when exposed to the air. It becomes fluid at 540° Fahrenheit. It is malleable, but its ductility is imperfect. Its specific gravity is 11.352.

8. IRON is obtained from the oxide of iron, by intensely heating it with charcoal. It is of a pale grey colour. Its specific gravity is 7.8. It is fusible only at an intense degree of heat; but becomes extremely soft and ductile when only ignited. It is attracted by the magnet. It soon be-

comes covered with a brown rust when exposed to the at mosphere.

9. Zinc is generally procured from the sulphuret of zinc, or from the carbonates of zinc, which are found abundantly in nature. It is rather whiter than lead. Its specific gravity is 7.19. It fuses as soon as it is ignited, and boils before it is white hot; and at this temperature, burns with a vivid flame.

10. Antimony is generally procured from sulphuret of antimony. It is nearly of the colour of lead. Its specific gravity is 6.86. It melts soon after ignition, and becomes covered with a white oxide. It is very little ductile or malleable.

11. Bismuth is found in a native state; likewise it is obtained from sulphuret of bismuth. It is of a dull yellow colour, a little inclined to red. It is not malleable. Its specific gravity is 9.822. After tin and tellurium, it is one of the most fusible of the metals.

12. Arsenic may be procured from the white oxide of arsenic, by heating it with oil, or with charcoal, in close vessels. It is white in its pure form, but soon becomes tarnished by exposure to the air. It sublimes at the temperature of ignition with great rapidity, and burns with a bluish flame. Its specific gravity is 8.31.

13. Cobalt is obtained from smalt (a blue glass containing the oxide of cobalt) by igniting it with charcoal and soda. It is of a grey colour. It is very difficult of fusion. Its specific gravity is 7.645.

14. Nickel is procured from an ore named kupfer nickel. Its colour is rusty light grey. Its specific gravity is 8.96. It is difficultly fusible. When perfectly pure it is not magnetic.

15. Manganese is procured by an intense heat from oxide of manganese by means of charcoal. It is of a dull white colour. It is fused only with extreme difficulty. Its specific gravity is 7. It is not at all malleable.

16. Tungsten is obtained by various processes from the tungstate of lime, and from wolfram, a mineral found in

Cornwall. It is very difficultly fused. Its specific gravity is 8.34.

17. Uranium is procured from pech blende, and from its carbonate by different processes. It is grey, with a tinge of brown. It has never been fused into a consistent mass. Its specific gravity is 6.44.

18. Molybdena has been obtained with very great difficulty from the molybdic acid. Its properties are but little known. Its specific gravity is said to be 6.

19. Titanium is obtained from the oxide of titanium by intense ignition of it with charcoal. It is very difficult of fusion. Its colour is red; and its specific gravity unknown.

20. Tellurium is procured from the aurum paradoxicum. It is of a bright grey colour. It pulverizes under the hammer. It is the most fusible and volatile of the metals after mercury. Its specific gravity is 6.115.

21. Chrome is obtained from the red lead of Siberia (the chromate of lead). Its properties are little known. Its colour is whitish; and it is very difficult of fusion.

### 5. *Fourth Class.*

The earths are distinguished from all other bodies by their infusibility, their insolubility in water, their incombustibility, and their want of conducting power with regard to elec tricity. They are four in number, silex, alumine, zircone, glucine.

1. Silex is obtained from rock crystal and other stones, after they have been fused with fixed alkalies, and acted upon by muriatic acid. It differs from the other earths in being acted upon by no acid but the fluoric.

2. Alumine is obtained from solution of sulphate of alumine by potash. Its colour is white. In its common state it contracts in volume by heat; and at an intensely high temperature it becomes softened. It is combinable with the acids.

3. Zircone is obtained from the jargon of Ceylon by the fusion of it with a fixed alkali, and particular treatment

with an acid. It is white, and diffusible through water, to which it communicates a gelatinous appearance. It combines with the acids. Its specific gravity is 4.3.

4. Glucine is procured from the beryl. It resembles alumine in its physical properties; but its chemical properties are very different. It forms sweet tasted salts with the acids.

It is said that two new earths have been lately discovered, denominated Agustine, and Ittria.

The Agustine is considered as a peculiar substance, on the authority of Professor Tromsdorf. It is procured from the beryl of Georgen-stadt. And it forms tasteless salts with the acids.

Ittria has been examined by M. Ekeburg and Professors Vauquelin and Klaproth. The salts it forms with the acids are sweet like those formed by glucine; but it is not soluble in the caustic alkalies. It was first announced as a peculiar substance by M. Gadolin.

### 6. *Fifth Class.*

It has been thought expedient to call such undecompounded substances alkaline as possess a certain degree of solubility in water, and the power of combining with the acids, and with sulphur; and of rendering green vegetable blues.

Potash, soda, strontian, barytes, lime, and magnesia, are the only known fixed alkaline substances.

1. Potash is obtained from the common caustic potash of commerce by solution in alcohol, and evaporation. It was formerly named fixed vegetable alkali. It is of a white colour. Its taste is intensely caustic, and it acts upon the animal fibre. It becomes fluid at a red heat; but it is volatile only at a very high temperature. It is extremely soluble in water.

2. Soda is obtained from muriate of soda (sea salt) by means of litharge. It is purified by treatment with alcohol, in the same manner as potash. Its taste and causticity, as well as many of its other properties, are analogous

to those of that alkali; but it possesses less affinity for the acids. It is fusible at a temperature a little below that of ignition. It was formerly called the fixed fossile alkali.

3. STRONTIAN is procured from the carbonate of strontian when it is intensely ignited with charcoal. It is white. Its specific gravity is greater than that of potash or of soda. It is much less soluble in water than those alkalies. It is infusible. Certain of its combinations when brought in contact with bodies in combustion, communicate a vivid redness to their flames.

4. BARYTES is obtained from nitrate of barytes by the long application of a high degree of heat. Its taste is caustic, like that of strontian. It is nearly four times as heavy as water. Of all the alkaline substances, it possesses the strongest affinity for the acids. It is less soluble in water than strontian.

5. LIME is procured from the carbonate of lime (marble) by a strong degree of heat. It is white and opaque. It is unalterable in the fire. It resembles strontian and barytes in most of its physical properties; but it is less soluble in water than either of those earths (requiring 500 times its weight of that fluid for its solution); likewise it has less affinity for the acids.

6. MAGNESIA is obtained from sulphate of magnesia by treatment with potash or soda. It is exhibited in the form of a white impalpable powder, possessing very little taste or smell. It is soluble in about 2000 times its weight of water. It has less affinity for the acids than any of the other solid alkaline substances, and it forms with them very soluble salts. It is perfectly unalterable in the fire.

### 7. *Sixth Class.*

We are acquainted with three undecompounded acids; the muriatic acid, the fluoric acid, and the boracic acid. They are combinable with water and the alkalies; and possessed of the power of rendering vegetable blues red.

1. MURIATIC ACID is procured from muriate of soda by

means of sulphuric acid. It is a permanent gas at all known temperatures. It is heavier than atmospheric air. It is soluble to a great extent in water. Its taste is very pungent and sour.

2. FLUORIC ACID is obtained from fluate of lime by means of sulphuric acid. It dissolves silicious earth, and renders it aëriform; therefore it cannot be preserved pure in glass vessels. Its taste and smell are analogous to those of muriatic acid; and, like that acid, it is a gas at all known temperatures. It is extremely soluble in water, and combinable not only with the alkaline, but likewise with the earthy substances.

3. BORACIC ACID is procured from alkaline borate of soda by means of sulphuric acid. It is a white solid body, possessing very little taste and no smell. It is fusible when dry at the red heat; and when moist, it is even volatile at a much lower temperature. It is soluble in 50 times its weight of boiling water.

## DIVISION III.

### OF BODIES COMPOSED OF TWO SIMPLE SUBSTANCES, OR BINARY COMPOUNDS.

#### 1. *Arrangement of Binary Compounds.*

The simplest chemical actions of the undecompounded substances on each other, are exerted in the production of binary compounds.

Of these compounds, some are found in nature, and others are produced by art, either directly, by bringing the principles that compose them into apparent contact at a certain temperature; or, indirectly, by analytical processes, in which bodies more compounded are the subjects of experiment.

The binary compounds, if we consider their relations to each other, and to the general chemical arrangment of substances, may be divided into six classes.

I. Compounds containing oxygene. II. —— Hydrogene. III. —— Sulphur. IV. —— The Metals. V. —— The Earths. VI. —— The Undecompounded Acids.

## 2. *First Class.*

Of all known bodies, oxygene has the greatest tendency to combination. It enters into union with a vast number of simple substances. Many of its compounds are possessed of analogous properties. It has been generally supposed to be the acidifying principle; and the history of its chemical agencies constitutes the antiphlogistic theory.

The binary compounds of oxygene are either decomposable acids possessing the sour taste, and the powers of reddening vegetable blues, and of uniting with the alkalies; or oxides, which in general are combinable with the acids, insoluble or sparingly soluble in water, and possessed of little taste or smell. These different substances will be treated of in their relations to their different bases.

1. Combination of oxygene with hydrogene. *Water*, or oxide of hydrogene, is produced whenever hydrogene gas is burnt in contact with oxygene gas. 15 grains of hydrogene, combined by slow combustion with 85 grains of oxygene, produce 100 grains of pure water. Water is a fluid at all temperatures between 32° and 212°. When cooled below 32° it becomes solid, and forms a mass of crystals. When heated above 212° it becomes a gas, and in that state is much lighter than the air of the atmosphere.

The physical properties of water are well known. It is possessed of great powers of combination, and acts a principal part in the chemical changes that take place upon the surface of the globe, and in the atmosphere.

2. Combinations of oxygene with Nitrogene. When the electric spark is passed for a long while through a mixture of oxygene gas, and nitrogene gas, *nitric acid* is formed. This substance is permanently aëriform at common temperatures. 100 cubic inches of it weigh about 76 grains. It is extremely soluble in water;

1 grain of water being capable of condensing about 10 grains of acid gas, forming with it a fluid of specific gravity 1.52. Nitric acid is a very powerful and useful chemical agent. For purposes of application, it is generally obtained from nitrate of potash (nitre of commerce) by means of sulphuric acid. One hundred grains of nitric acid consist of about 71 of oxygene, and 29 of nitrogene.

*Nitrous gas,* or nitric oxide, is an elastic fluid permanent at all known temperatures. It is produced whenever nitric acid is decomposed by certain metallic bodies, such as copper, silver, &c. Its specific gravity is to that of atmospheric air, as 1.093 to 1. It is very little soluble in water. It combines with oxygene at common temperatures, producing an orange coloured gas, which is nitric acid with excess of nitrous gas, i. e. *nitrous acid.* Nitrous gas is composed of 56 parts oxygene, and 44 nitrogene. It is readily absorbed by the green sulphates, and muriates of iron. Pyrophorus takes fire in it at common temperatures; and phosphorus continues to burn when introduced into it in a state of vivid inflammation.

*Nitrous oxide,* or gaseous oxide of azote, is obtained when nitrate of ammoniac is decomposed at any temperature near 400° Fahrenheit. It is permanently aëriform. The cubic inch weighs .5 pts. of a gr. It is possessed of a faintly sweetish taste, and a slight but agreeable odour. All the combustible bodies burn in it with vivid light at high temperatures. It does not diminish when mingled with nitrous gas. It is soluble in twice its volume of water, and in less than half its volume of most of the inflammable fluids. It is combinable, when in a nascent state, with potash and soda. One hundred grains of it are composed of 37 oxygene, and 63 nitrogene.

3. COMPOUNDS of OXYGENE and PHOSPHORUS. *Phosphoric acid,* or the most oxygenated compound of oxygene and phosphorus, is produced when sulphuric acid is made to act upon phosphate of lime (i. e. earth of bones). It is likewise procured when phosphorus is burnt in atmospheric air, at a temperature above 122°. Phosphoric acid

is a solid at temperatures below those of ignition. It is very soluble in water. It is inodorous; and possesses no volatility. It is composed of nearly 1 of phosphorus to 1.6 of oxygene.

*Phosphorous Acid,* or the least oxygenated compound of oxygene and phosphorus is produced during the slow combustion of phosphorus in the atmosphere at common temperatures. It is a fluid body, inodorous, and possessed of a strong affinity for water.

4. COMBINATIONS of OXYGENE with SULPHUR. Sulphur, like phosphorus, combines with oxygene in two proportions, and forms sulphuric and sulphureous acids.

*Sulphuric Acid* is produced during the vivid combustion of sulphur in oxygene gas, and likewise during the decomposition of nitrate of potash by heated sulphur. In its common state it appears in the form of a transparent oleaginous fluid, nearly twice as heavy as water. At a very low temperature it becomes solid. It is composed of about 1.7 parts sulphur and 1 part oxygene. It acts with great power upon animal and vegetable substances; which, by abstracting a portion of its oxygene, convert it into sulphureous acid.

*Sulphureous Acid* is a permanently aëriform fluid at the common temperatures of the atmosphere; but it has been rendered fluid by a high degree of artificial cold, aided by strong pressure. It is absorbable by $\frac{1}{3}$ of its volume of water. Its composition has not yet been accurately ascertained. It is generally obtained for accurate experiments from the decomposition of heated sulphuric acid by mercury. The cubic inch weighs .73 pts. of a gr. It extinguishes flame. When suffered to remain for a long while in contact with oxygene gas, it is converted into sulphuric acid.

5. COMPOUNDS of OXYGENE and CARBON. Three compounds containing oxygene and carbon, in different proportions, are known. Charcoal, gaseous oxide of carbon, and carbonic acid.

*Charcoal* is procured pure by passing alcohol through a tube heated red. It is carbon in the first degree of oxygenation. It forms a considerable part of the solid matter of organized bodies, and it is obtained from them mixed with other substances by the action of heat. Its colour is intensely black. It has no taste or smell. It is a perfect conductor of electricity. It is solid at all known temperatures. It burns with the production of vivid white light in oxygene gas. It is perfectly insoluble in water. It is capable of absorbing certain quantities of different known gases, which are liberated from it by the action of heat.

*Gaseous Oxide of Carbon* is obtained by the action of ignited charcoal on certain metallic oxides, such as those of zinc, and iron. It is carbon in the second degree of oxygenation. It is devoid of taste and smell. It is very little absorbable by water. It burns in contact with atmospheric air with a lambent blue flame. Its specific gravity is to that of common air nearly as 22 to 23. It is composed of about 9 parts carbon and 21 parts oxygene.

*Carbonic Acid* is produced when charcoal, or diamond is burned in pure oxygene: likewise it is obtained when muriatic acid is made to decompose carbonate of lime. It has a pleasant smell, and a faintly acidulous taste. It is a permanent gas at all known temperatures. It is soluble in half its volume of water. It extinguishes flame. The cubic inch weighs about .46 pts. of a gr. It is carbon perfectly oxygenated, and combined with four parts of oxygene.

6. Combinations of Oxygene with the acidifiable metals. The acidifiable metals are, arsenic, tungsten, molybdena, chrome, and, as it is said, cobalt.

*Arsenic* is capable of combining with oxygene in two proportions, so as to form the arsenious and arseniac acids.

The *Arsenious Acid*, or, as it has been generally called, white oxide of arsenic, is procured by the action of oxygene gas on metallic arsenic. Its taste is disagreeably acrid, and its smell is analogous to that of garlic. It is soluble in 15 parts of boiling water. Its specific gravity is 3.706. It is volatile at the temperature of 283°. It is said to be composed of 93 parts of arsenic and 7 of oxygene.

The *arseniac acid* is procured by the action of nitric acid upon the arsenious acid. Its taste is sour. Its colour is white. It fuses at a red heat, but it is not volatile. It is said to be composed of 91 parts of arsenic and 9 of oxygene.

One combination of oxygene with tungsten only is known. The *tungstic acid* is procured by the fusion of tungstate of lime with carbonate of potash, and subsequent treatment of the mixture with nitric acid. It exists in the form of a white powder. Its taste is faintly acrid. Its specific gravity is 3.6. It is neither fusible nor volatile at any known temperature. It is soluble in 20 parts of boiling water.

Molybdena combines with oxygene in two proportions, so as to produce the molybdic oxide and the molybdic acid.

The *molybdic oxide* is procured when molybdena is intensely heated in contact with oxygene. It is white, and volatile. It is easily converted into molybdic acid, by treatment with nitric acid.

The *molybdic acid* is soluble in 500 parts of water. Its specific gravity is 3.4. Its taste is distinctly sour.

Chrome exists in two states combined with oxygene.—*The oxide of chrome* is of a green colour. It is procured by the action of heat and light on the chromic acid.

The *chromic acid* is obtained by the decomposition of the chromate of lead found in Siberia. It is of a red colour, and has a peculiar metallic taste. It is soluble in water.

Cobalt has long been known as combined with oxygene in the state of an *oxide,* capable of communicating a fine blue colour to glass; but the existence of the *acid of cobalt* has been only lately proved by the experiments of Brugnatelli. It is produced from what he calls the ammoniuret of cobalt. It is soluble in water, and has a distinctly sour taste.

7. Combinations of oxygene with the oxidifiable metals. Manganese, zinc, iron, tin, lead, antimony, bismuth, nickel, titanium, tellurium, copper, and mercury, are capable of combining with oxygene gas, when they are exposed to it at different high temperatures;

but their *oxides* are, in general, obtained for common purposes, either from certain ores found in nature, or from the agency of different acids on the metallic bases.

Silver, gold, and platina, do not act upon oxygene gas except when they are ignited by the galvanic spark. The *oxide of silver* is obtained by treatment of the metal by nitric acid and potash. The *oxides of gold* and *platina* are procured by means of oxymuriatic acid.

The *oxide of uranium* is found in the uranite.

Oxygene is capable of combining in different proportions with many of the metals, and of forming with them, oxides possessed of distinct properties.

Amongst the most remarkable of the metallic oxides, are the *red* and *black oxides of iron,* containing respectively, 47, and 28 per cent. of oxygene; the *red, black,* and *white, oxides of mercury,* of which the red gives out oxygene gas when exposed to heat: the *red, yellow, and grey, oxides of lead;* the *black oxide of manganese;* and the *white oxide of antimony.*

The metallic oxides in general are insoluble in water, tasteless and inodorous. Many of them are fusible at high degrees of heat, and a few of them are volatile. They are all of less specific gravity than their bases. In certain states of oxygenation they are combinable with acids.

8. COMBINATION of OXYGENE with MURIATIC ACID. *Oxygenated muriatic acid* is procured when muriatic acid is distilled from black oxide of manganese, or red oxide of lead. Its taste is acrid. It renders vegetable blues white, differing in this respect from the other acids. It is a gas at common temperatures; but it may be condensed by a moderate degree of cold. Its colour is light yellow. It is absorbable by water. Most of the combustible bodies burn in it. It is combinable with the fixed alkaline substances. It gives out oxygene gas when acted upon by vivid light. Its specific gravity is much greater than that of atmospheric air.

## 3. *Second Class.*

Hydrogene appears to be capable of combining with only three simple bodies besides oxygene; nitrogene, sulphur, and phosphorus. For the hydrocarbonates, which were formerly supposed to consist wholly of hydrogene and carbon, contain, as it would seem from some late experiments, a portion of oxygene. See Div. IV. Sec. 2. Its compounds are not possessed of many analogous properties; one of them is an alkali, and another an acid.

1. COMPOUND of HYDROGENE and NITROGENE. *Ammoniac* or volatile alkali is obtained by the action of lime upon muriate of ammoniac; likewise it is formed when nascent hydrogene is exposed to nitrogene gas at a low temperature. It is a permanent gas at common temperatures, weighing in the cubic inch about .18 pts. of a gr. Its smell is highly pungent; and its taste burning and acrid. It renders green, vegetable blues. It extinguishes flame. It produces white fumes when brought in contact with the volatile acids. It is extremely soluble in water, 75 grains of water being capable of absorbing 25 grains of gas, forming with it a fluid of specific gravity .908. Ammoniac is decomposed into its constituent parts by the action of electricity, or of a high degree of heat. It is compounded of one part hydrogene and five parts nitrogene.

2. COMPOUND of HYDROGENE and SULPHUR. *Sulphurated hydrogene* or hepatic gas is formed when hydrogene gas is passed over heated sulphur. It is obtained for common purposes by the action of an acid on solution of sulphuret of potash. It is a permanent elastic fluid. Its smell is extremely fœtid. Its taste is sour, it reddens vegetable blues, it combines with the alkalies, and is very soluble in water; so that it is a true acid. It burns, when highly heated in contact with oxygene gas, with a blue flame, depositing sulphur. It is decompounded into its constituent principles by the electric spark. The cubic inch weighs .34 pts. of a gr.

3. COMBINATION of HYDROGENE with PHOSPHORUS. *Phosphorated hydrogene* is formed by the action of phosphorus upon the heated aqueous solution of potash. It is likewise obtained by the action of water upon the phosphuret of lime, a substance formed by passing phosphorus in vapour through ignited lime. It is a permanent gas, soluble in about four times its volume of water. It is possessed of the peculiar property of inflaming when brought in contact with oxygene gas at common temperatures. It is decomposable by the electric spark.

## 4. *Third Class.*

Sulphur is possessed of great powers of combination. It enters into union with all the metals, except gold, platina, titanium, and probably, chrome. It combines with the alkaline substances, and with phosphorus. Its acid compounds, containing oxygene, and hydrogene, have already been noticed.

1. COMBINATIONS of SULPHUR with the METALS. The greater number of the metallic sulphurets are found in nature. They may be made artificially, by bringing sulphur in contact with the metals, at different high temperatures; and during the process, heat and light are evolved. They are solids, in general possessed of a high degree of specific gravity. They are opaque, and often brilliant in their appearance like the metals. They are conductors of electricity. They have no taste or smell. They are all decomposable at certain degrees of heat.

Of the metallic sulphurets, the best known are the *sulphuret of iron* or martial pyrites, the *sulphuret of zinc* or blende, the *sulphuret of lead* or galena, and the *sulphurets of copper, tin, arsenic,* and *mercury.*

Almost every metal is capable of combining with many different proportions of sulphur.

2. COMPOUNDS containing SULPHUR and the FIXED ALKALINE SUBSTANCES. The alkaline sulphurets or the hepars of sulphur, may be obtained by the fusion of sul-

phur with the different alkaline substances, or by the decomposition of alkaline sulphates by charcoal at a high degree of heat. They are solid bodies, in general opaque, and of a red, or brownish red colour. They are of considerable specific gravity. They burn, when intensely heated, in contact with the atmosphere. They undergo peculiar changes from the action of water. They are decomposable by the acids. The *sulphurets of potash, of soda, of strontian,* and *of magnesia,* are not possessed of any specific properties worthy of particular notice. The *sulphurets of barytes,* and *of lime,* become phosphorescent after having been exposed to light.

3. Compound of sulphur and phosphorus. Sulphur and phosphorus are capable of combining in different proportions. To effect their union with safety, they must be fused together under hot water. The *sulphurets of phosphorus* are yellowish, and less transparent in proportion as they contain a larger quantity of sulphur. They are all more fusible than sulphur. They are so combustible, that they inflame in the atmosphere by mere friction.

### 5. *Fourth Class.*

The binary compounds containing the metals, which have not been already described, are the metallic phosphurets, the carburets, and the alloys.

1. Combinations of phosphorus with the metals. Phosphorus is capable of combining in different proportions with the greater number of the metallic substances. The *phosphurets* generally are obtained by exposing the metals to phosphorus, at the time that it is produced from ignited phosphoric acid, by means of charcoal. They are opaque, of great specific gravity, and usually possessed of the metallic splendour. They are fusible at different high temperatures, and they burn at those temperatures when in contact with oxygene.

2. Combinations of metals with carbon. Iron, zinc,

and manganese, are the only metals supposed to be capable of combination with carbon.

When diamond and iron are intensely heated together the *carburet of iron* or steel is formed. This substance is obtained for use, from the cementation of iron with charcoal. It is fusible at a high degree of heat. It is harder than iron. It is capable of receiving an extremely fine polish. It is very combustible.

Plumbago, or the *hypercarburet of iron,* is supposed to be a combination of carbon and iron, with probably a minute portion of oxygene. It is found in nature. It is of a black glossy colour. It is infusible. It burns, when intensely heated, in contact with the atmosphere.

The properties of the *carburets of zinc,* and *of manganese,* have been but little examined. It is likely, that they, as well as the hypercarburets of iron, contain a minute quantity of oxygene.

3. Binary combinations of metals with one another. The *binary alloys* are formed by bringing two metals possessed of affinity for each other together, one of them at least being in a state of fusion. The alloys are analogous to the simple metals in all their physical properties. Their number is almost infinite, for when metallic substances are possessed of the power of attracting each other chemically, they are capable of combining in a number of different proportions. The chemical properties of alloys have been very little studied, and no definite knowledge is obtained concerning the change of volume taking place during the different combinations of metals. The most important of the binary metallic compounds are *brass,* which is composed of about three parts of copper and one of zinc; *bronze,* which is a compound of copper and tin; the *fusible compounds of lead*; and the *amalgams of mercury.*

### 6. *Fifth Class.*

Certain of the earths are possessed of affinities for one another: all of them except zircone, are capable of combining with some of the fixed alkaline substances; and that body, as well as alumine, and glucine, is acted upon by the undecompounded acids.

1. BINARY COMPOUNDS containing EARTHS only. The *combination of silex* and *alumine* may be effected by mingling their alkaline solutions together. The *compound of jargon* and *silex* is formed when these earths are intensely heated in contact with one another. The mutual attractions of the other earths have not been much examined.

2. COMBINATIONS of EARTHS with ALKALINE SUBSTANCES. When equal parts of potash, or of soda, and of silex are fused together, they combine and form the compound denominated *glass*, the properties of which are well known. When one part of silex is united, by fusion, to three parts of potash, or of soda, a substance is formed which is soluble in water, and which forms with it the *liquor silicum.*

Alumine, and glucine are combinable with potash, and soda, both when they are dry, and in aqueous solution at certain degrees of temperature.

Barytes, strontian, or lime, when intensely heated in certain proportions with silex, combine with it and form vitreous compounds.

3. The COMBINATIONS of the EARTHS with the SIMPLE ACIDS, will be considered in the next section.

## 7. *Sixth Class.*

The binary compounds containing the simple acids, are possessed of very analogous properties. They have been called *compound salts*; and under this name, have been generally arranged with substances containing the decomposable acids.

1. COMBINATIONS of the SIMPLE ACIDS with FIXED ALKALINE SUBSTANCES. The simple acids are capable of combining with all the fixed alkaline substances, when their aqueous solutions are brought into contact with them

at common temperatures; and the compounds when deprived of water become permanent solids.

The compounds of the muriatic acid and the fixed alkaline substances, or the *fixed alkaline muriates,* are possessed in general of a bitter taste. They are white semipellucid bodies, regularly crystallized. They are extremely soluble in water.

Amongst the compounds of fluoric acid and the fixed alkaline substances, the *fluates of potash,* and *of soda* are soluble in water, and nearly insipid; the *fluates of strontian, barytes, lime,* and *magnesia,* are tasteless substances, not combinable with water.

The combinations of the boracic acid with potash and soda, or the *borates of potash* and *soda* are crystallized, solid, substances, soluble in water. The *borate of soda* with *excess of alkali* is the borax of commerce.

The *borates of barytes, strontian, lime,* and *magnesia,* have been very little examined. They are white, solid, substances, but little combinable with water.

2. COMPOUNDS containing UNDECOMPOUNDED ACIDS and EARTHS. All the earths except silex, are dissolved when acted upon by an aqueous solution of muriatic acid. The compounds formed, are called *muriates.* When deprived of water they exist in the solid form. Generally they are white and transparent. They are possessed of no smell. Their taste is bitter, or astringent.

Fluoric acid combines with all the earths, when it is brought in contact with them at common temperatures, and forms compounds called *fluates.* The *fluate of silex* exists permanently in the aëriform state. The properties of the *fluates of zircone, alumine,* and *glucine,* have been very little examined.

The compounds of the earths and the *boracic acid,* are called *borates.* In general they are difficultly soluble in water. They are possessed of little taste and no smell.

## DIVISION IV.

### OF BODIES COMPOSED OF MORE THAN TWO SIMPLE SUBSTANCES, OR TERNARY COMPOUNDS, QUATERNARY COMPOUNDS, &c.

### 1. *Classification of Substances composed of more than two Simple Substances.*

Very few of the substances composed of more than two simple principles are capable of being formed by art, immediately from their elements. In general, they are either found in organized bodies, or are produced during their spontaneous or artificial decomposition. We are acquainted with their nature chiefly from analysis. Considering their composition, and the mode in which they are procured, they may be divided into five classes.

I. Oxides with bases compounded chiefly of hydrogene and carbon. II. Acids composed chiefly of hydrogene, oxygene, and carbon. III. Oxides with bases compounded chiefly of nitrogene, hydrogene, and carbon. IV. Acids composed chiefly of oxygene, nitrogene, hydrogene, and carbon. V. Compounds containing earths, and alkalies, or metals.

### 2. *First Class.*

The oxides containing hydrogene and carbon are found in general in the vegetable kingdom. Their composition, and their properties are very different and various. Amongst them may be found, gases, fluids, and solids. In general, they are combustible, easily decomposable by heat, and nonconductors of electricity.

1. HYDROCARBONATES. *Heavy hydrocarbonate* is one of the products evolved during the decomposition of spirits of wine by heated sulphuric acid. It is a permanent gas at all known temperatures. It burns, when heated

in contact with the atmosphere, with a blue flame. It is insoluble in water. The cubic inch weighs .26 pts. of a gr.

*Light hydrocarbonate* is obtained when water is made to act upon ignited charcoal. Its properties are analogous to those of heavy hydrocarbonate. The cubic inch weighs .15 pts. of a gr.

The proportions between the constituent parts of the hydrocarbonates have not hitherto been accurately ascertained. The existence of hydrogene, carbon, and oxygene, in them is proved when they are decomposed by heated sulphur; for in this case, charcoal and sulphurated hydrogene are formed.

2. Alcohol is obtained in its purest form from ardent spirits, by their treatment with potash, and subsequent distillation. It is an inflammable fluid. It is possessed of a strong affinity for water, and is seldom procured perfectly devoid of that fluid. Its specific gravity, when in its purest state, is about .829. It contains a larger proportion of carbon and oxygene than the hydrocarbonates, for when it is passed through a tube heated red, it is decompounded into heavy hydrocarbonate and charcoal. Alcohol has never yet been rendered solid by any degree of cold. It becomes a gas at the temperature of 176°.

3. Ether is produced during the action of sulphuric, nitric, or muriatic, acid upon alcohol. It is the lightest known fluid body. Its specific gravity being only .739. It is possessed both of a strong and peculiar smell and taste. It is soluble in water. It does not become solid by artificial cold. It boils at 96°. It is very inflammable. It is decompounded by being passed through a tube heated red, affording products analogous to those produced by the decomposition of alcohol. It differs from that body in composition, probably by containing more oxygene and hydrogene.

4. Oils are obtained by expression, or distillation, from different vegetable and animal substances. In general they are capable of freezing at low temperatures. They are immiscible with water. They are usually of less specific gravity than water. They are inflammable. They are

decomposed when passed through ignited tubes; the products being chiefly charcoal and hydrocarbonate.

The oils procured in different manners are extremely different in their properties; and it is probable that they owe their peculiarities to the different substances which they hold in solution.

The oils called fixed, appear to be generally combined with mucilage; whereas those denominated volatile, contain vegetable aromatic matters.

5. SUGAR is obtained from the inspissated juice of certain plants, such as the sugar cane, and the white beet. Its physical properties are well known. It is combustible. It is decomposable, like most of the other vegetable products, by a high degree of heat. It is capable of forming alcohol by fermentation. Its composition has not been hitherto exactly ascertained.

6. RESIN is exuded from the barks of certain trees. It is very little vapid or odorous. It is inflammable. It is soluble in alcohol, but not in water. It is capable of being rendered fluid by heat. It appears to differ from volatile oil, only by containing more oxygene.

7. WAX in its composition strongly resembles resin. It is collected by bees, probably from the pollen of flowers. Its properties are well known.

8. GUM is found plentifully in many vegetables. It is often exuded from their barks. It is a transparent substance; very brittle, tasteless, and inodorous. It is very slightly inflammable. It is soluble in water; but insoluble in alcohol. It contains less oxygene than sugar; consisting chiefly of carbon and hydrogene, with probably a little nitrogene. Gum under certain modifications of its principles, assumes the forms of MUCILAGE, and of FECULA.

9. TANNIN, or the tanning principle, is obtained when the precipitate obtained from a decoction of galls, by means of muriate of tin, is acted upon by sulphurated hydrogene. It appears in the form of a light brown pulverulent mass. Its taste is bitter. It is soluble in water, and in alcohol. It is decomposable by heat. It is possessed of affinity for

many of the metallic oxides. Its composition is not accurately known.

10. EXTRACT is obtained by evaporating the infusion of saffron in water. It is extremely soluble both in water and alcohol. It is insoluble in sulphuric ether. It is softened by a moderate degree of heat, though it is not fusible. At high temperatures it is decomposed.

11. The WOODY FIBRE and COLOURING MATTERS of vegetables have been very little examined, but their composition is supposed to be analogous to that of the substances which have been just described.

### 3. *Second Class.*

The acid substances chiefly composed of oxygene, hydrogene, and carbon, belong more particularly to the vegetable kingdom. They form a numerous class of bodies, and are possessed of very analogous physical properties. In general they are soluble in water, decomposable by heat, possessed of the sour taste, and capable of rendering vegetable blues red.

1. ACETOUS ACID or vinegar, is formed during the fermentation of wine. Its taste is pleasantly sour; its smell is agreeable. It is a fluid easily rendered aëriform by heat. At a high temperature it is decomposable. It is capable of being deprived of a portion of carbon by distillation from metallic oxides, when it becomes possessed of new properties, and is called ACETIC ACID. Certain of the empyreumatic oils when dissolved in acetous acid materially alter its properties. The substances that were formerly termed pyromucous, pyroligneous, and pyrotartareous, acids, are wholly composed of acetous acid and empyreumatic oils.

2. TARTAREOUS ACID is procured from acidulous tartrite of potash, which is found in wines, by treatment with lime and sulphuric acid. It is a solid substance, generally composed of needle-formed crystals. Its taste is very sour. It is soluble in water, and decomposable by heat.

3. OXALIC ACID is generally obtained from the juice of

the wood sorrel, oxalis acetosella. It may likewise be obtained from the action of nitric acid upon sugar and other vegetable oxides. It contains more oxygene than tartareous acid. It is a crystallized solid, soluble in half its weight of boiling water. Of all the acids it is possessed of the strongest affinity for lime.

4. CITRIC ACID is obtained from the juice of lemons, when it is treated with lime and sulphuric acid. It is a solid crystallized body; extremely soluble in water, and in its aqueous solution is possessed of a very pleasant acid taste.

5. MALIC ACID is extracted from the juice of ripe fruits by means of lime and acetite of lead. It is easily decomposed by heat. It is converted, by nitric acid, into oxalic acid.

6. GALLIC ACID is obtained by sublimation from the aqueous extract of galls. It generally appears in the form of small grey crystals. It precipitates the red oxide of iron black from its solutions, Its taste is very acrid.

7. SUCCINIC ACID is obtained by the distillation of amber. It is crystallized in three sided prisms of a beautiful white colour. It is inflammable.

8. BENZOIC ACID is procured from benzoin, storax, and other substances, by means of heat. Its smell is aromatic, and its taste extremely pungent. It is crystallized in compressed prisms. It is very fusible, and volatile. It burns in contact with oxygene. It is soluble in nitric acid.

9. CAMPHORIC ACID is produced during the distillation of camphor with nitric acid. It crystallizes in parallelopipeds. It is very little soluble in water. It burns in contact with the atmosphere, forming new compounds, wholly gaseous.

10. SUBERIC ACID is formed by the distillation of nitric acid from wood. It is soluble in about fifty times its weight of water. Its taste is slightly sour. It is easily decomposed by heat.

11. MUCOUS ACID, or saccholactic acid is obtained by the distillation of gum or mucilage with nitric acid, and

likewise from sugar of milk. It appears in the form of a white powder, very little soluble in water. It is decomposed with more difficulty than most of the other vegetable acids.

### 4. *Third Class.*

The compounds possessed of no acid properties, chiefly containing oxygene, hydrogene, carbon, and nitrogene, are in general found in the animal kingdom. The relative proportions of the principles that compose them are unknown. One of their most characteristic properties is the facility with which their composition is altered.

1. Gelatine is obtained from different animal matters, and particularly from skin, by means of boiling water. In its solid form it appears as a semiductile, transparent, substance, without taste or smell. It is extremely soluble in warm water; but insoluble in alcohol. It is combustible; and decomposable by heat. It is soluble in the acids. It is precipitated from its aqueous solutions by nitromuriate of tin, and likewise by tánnin. Combined with tannin it forms an insoluble compound, analogous to leather.

2. Albumen is found plentifully in the eggs of birds, and in other animal productions. In its natural state it appears in the form of a transparent viscous fluid, possessed of no distinct taste or smell. Its most characteristic property is its coagulation by a heat of 165° into a permanent solid mass. Albumen, when liquid, is combinable with water; but when coagulated, it seems to have little affinity for that fluid. Coagulated albumen is soluble in solutions of alkaline substances. Albumen is capable of being combined with tannin. It contains a little sulphur united with its other constituent parts.

3. Fibrine is procured from the blood of animals by repeated washing of the coagulum. It is of a white colour. It is insoluble in water, and in alcohol. The alkaline aqueous solutions, when cold, do not dissolve it; but when very concentrated, they decompose it. It is soluble in many of the acids.

4. UREA is a crystallized substance of a fœtid smell, obtained from urine. It is soluble in water and in alcohol. It is combinable with certain of the acid and alkaline solutions.

5. GLUTEN is obtained from wheat flour, when all its other constituent parts have been separated by water. Though of vegetable origin, it bears a strong analogy to the substances which have been just described; and evidently contains a considerable quantity of nitrogene. It is insoluble in alcohol. It is combinable with heated alkaline solutions.

### 5. *Fourth Class.*

Amongst the acid substances, chiefly containing oxygene, hydrogene, carbon, and nitrogene, some are found native in animal solids and fluids, others are produced during their natural or artificial decomposition. The native animal acids are the formic acid, the bombic acid, the laccic acid, the sebacic acid, and the uric acid. The acids produced by the decomposition of animal substances by heat, are the prussic and zoonic acids. The lactic acid is formed during the fermentation of milk.

1. The FORMIC ACID is found in a particular species of ants (the formica rustica); and it is obtained by their distillation. It is extremely analogous to the acetic acid. It has a strong smell, and a very sour and caustic taste. In its common form it is fluid, but it may be easily volatilised. It is soluble in alcohol, and is decomposed by nitrous acid.

2. The BOMBIC ACID is obtained from the silkworm, and from certain species of moths. Its taste is slightly sour; and it reddens vegetable blues. Its properties are very little known.

3. LACCIC ACID is obtained by a low degree of heat from a substance called white lac, formed by certain insects of the coccus tribe. It is a fluid possessed of a salt, bitterish, taste. It is capable of being crystallized. It boils at 200°. It is easily decomposed at a higher temperature.

4. SEBACIC ACID is procured by treating a mixture of

lime and suet, which has been exposed to heat, by sulphuric acid. It has an acrid taste, and a very pungent smell. It is decomposable by heat. When mixed with nitric acid it enables it to dissolve gold.

5. Uric acid is obtained from an alkaline solution of the urinary calculus, by means of acetous acid. It crystallizes in thin plates. Its colour is brown. It has very little taste or smell. It is soluble in three hundred parts of boiling water. It combines readily with alkaline substances. It is acted upon by nitric acid, to which it communicates a pink colour.

6. Prussic acid is formed when ammoniacal gas is passed over ignited charcoal. It is obtained for common purposes from the decomposition of alkaline prussiates, by acids. It is exceeding volatile. Its smell is peculiar, and its taste is sweetish, but acrid. It is easily decompounded by heat, when united to the alkalies, producing carbonate of ammoniac. It has a very strong affinity for the metallic oxides. Combined with red oxide of iron it forms a bright blue substance, known by the name of prussian blue.

7. Zoonic acid is procured from animal substances by distillation; and likewise from gluten. It is purified by treatment with lime and phosphoric acid. Its smell is like that of roast meat. Its taste is acrid. It is easily volatilised. It produces a white precipitate in the solutions of acetite of lead, and nitrate of mercury.

8. Lactic acid is procured from sour milk by treatment of it with lime and alcohol. It is a solid body, very soluble in water. Its chemical properties are very little known.

### 6. *Fifth Class.*

The fifth class of the more compounded substances, may be divided into metallic compounds, and earthy, and alkaline compounds.

1. The metallic compounds, containing more than two simple principles, are extremely numerous, but of very little importance in the chemical arrangment. Their pro-

perties in general have not been studied. Amongst the ternary and quaternary alloys in common use, are the alloys of *bismuth* with *lead* and *tin*, which are extremely fusible; the *alloys* of *mercury* with *zinc*, *tin*, and *lead*, used in electrical experiments; different compound *alloys* of *copper*. There are no known ternary combinations of the inflammable bodies and metals.

2. The earths are capable of combining with each other, and with the alkaline substances, in many different proportions. A very great number of their compounds is found in nature; and many of them are made in different artificial processes. The compounds of alumine, silex, lime, and magnesia, in different proportions, are capable of being softened, and, in certain cases fused, by heat.

In general the earthy, or alkaline substances, which are infusible alone, lose this property by being mixed together, and become fluid at the time that they enter into combination.

## DIVISION V.

### OF SUBSTANCES COMPOSED OF DIFFERENT COMPOUND BODIES, OR OF COMPOUND BODIES AND SIMPLE BODIES.

### 1. *Classification of Substances containing different Compound Bodies, &c.*

The substances considered in this division are in general capable of being composed either from different compound bodies, and from compound bodies and simple bodies, or of being decomposed into them. Hence they are considered as owing their formation to peculiar attractions of undecompounded principles, modified by a previous combination. They exist for the greater part in nature: many of them are capable of being formed artificially. If we derive the methods of arranging them from their physical relations, they may be considered under four classes.

I. Saline compounds. II. Mineral substances. III. Vegetable substances. IV. Animal substances.

### 2. *First Class.*

The saline compounds are substances containing, as one of their constituent parts, at least, an acid, an alkali, or an oxide. They are very numerous, and are capable of being formed, and decomposed, artificially. In general they are more or less soluble in water. They are often possessed of taste. They are chiefly incombustible. When solid they are nonconductors of electricity.—They may be considered under three genera. 1. Compounds containing acids. 2. Compounds containing alkalies. 3. Compounds containing oxides.

1. COMPOUNDS containing ACIDS. The acids are capable of combining with the fixed alkaline substances, with ammoniac, with the metallic oxides, and with all the earths except silex, when they are merely brought in contact with them; and the bodies they form with them have been generally called compound salts. The compound salts are usually transparent, solid, crystallized, substances. Their names are derived from the acids, and the bases, that constitute them. They are not of such importance in the general arrangement of chemistry as to require description individually; and they may be considered in *species* possessed of analogous properties, and corresponding in number with the acids.

A. The sulphuric, and sulphureous acids combined with the alkaline substances, &c. form salts called respectively *sulphates*, and *sulphites*, which are convertible into sulphurets by ignition with charcoal.

B. The compounds of the nitric acid are called *nitrates*. They are decomposable by heat, and detonate when mingled with inflammable substances.

C. Many of the compounds containing muriatic acid, or the *muriates*, have been described in Div. III. Sect. 6. and the rest have no important characters.

D. The compounds containing phosphoric, and phosphorous acids, or the *phosphates* and *phosphites* are not decomposable by heat; and they are known from the disengagement of their acids, by means of sulphuric acid.

E. The compounds containing carbonic acid, or the carbonates, are in general decomposable by heat; and they retain, more or less, the characters of their bases.

F. The compounds of fluoric acid, or the *fluates*, have already, in part, been described, Div. III. Sect. 6. In general they evolve a dense white vapour on the contact of sulphuric acid, which corrodes glass.

G. Many of the compounds of the boracic acid, or the *borates*, have been noticed in the same division as the fluates. They are all fusible at high temperatures, and easily decompounded by different acids.

H. The *Arseniates* and *Arsenites*, or the salts containing the arseniac and arsenious acids, are known by the arsenical smell they emit when brought in contact with hot charcoal.

I. The properties of the *Tungstates*, and of the *molybdates*, or the salts containing the tungstic, and molybdic acids, are very little known. The compounds of the chromic acid or the *chromates* are characterized by their peculiar colours.

K. The *Acetites* or the compounds of the acetous acid, are decomposable by heat, and they are known by their acid when it is disengaged by means of sulphuric acid.

L. The compounds of the tartareous acid or the *tartrites*, are ascertainable by their faintly acidulous taste, and the facility with which they are decomposed by heat.

M. The *oxalates*, or the compounds of the oxalic acid, are distinguished by the power of their acid to decompose all calcareous salts.

N. The compounds of the citric, the malic, and the benzoic acids, or the *citrates*, *malates*, and *benzoates*, are known only from the disengagement and examination of their acids.

O. The *gallates*, or the compounds of the gallic acid; when metallic, are characterized by their striking colours; and when alkaline, by their power of precipitating red oxide of iron black from all its solutions.

P. The compounds of camphoric, suberic, mucous, and succinic, acid, or the *camphorates, suberates, mucites,* and *succinates* are very imperfectly known, and they are chiefly distinguished by simple decomposition, when their acids are evolved.

Q. The *formiates,* the *bombiates,* the *laccates,* the *sebates,* and the *lactates,* or the compounds containing the formic, the bombic, the laccic, the sebacic, and the lactic, acids have in general been very little examined, and they are only known by the disengagement of their acids.

R. The *prussiates,* or the compounds containing prussic acid, are distinctly characterized by their various colours, or by their powers of producing colours, when mingled with certain metallic solutions.

S. The *zoonates,* or the compounds containing zoonic acid, are sufficiently distinguished by the animal smell produced during the disengagement of their acid.

T. The compounds containing oxygenated muriatic acid, or the *oxygenated muriates,* are known by their power of detonating by concussion, when mingled with inflammable substances; and likewise from the disengagement of their acid.

U. The *hydrosulphurets,* or the combinations of sulphurated hydrogene, are known by their peculiar smell and colour, and the facility with which they are decomposed.

All these compound salts may be considered as binary combinations of acids with single bases, and may be called double salts. But there are other substances which consist of an acid and two bases. These compounds have as yet been very little examined. Many of them contain magnesia and ammoniac, or ammoniac and metallic oxides. They are called triple salts.

2. SALINE BODIES containing ALKALINE SUBSTANCES. The alkaline substances are capable of combining with many other bodies besides the acids. They enter into union with oils, fat, albumen, alcohol, and other compound bodies.

Amongst the alkaline compounds most worthy of notice are, the soaps, the hydrogenated sulphurets, and the substances containing alkalies and metallic oxides.

A. The *soaps* are formed by the combination of volatile or fixed oils or fat with the alkaline substances. Amongst them the *soaps* containing *potash*, *soda*, and *ammoniac*, are soluble in water, decomposable by heat, and possessed of an acrid taste and a peculiar smell. The *soaps* containing *barytes*, *strontian*, *lime*, and *magnesia*, are nearly insoluble in water, and possessed of no important properties.

B. The *fixed alkaline hydrogenated sulphurets* are produced, when the alkaline sulphurets are acted upon by water. They are compounds of sulphurated hydrogene, and sulphurets. They are soluble in water. They are readily decompounded by acids, which combine with the alkali, when the sulphurated hydrogene and sulphur are rendered free. They are of a yellow colour, and possessed of a disagreeable smell and a nauseous taste. They blacken the skin when applied to it. They readily absorb oxygene gas; and in consequence, have been successfully employed as eudiometrical substances.

Ammoniac is capable of combining with sulphur and sulphurated hydrogene, so as to form a compound soluble in water, called *hydrogenated sulphuret of ammoniac.* This compound is usually formed by the distillation of a mixture of lime, muriate of ammoniac, and sulphur.

C. The *substances containing alkalies* and *metallic oxides* will be immediately noticed.

3. SALINE BODIES containing OXIDES. Many of the metallic oxides are capable of combining with the alkalies; and the substances they form with them are possessed of very singular properties. Amongst the compounds of the metallic oxides and alkalies, the most important are the ammoniurets of silver, gold, mercury, and copper.

A'. The *ammoniuret of silver* or ammoniacal fulminating silver is formed when oxide of silver is digested for some time in caustic solution of ammoniac. It is a crystallized substance; and it detonates with astonishing violence when slightly heated, or even when gently touched.

B. The *ammoniurets of gold, mercury,* and *copper,* are procured in a manner similar to that in which the ammoniuret of silver is formed. The ammoniuret of gold fulminates when it is briskly rubbed, or heated pretty strongly. The ammoniuret of copper does not fulminate. It is of a beautiful blue colour.

C. The oxides of mercury and silver, when treated with nitric acid and alcohol, are capable of becoming powerful detonating compounds. And in this state, appear to be combined with oxalic acid, and nitrous etherized gas.

The *fulminating mercury,* and *fulminating silver,* are both opaque bodies, one white, and the other grey. They explode at temperatures much below those of ignition. The discovery of these substances is owing to Mr. Howard.

The metallic oxides are capable of combining with oils; but the properties of the compounds they form with them have been very little studied.

### 3. *Second Class.*

The substances composed of different compounds of the earths, alkaline substances, and metals, have been classed under the general name of mineral bodies, for they exist for the most part in nature. The accurate classification of them, according to a minute observation of their external properties, chemical composition, and relations to each other and to different natural and artificial substances, belongs to an extensive branch of chemical science named *mineralogy.* In this place, they will be noticed only in their connexions with the substances, which may be considered as their constituent parts, mentioned in the preceding sections.

They may be divided into compounds chiefly metallic, which are generally ores; or compounds chiefly earthy, which are principally stones.

1. The COMPOUNDS CHIEFLY METALLIC. The metallic oxides, alloys, and sulphurets, may be considered as forming the bases of the very compounded metallic substances.

The metallic oxides are often found in nature, combined with silicious and aluminous earth, and likewise with certain of the fixed alkaline substances forming different ores. Thus, the oxide of iron is found combined with alumine and lime in the aluminous iron stone.

The compounds containing metallic oxides are extremely various in their composition: and their properties are very little analogous. Amongst them may be mentioned the hematites, calamine, and molybdate of lead.

The metallic alloys and sulphurets are often found combined together in different ores. Thus the blendes or ores of zinc often contain copper and lead; and galena, or the sulphuret of lead is often united to silver. These combinations are as yet very little understood.

2. The COMPOUNDS CHIEFLY CONTAINING EARTHS are in general divided into genera, which are named from the simple earth or alkaline substance of which they contain the largest proportion. The genera containing the greatest number of bodies are, 1. The silicious. 2. The aluminous. 3. The calcareous. 4. The magnesian. These genera, in the mineralogical system, apply not only to the more compounded substances, but likewise to the binary and ternary compounds, &c.

In the *silicious genus*, the most important of the more compounded stones are quartz, felspar, hornstone, carnelian, chalcedony, flint, &c. all of which are found, owing their colours to metallic oxides.

The *aluminous genus* contains, amongst other substances, corundum, ruby, emerald, topaz, shistus, smectis, lithomarga, bole, lepidolite, sappare, talc, hornblende, wacken, trap, killas.

In the *calcareous genus* are classed the varieties of limestone, dolomite, the marlites, the fluates, phosphorites, &c. which are all, in fact, compound salts containing metallic oxides, &c.

Amongst the stones belonging to the *magnesian* genus are the steatites, the serpentines, jade, asbestus, chrysolite, &c.

3. The earths and the alkaline and metallic substances, in their different compounds, constitute by far the greater portion of the known solid matter of the globe. And these compounds, in their natural arrangement, are found either collected in immense indurated, and often stratified, masses, as rocks, or in smaller masses, as stones and pebbles, or in a state of loose mixture, as in soils.

### 4. *Third Class.*

The epidermis, the parenchyma, the cortical layers, the wood, the pith, the sap, and other substances found in the roots, trunks, leaves, flowers, and seeds of plants, appear for the most part, to be compounded of the oxides and acids containing oxygene, hydrogene and carbon, of water, and different earths and salts. We are, however, very little acquainted with the arrangement of these their constituent parts.

We can only examine vegetable substances chemically in their dead state. Our analysis of them is generally made by heat, and we are wholly incapable of proving the accuracy of it by synthesis.

The organs of different vegetables, as far as they have been examined, differ as much in their composition, as in their external properties, so that it is impossible to speak with accuracy in any but general terms, of the nature of the substances that compose them.

1. The SOLID PARTS OF PLANTS. The *epidermis* of plants in general, appears to be in a great measure formed of extract and woody fibre, combined with different earths and oxides of iron.

The *parenchyma* and *cortical layers* in plants, very often contain tannin, gallic acid, mucilage, sugar, and resin.

The *wood* of plants, which is chiefly formed of woody fibre, likewise contains tannin, resin, mucilage, and gallic acid.

The composition of *flowers* is very little known. The pollen in them is composed of a very inflammable substance. Many of the *fruits* and *grains* contain large quantities of fecula, of sugar, and of different acids, always combined with water and woody fibre, and in certain instances with gluten.

The *soft matter* of the *leaves* of plants often contains extract and mucilage, and sometimes albumen. The *external surface* of leaves is sometimes thinly covered with wax.

2. The FLUID PARTS. The *sap* in plants is chiefly water holding in solution different salts and acids, with a little sugar and mucilage.

The *other juices* contained in the vessels of plants, are very various in their composition. Amongst them may be found oils combined with mucilage, and colouring, and aromatic matters, and other peculiar fluids, capable of forming gum, resin, and other substances of the same kind, when exposed to the air.

### 5. *Fourth Class.*

The chemistry of animal substances is as yet in its infancy, and the only instrument it can employ is imperfect analysis. The animal organs in the only state in which they can become the subjects of experiments, even in the dead state, are constantly undergoing changes which cannot be accurately estimated; and consequently the account that can be given of their composition must be considered as more or less general, vague, and uncertain.

The more compounded substances which enter into their composition, and which are capable of being chemically examined, are either solids or fluids. Amongst the solids may be enumerated skin, muscular fibre, the matter of fat, the soft matter composing the nerves, membrane, cartilage, and bony matter. The principal fluids are, blood, chyle, bile, milk, the gastric and pancreatic juices, and the saliva.

These bodies, as far as they have been analysed, by reagents, and by heat, appear to consist in general of different proportions of the substances described in Div. IV. Sect. 4. and 6. combined, in unknown arrangements, and in general in organized forms, with water, mucilage, and different earths, and salts.

1. The SOLID PARTS. In the skin, the epidermis appears to consist chiefly of albumen, gelatine, and phosphate of lime; and the cutis of gelatine, and fibrine, with a very little albumen.

The *muscular fibre* is almost wholly composed of fibrine, combined with gelatine, albumen, and probably certain neutral salts.

The *matter of fat* is chiefly composed of *pure* fat, and the sebacic acid. In the state in which it is found in animals, it is soft, and is possessed of no regular organized appearance.

The *soft matter* composing the nerves has been very little examined. In some of its properties it is analogous to albumen; but there is every reason to believe that its composition is extremely complicated.

*Membrane* and *cartilage* are chiefly composed of gelatine and albumen, with a minute quantity of phosphate of lime.

*Bony matter* is chiefly composed of phosphate of lime combined with gelatine, and sometimes with a little carbonate of lime and albumen.

2. ANIMAL FLUIDS. *Blood* is found in two states, as arterial blood, which is of a bright vermilion colour; and as venous blood, which is of a dark red colour. The principal constituent parts of these two fluids are nearly the same; and they both, as soon as they are taken out of the living vessels, separate into two distinct parts, one of which is solid, the coagulum; and the other fluid, the serum. The coagulum consists of fibrine, and of colouring particles; of which the colouring particles are composed of water, albumen, gelatine, phosphate of iron, and soda. The serum is composed of albumen, gelatine, and certain neutral salts, held in solution by water. The red particles in the arterial blood appear to contain more oxygene than those in the venous blood; and this is probably one of the essential causes of the difference between the two fluids.

The composition of *chyle* is very little known. There is every reason to believe that its constituent principles are analogous to those of blood; and the theory of the conversion of chyle into blood is a most interesting subject for physiological investigation.

*Bile* is chiefly composed of animal oil combined with soda, and held in solution by water. It contains, likewise, albumen, and small portions of different compound salts.

*Milk* may be separated, by very simple processes, into three distinct parts, the serum, the coagulum or the caseous part, and the oily part or butter. The serum appears to be composed chiefly of water, holding in solution mucilage, sugar, and different salts. The caseous matter approaches near to albumen in its chemical properties; and the oily matter or butter, seems to consist chiefly of a pure oil, probably combined with a small quantity of mucilage and saccharine matter.

The chemical composition of the *gastric* and *pancreatic juices* is very little known.

The *saliva* appears to be chiefly composed of water, holding in solution mucilage, albumen, and minute portions of neutral salts.

## DIVISION VI.

### GENERAL PHENOMENA OF CHEMICAL ACTION.

#### 1. *Classification.*

The phenomena connected with the composition and the decomposition of the compound bodies, described in the three last divisions, are capable of being generalized; and as far as they relate to the chemistry of ponderable substances, they may be explained by the propositions concerning the laws of attraction mentioned in Div. I. Sect. 5.

All chemical action, which can be considered as resulting from the primary powers of ponderable substances, may be divided into four kinds. I. Simple combination. II. Compound combination. III. Simple decomposition. IV. Complex decomposition.

## 2. *Simple Combination.*

1. Whenever two simple bodies enter into union, their attraction is mutual, and they appear to act upon each other with different forces. In considering these forces, they will be found to depend, not only upon the difference between the primary affinities of the substances for each other, but likewise upon the difference of their masses, that is, upon the number of different particles brought into the sphere of activity. Div. I. Prop. 1. and 4.

Instances of these expressions of facts may be found in the binary combinations of simple principles, Division III. Thus in the different oxides of iron, the oxygene is condensed in the solid form; and it adheres to the iron with a force so much greater, in proportion as the iron is less saturated with it.

2. When three or more simple bodies combine, so as to form one compound, their forces of attraction depend upon similar causes. They may all possess different affinities for each other, or their affinities may be intermediate; and the numbers of the particles of each in the sphere of activity may be different. In cases of ternary and quaternary combination, &c. the conditions are very complicated; and they can only be estimated accurately, by a comparison of the forces exerted by the different substances, considered as to their simplest, or binary attractions for each other. For instances of ternary and quaternary combination, &c. see Div. IV.

3. When two simple principles, possessed of no affinity for each other, act upon a third simple principle with different forces, two compounds are generally formed; and the simple principle acted upon is divided according to the masses of the acting bodies, and the different force of their affinities.

Thus when different masses of potash and of soda are mingled and made to act upon a small quantity of muriatic acid, much muriate of potash, and a small quantity of muriate of soda will be formed, though either of the quantities of alkali would have been sufficient for the saturation of the acid, and though the affinity of potash for it is very much greater than that of soda.

4. All chemical action is connected with change of volume and change of temperature Div. I. Prop. [6]. This circumstance it is necessary to attend to minutely, in judging of the efficacy of combining forces. For as the affinities of substances for each other, are modified by their temperature, Div. I. Prop. [5] it follows, that in all cases of combination, the primary combining forces must be perpetually undergoing alteration, in consequence of the increase or diminution of the temperatures of the substances acted upon.

## 3. *Of Compound Combination.*

1. The affinity of one body A, for another B, is not destroyed by its combination with a third C, but only modified; either by condensation or expansion, or by the affinity of B for C. This is an application of the observation mentioned in the last Section, [3] relating to the combination of more than two bodies. When we reason accurately upon it, we must resolve the affinity of compound bodies for each other, into the affinities of their simple constituent principles; and we must account for the peculiar circumstances of their combination from the modified forces exerted by these affinities. Thus, in the combination of sulphuric acid and ammoniac, five simple affinities may be supposed to exist. 1. That of oxygene for sulphur. 2. That of oxygene for hydrogene. 3. That of sulphur for hydrogene. 4. That of nitrogene for hydrogene, and 5. That of nitrogene for oxygene. The result of the modification of these affinities by each other, is that equilibrium of attracting forces, by which sulphate of ammoniac is produced. See Div. I. Prop. [1] and all the observations in the last section.

2. The modes in which compound affinity is exerted, are extremely various. In considering them, it is necessary to attend minutely to the elasticity and cohesion of the different acting principles, and to consider how far these properties are capable of modifying the force of combination.

3. Amongst the cases of compound combination, some of the most remarkable are those produced by what is called predisposing affinity. Such cases, and various other analogous cases, occur in the formation of the substances mentioned in Div. V.

## 4. *Simple Decomposition.*

1. When a simple substance acts upon a compound body, and combines with one or more of its constituents; leaving the other constituent or constituents apparently unaltered, it is said to act by a simple affinity. Thus, Charcoal when ignited, and placed in contact with oxide of copper, is said to combine with its oxygene, in consequence of its simple affinity for it; so that carbonic acid and gaseous oxide of carbon, are formed, and the copper remains free. Div. I. Prop. 2.

2. It seldom, however, happens, that any perfect decomposition of a compound body is effected by the affinity of a simple substance alone. For, according to the observation mentioned in Section 2. 3. the body in combination is acted upon by two forces of different degrees of power; and though a new compound is formed, yet the old compound is not perfectly destroyed; and the principle acted upon, is divided between the acting bodies, according to the force of attraction resulting from their primary affinities, and their masses. Thus, when mercury acts upon heated sulphuric acid, two new compounds are formed, oxide of mercury at its minimum of oxidation, and sulphureous acid; i.e. the oxygene is divided between the sulphur and the mercury, according to their respective attracting forces.

3. In all cases, in which complete decomposition *appears*

to take place from simple affinity, it generally happens that other powers are brought into action; such as a considerable increase or diminution of the force of cohesion in the particles of the body acted upon, which, by altering according to circumstances its powers of remaining in its primary compound, dispose it either to become free, or to combine with the new agent. Div. I. Prop. 5. and 6. and Div. VI. Sec. 2. 4. Thus a complete decomposition of the white oxide of mercury is produced by the agency of ignited charcoal. But the heat applied in this process, acts as much as the charcoal in producing the decomposition: for heat alone is capable of expelling oxygene gas from the white oxide of mercury.

4. To determine the elective affinity of two substances for a third, it is necessary to determine in what proportion, as equal masses, they are saturated respectively by equal quantities of the third body. For their affinities are inversely as their saturation. From the constant exertion, however, of the fifth law of attraction, by which the elasticity and force of cohesion of the particles of different bodies are perpetually varying in different ratios during chemical action, it is almost impossible to determine with perfect accuracy their relative forces of attraction for other bodies. And the tables of elective affinities laid down in various books, must be considered as presenting useful rather than accurate approximations to the true nature of relative affinity.

### 5. *Complex Decomposition.*

1. The forces by which a new arrangement of the principles of two or more compounded bodies is produced, are usually said to be exerted by complex affinity. Thus, red sulphate of iron, and prussiate of potash are said to be converted into blue prussiate of iron, and sulphate of potash by complex affinity.

2. The same laws apply to complex decomposition as to simple decomposition, and in all cases the phenomena

must be accounted for, from the forces of affinity resulting from the masses of the acting bodies, their primary attractions, and their dispositions towards cohesion, or elasticity. Div. I. the whole of Sect. 5.

3. The phenomena of compound decomposition have been very little studied; and the instances relating to it, which have been chiefly noticed, are those of *double* affinity, derived from the mutual action of two compound salts.

### 6. *Of Crystallization.*

When, in consequence of chemical action, solid bodies are slowly produced, or evolved, they generally appear in regular polyhedral forms, i.e. as crystals.

The numerous varieties of crystallization, which immediately depend on variously modified, and complicated forces of attraction, are capable of being explained from different arrangements of six primitive forms. 1. The parallelopipedon in general. 2. The regular tetrahedron. 3. The octahedron with triangular sides. 4. The hexagonal prism. 4. The dodecahedron, bounded by rhombs. 6. The dodecahedron, bounded by isosceles triangles.

# SYLLABUS

# OF A COURSE OF LECTURES.

## PART II.

## THE CHEMISTRY OF IMPONDERABLE SUBSTANCES.

### DIVISION I.

### OF HEAT OR CALORIC.

#### 1. *Introduction.*

A numerous class of beautiful and important appearances is produced in nature, by agents, which, though very imperfectly known, are yet sufficiently distinguished by their imponderability, and other properties, from the substances considered in the first part of this syllabus.

Heat or caloric, as well as light, electricity, and galvanism, are terms representing the unknown causes of certain effects, which form an interesting part of chemical science, and which without reference to the nature of the powers by which they are produced, may be investigated and arranged as simple collections of facts.

#### 2. *Of the Effects of Heat.*

1. Heat was considered as the general power of expansion in Part I. Div. I. Its particular agencies, and the laws by which it is governed, are worthy of a minute examination.

2. The effects of those actions of heat upon living or-

gans, by which the peculiar sensations of heat and cold are produced, are well known. They are relative, and influenced by the state of the organ.

3. Bodies increase in volume when heat is added to them, and diminish in volume when it is subtracted from them. The exceptions to this law are very few. Different bodies, and even the same bodies, when differently heated, expand in different ratios, by the additions of equal quantities of heat. In general gases are more expansible by heat than fluids, and fluids than solids.

4. The more powerful agencies of heat upon bodies, are often connected with changes in their forms of aggregation. Solids by a certain increase of heat are converted into fluids, and fluids into gases. Also by a subtraction of heat, gases become fluids, and fluids solids.

5. It was formerly supposed that the absolute weights of bodies were diminished by heat, but some delicate experiments lately made have proved that this opinion is erroneous.

6. Heat is possessed of most extensive powers in producing chemical combinations, and decompositions. For as it expands different bodies in different ratios, so it likewise diminishes in different ratios the attractions of their particles for each other. See Part I. Div. I. and VI.

### 3. *Of Radiant Heat.*

1. Heat, when existing in the radiant state, moves through space with a velocity almost inconceivable. Like light, it is capable of being reflected, and refracted. And its rays, as would appear from the valuable discoveries of Dr. Herschel, are of different degrees of refrangibility, being for the most part, less refrangible than those of light.

2. When radiant heat falls upon the surface of an opaque body, it is never wholly reflected. Portions of it are absorbed by the body, which become common heat of temperature or free caloric. The powers of absorbing radiant heat, appear to be different in different bodies, and they

are, in some measure, connected with their peculiar colours.

3. The radiant heat emitted from the sun is uniformly combined, or mixed with light; but these agents are capable of being separated to a certain extent by the prism. And, as the experiments of Professor Pictet have proved, the radiation of heat from bodies, on the surface of the earth, is apparently perfectly independent of the presence of light.

### 4. *Of Temperature, Capacity for Heat, &c.*

1. The *temperatures* of bodies are said to be high, or low, in proportion as they are capable of communicating, or receiving heat.

2. And their *capacities for heat*, are considered as great, or small, in proportion as their temperatures are less or more raised by the addition, or diminished by the subtraction of equal quantities of heat.

3. Bodies, in changing their states of existence, have their capacities uniformly changed. And in this case, they absorb or give out that heat, which, in consequence of its peculiar relation to the heat of temperature, is called *latent heat*, or caloric of combination.

### 5. *Of the Communication of Heat.*

1. When many bodies of different temperatures, and in different forms of aggregation, are brought into contact, they all, after a certain time, whatever change they may have undergone, acquire a common temperature; though their heat is communicated, or received in different manners, and with different degrees of celerity.

2. *Solids* are the only perfect conductors of heat, for they are the only substances through which heat is communicated from particle to particle, till the mass or system of bodies, becomes of the same temperature.

3. *Fluid* and *aëriform* substances, strictly speaking, are either perfect or nearly perfect nonconductors of heat.

For, according to the important discoveries of Count Rumford, though their particles are capable of receiving heat from other bodies, or of communicating it to them, yet, amongst those particles themselves, all communication of heat appears impossible. And masses of fluids are heated, or cooled, only in consequence, of changes in the specific gravities of their particles, by which they are carried in succession to the heating, or cooling body.

### 6. *Of the Artificial Production of Heat, and of Cold.*

1. Whenever, during chemical combination, the capacities of bodies are diminished, their temperatures are uniformly increased; and vice versa, when their capacities are increased, their temperatures are diminished. See Part I. Div. I. Sect. 5.

2. The chemical changes which are connected with the production of the greatest quantities of radiant heat, and of heat of temperature are, 1. The absorption of oxygene gas by phosphorus, charcoal, hydrogene, iron, &c. 2. The deflagration of combustible bodies by means of nitrate, or oxygenated muriate, of potash. 3. The combination of the alkalies with the acids. 4. The combination of sulphur with certain of the metals.

3. One of the greatest diminutions of temperature, producible by chemical change, is that which takes place from the action of muriate of lime, or of nitrate of ammoniac, or of potash, upon snow.

4. Heat is capable of being excited by mechanical means. Whenever hard solid bodies are violently struck together, their temperatures are uniformly raised. Likewise an increase of temperature is produced by the friction of solids; and that, as it would appear from the valuable experiments of Count Rumford, under circumstances, when these substances are incapable of undergoing either a chemical change, or a change of capacity.

### 7. *Theories concerning the Nature of Heat.*

1. Two theories concerning the nature of heat, have been most prevalent amongst philosophers. 1. It has been supposed to be a peculiar ethereal fluid. 2. It has been conjectured to be a property of common matter; a specific motion of the particles of bodies.

2. The arguments in favour of the first of these theories, have been chiefly deduced from the phenomena of latent heat, of radiant heat, and of change of capacity; whilst the last of them has been supported by experiments on the excitation of heat by friction, in cases in which there existed no perceptible source, from which, considered as a substance, it could possibly be derived.

3. The late experiments of Dr. Herschel have demonstrated, that radiant heat must be constituted by the motions of a peculiar substance. And these motions may be conceived to be either rectilinear projections, or undulations.

4. It has been lately supposed that they are undulations. And on this theory it has been assumed, 1. That an elastic ethereal medium exists in space. 2. That this medium is diffused through the pores of different ponderable substances, in different states of density. 3. That radiant heat is constituted by particular undulations of it, when in a free state. 4. That sensible heat is occasioned by particular undulations of it, in its states of diffusion through the pores of ponderable substances. 5. That certain peculiar vibratory motions of the particles of ponderable substances are capable of producing the undulations in the ethereal medium which constitute heat. 6. And reciprocally that those undulatory motions of the ethereal medium are capable of producing peculiar vibrations of the particles of ponderable substances.

5. These propositions are evidently countenanced by the experiments of Count Rumford, and Professor Pictet, on the heat produced by friction. They are rendered more conclusive by the analogy between the laws of the motions

of radiant heat, and those of sound. And they in some measure, reconcile the two different theories.

8. *Of the Instruments used in Experiments upon Heat.*

1. Thermometers and pyrometers are instruments for measuring the temperatures of bodies.

2. *Thermometers* are used for ascertaining degrees of temperature, which are generally not much higher or lower than those of the atmosphere. They are formed on the principle of the expansion of bodies by heat: and such substances are employed in them, as expand most uniformly by successive equal increments of heat. The common thermometers with mercury and alcohol are well known.—As thermometers in all cases, act only as substances giving, or receiving heat, the quantity of fluid they contain, should, in all cases be very small: for, in proportion as it is small, so in proportion will the thermometrical expansions or contractions more accurately denote the real temperature of the body experimented upon.

3. *Pyrometers* are employed for measuring very high temperatures. They are usually formed of baked clay, a substance which, differing from almost all other bodies, contracts in volume by heat. The contractions of the pyrometer are considered as the measure of its temperature; and they are apparently great, in proportion as the temperatures to which it is exposed are high.

4. The *calorimeter* is an instrument that has been used for the purpose of ascertaining the relative capacity of bodies for heat. It is founded upon the principle, that ice, during its conversion into water, absorbs uniformly, the same quantities of heat: and it is composed of a tin vessel filled with ice, and surrounded by ice. In this vessel, the substance experimented upon is placed: and its capacity is supposed to be directly as the quantity of ice, which, when of a given temperature it is capable of converting into water.

### 9. *Agency of Heat in Nature.*

Upon the various operations of the radiant heat of the sun absorbed, or rendered sensible in bodies, almost all the phenomena which are the subjects of *meteorological science* depend: evaporation, the solution of water in air, and its precipitation from the atmosphere, the existence of rivers, the fluidity and solidification of water, &c.

By this agent likewise are most of the new combinations, and decompositions, of substances produced, by which they are rendered capable of organization, and of becoming parts of living beings.

From the chemical generation of heat in animal bodies, during respiration, and other changes, the organs are preserved in those states of temperature, which are necessary to the exertion of the vital functions.

In short, the agency of heat in nature is almost universal; and it either primarily occasions, or materially influences, all the different changes that take place upon our globe.

## DIVISION II.

## OF LIGHT.

### 1. *Effects of Light.*

*Light* is known to us as the cause of a numerous class of sensations. It is possessed of powerful chemical agencies. One of its most common effects is the expulsion of oxygene in the state of gas from bodies with which it is loosely combined. Thus, it decomposes the nitric and oxygenated muriatic acids, and blackens the salts containing oxide of silver.

### 2. *Laws of Light.*

Light moves through space at the rate of 200000 miles in a second. It is reflected from certain opaque bodies.

In passing through transparent bodies it is refracted; and its rays are of different degrees of refrangibility. They are separated when passed through the prism, into seven species, red, orange, yellow, green, blue, indigo, violet. The laws of light in their relation to vision, constitute the subject of *optics*.

### 3. *Of the artificial Production of Light.*

1. Light is produced during a number of chemical operations. 1. By the union of oxygene gas, and of oxygene in particular states of combination, with certain combustible bodies. 2. By the action of the mineral acids on the fixed alkaline substances. 3. By the combination of sulphur with the metals. 4. By the action of sulphuric acid upon the moistened oxygenated muriates.

2. All solid, and fluid substances become luminous, when heated to a temperature corresponding to about 850°.

3. Certain bodies, called solar phosphori, after having been exposed to light, exhibit a luminous appearance in the dark; and this appearance is rendered more vivid by increase of their temperature. By a high degree of heat indeed, it is at length destroyed; but it is capable of being restored by a second exposure to light.

4. Light is produced during the collision of different bodies, but this phenomenon is probably in general either dependent on combustion, or on the excitation of electricity.

### 4. *Opinions concerning the Nature of Light.*

1. Two opinions have been formed concerning the nature of light, in its visible state. 1. It has been supposed to be produced by the rectilinear rapid motions of the minute particles of a peculiar substance. 2. It has been considered as the undulatory motion of an elastic ethereal medium extended through space.

2. The first of these opinions has been for a long while most prevalent; and, indeed, even now, it is generally

adopted. The last of them, however, has been lately supported by some important arguments deduced by Dr. Young, from the analogy between the laws of known undulatory motions, and those of light.

3. Though the phenomena of the reflection and refraction of light are very analogous to those of radiant heat; and though these bodies are usually present at the same time, yet the distinctness between their physical, as well as their chemical powers of action is sufficient to induce us to believe that they are perfectly different agents.—The heat, and light in the solar spectrum produce perfectly different effects: for if muriate of silver be exposed to the differently refracted rays, it is found that the invisible heat-making rays produce no effect upon it; its colour is altered by the violet rays in about $\frac{1}{80}$ part of the time in which it is changed by the red; and, what is very curious, it is likewise acted upon in the space beyond the violet rays. This circumstance has been noticed by Messrs. Ritter and Böckmann, and by Dr. Wollaston. It would appear from it, that invisible rays exist, which, though possessed of chemical agencies, and of the highest degree of refrangibility, are, nevertheless, incapable of producing heat,

### 5. *Of the Photometer.*

The photometer is an instrument for measuring the intensity of light. Photometers have been generally constructed on the supposition that the intensity of light is proportional to its power of heating bodies, or to its power of producing chemical changes in them. This supposition is, however, contradicted by all the late experiments on the solar spectrum: and, in consequence, the ingenious instruments, to the invention of which it has given rise, are rendered useless, as to their primary purpose.

For measuring the relative intensities of the light emitted by two different bodies in combustion, a very simple and useful photometer has been invented by Count Rumford; and it is founded upon the principle, that the power of a burning body to illuminate any defined space, is directly as the intensity of the light, and inversely as the squares of the distance.

### 6. *Agencies of Light in Nature.*

1. The action of solar light upon living vegetables, is in most cases connected with the production of oxygene gas; a circumstance, probably intimately related to the uniformity of the constitution of our atmosphere; from which oxygene is constantly absorbed, by the respiration of animals, combustion, and other causes.

2. Light is possessed of a decided influence in modifying many natural phenomena. The crystallization of salts is materially affected by its agency. It is capable of altering most of the colours of bodies. And it is perpetually producing numerous decompositions, and new combinations upon every part of the surface of the globe.

3. Light is possessed of great powers of action upon organized beings. The colours of the leaves of vegetables, and of their flowers, are almost wholly dependent upon it: and vegetables are incapable of existing for any great length of time, when deprived of its benign influence.

## DIVISION III.

## OF THE ELECTRICAL INFLUENCE.

### 1. *Effects of Electricity.*

1. Electricity in its different states of accumulation produces different effects. In general, its presence is denoted in substances, by their powers of attracting, or repelling, under different circumstances, light bodies. Electricity often appears in the form of light; and, in this state, it is capable of igniting bodies, and of inflaming such of them as are combustible. It occasions vivid sensations, called elec-

trical shocks, in passing through living bodies. It is sensible to the organs of taste and smell.

2. Electricity is possessed of very powerful chemical agencies. It is capable of producing a number of combinations, and of decompositions; and some of its effects are analogous to those produced by very intense degrees of heat.

3. Nitric acid is formed from oxygene gas and nitrogene gas, by means of electricity. Water is converted by it into oxygene and hydrogene. And ammoniac is decomposed into nitrogene and hydrogene.

### 2. *Of the Conductors and Nonconductors of Electricity, and of their different States with regard to Electricity.*

Amongst the conductors of electricity are the metals, charcoal, the fluid acids, water, and moist animal and vegetable substances. Amongst the nonconductors are glass, resin, wax, sulphur, phosphorus, oils, dry gases, and all the solid compounds containing earths only, or alkaline substances.

Bodies when actively electrified, are either in the positive, or the negative state. When in the positive state, they are supposed, in the common theory, to contain more than their natural quantity of electrical influence, and when in the negative state less.

The processes by which the equilibrium of electricity in bodies is destroyed and restored, the effects connected with these processes, and their relations to the general properties of matter, are capable of being explained upon mathematical principles, and they are considered as constituting the *general science of electricity.*

### 3. *Of the Excitation of Electricity.*

1. One of the most simple modes of exciting electricity, is by the friction of two nonconductors, or of a nonconductor and a conductor.

2. When a glass cylinder, or a circular plate of glass, mounted upon a nonconducting stand, is made to revolve

upon its axis, so as to rub against cushions of leather covered with an amalgam of mercury and zinc, the electrical equilibrium is destroyed. The cushions, and the conductors in contact with them, become negatively electrified; and a conductor placed near any part of the glass, which is not in contact with the cushion, becomes positively electrified.

3. When globes, or cakes of resin are used in the same manner, electricity is likewise excited; but in this case, the cushions and their conductors become positively, and the other conductors or the prime conductors negatively, electrified.

4. Electricity is excited in certain nonconducting bodies, merely by changes in their states of temperature. The topaz of Brazil, and the tourmaline, become electrical whenever they are gently heated; and sulphur and sealing wax when cooled after having been melted, are found strongly electrified.

5. Indeed, whenever bodies change their forms of aggregation, whether from the agency of heat, or other causes, there is every reason to believe, that their states, with regard to electricity, are changed. Water, during its conversion into vapour, appears to absorb much electricity from the bodies in contact with it, so that they become negatively electrified. And during the condensation of aqueous vapour, electricity is evolved.

6. Electricity is capable of being excited by the action of different conducting substances on each other; but the modes of this excitation, and its general connexion with chemical changes, constitute a science which has been hitherto distinguished from common electricity, by the name of *galvanism*, and which will be immediately considered.

## 4. *Theories concerning Electricity.*

Electricity has been supposed to depend upon the agencies of two particular substances, which have been called, from the modes of their excitation, vitreous, and resinous electricity. It has likewise been supposed to owe its existence to the agencies of one specific body. The last of these theories has been lately generally adopted by the greater number of philosophers. It has been elucidated by the investigations of Dr. Franklin, Mr. Æpinus, and Mr. Cavendish: and it is adequate to the solution of all the phenomena.

In this theory, the different electrical appearances are accounted for from the following suppositions.

1. The particles of the electrical fluid repel each other with a force diminishing as their distances increase. 2. They attract particles in all other bodies, with forces increasing as the distances decrease; and the attraction is mutual. 3. They move through the pores of conductors with perfect ease, and with great velocity; but they either move with great difficulty, or they are altogether incapable of moving through the pores of nonconductors. 4. They are capable of being transferred from the pores of one body to those of other bodies; so as to exist in states of accumulation, and of deficiency.

### 5. *Of Electrical Instruments.*

1. The Leyden phial is a glass vessel, partially coated on its internal and external surfaces with tinfoil, or other conducting substances. It is charged by electrifying one of its surfaces positively, at the same time that the other surface is connected with the ground, by which it is enabled to become negatively electrified. It is discharged by connecting, by means of a conductor, its positively and negatively electrified surfaces; when the equilibrium is restored.

2. The electrophorus is composed of a nonconducting plate, which is generally of resin, attached to the upper surface of a conductor, and of a conducting plate having a nonconducting handle. After the nonconducting plate has been once excited, its under surface being connected with the ground; the conducting plate, as often as it is laid upon it and brought in contact for a moment with another conductor, will so often be capable of furnishing a

spark, after having been removed from it, by the nonconducting handle.

3. Bennet's electrometer is composed of two gold leaves, attached to a conducting plate, and enclosed in a tube of glass. It is used for ascertaining the presence of small quantities of electricity in bodies; which are denoted by the separation of the leaves.

4. The condenser, the doubler, and the multiplier, are instruments generally employed for the purpose of rendering sensible, by means of the electrometer, quantities of electricity immediately imperceptible.

### 6. *Agency of Electricity in Nature.*

Electricity appears to act an important part in most of the natural operations that take place upon the surface of our globe, and in the atmosphere. Lightning, thunder, the aurora borealis, and many other phenomena of meteorology, are caused immediately by this powerful agent.

By the extensive action of electricity various changes in living and dead matter are perpetually produced. It occasions, or accelerates, in many instances, the phenomena of fermentation, of putrefaction, and of the general decomposition of organized compounds.

## DIVISION IV.

### OF GALVANISM.

### 1. *Of the Nature of Galvanism.*

Galvanism relates to the peculiar chemical and electrical phenomena, which are occasioned by the contact of different conductors of electricity.

This science, though yet in its infancy, is composed of a number of important facts. Its relations are very extensive, and it furnishes powerful and novel instruments of chemical and physiological investigation.

## 2. *Of the Construction of the least complicated Galvanic Arrangements, i. e. Simple Circles.*

1. The conductors of electricity, which by their mutual agencies, are capable of producing galvanic appearances may be divided into two classes. 1. Perfect conductors, which are either metals or charcoal. 2. Imperfect conductors, which are either oxidated fluids, or substances containing such fluids.

2. For the composition of a simple galvanic circle, at least two conductors of one class, and one of another class are required. And they must be so disposed that the conductors of the one class may be in contact with each other in one or more points, at the same time that they are connected in other distinct points with the conductor of the other class. Thus, if plates of zinc and gold be made to touch each other in one point, and be connected together in other points, by a portion of common water, or diluted muriatic acid, a simple galvanic circle is formed. A simple galvanic circle is likewise formed when separate portions of water, and solution of hydrogenated sulphuret of potash are connected together in one point, and brought in contact in other points with a piece of silver.

3. Every arrangement, however, of two conductors of one class with one of the other, is not an acting galvanic circle. For the production of galvanic effects, it is necessary, that the fluid part or parts of the circle should be capable of acting chemically upon the solid part or parts of the circle. The most powerful circles are those in which two different chemical actions are exerted in different parts of the arrangement; and in every acting circle there is at least one point, in which oxidation, or some other chemical change is taking place.

The following tables, in which some different simple circles are arranged in the order of their powers, will show how intimately primary chemical changes are connected with the production of galvanism.

TABLE OF SOME GALVANIC CIRCLES,

*Composed of two perfect Conductors and one imperfect Conductor.*

| More oxidable substances. | Less oxidable substances. | Oxidating fluids. |
|---|---|---|
| Zinc. | With gold, charcoal, silver, copper, tin, iron, mercury. | Solutions of nitric acid in water, of muriatic acid and sulphuric acid, &c. Water holding in solution oxygene, atmospheric air, &c. |
| Iron. | .... gold, charcoal, silver, copper, tin. | |
| Tin. | .... gold, silver, charcoal. | |
| Lead. | .... gold, silver. | |
| Copper. | .... gold, silver. | Solution of nitrate of silver and mercury. Nitric acid, acetous acid. |
| Silver. | .... gold. | Nitric acid. |

TABLE OF SOME GALVANIC CIRCLES,

*Composed of two imperfect Conductors and one perfect Conductor.*

| Perfect conductors. | Imperfect conductors. | Imperfect conductors. |
|---|---|---|
| Charcoal.<br>Copper.<br>Silver.<br>Lead.<br>Tin.<br>Iron.<br>Zinc. | Solutions of hydrogenated alkaline sulphurets, capable of acting on the first three metals, but not on the last three. | Solutions of nitrous acid, oxygenated muriatic acid, &c. capable of acting on all the metals. |

### 3. *Of the Agencies of single Galvanic Circles.*

The galvanic influence is manifested in single circles, either by its power of acting upon living animal organs, or by its chemical agencies.

1. When the tongue is made part of a simple galvanic circle, an acid taste is perceived, and when the eye is connected with it, a flash of light is produced.

2. When the galvanic agency is made to act on a muscle,

and the nerve attached to it, which have been just separated from the body of a living animal, muscular contractions are uniformly produced.

3. In all the single galvanic circles, the primary chemical actions are increased, and to a certain extent modified. Thus, when zinc, which oxidates slowly when exposed to the atmosphere in contact with water, is made to form a galvanic circle with that fluid and silver, it oxidates rapidly; and an alkali appears to be formed in the water at its points of contact with the silver. Likewise, when iron and silver form a circle with diluted muriatic acid, the action of the acid upon the iron is increased; and hydrogene gas is not only evolved from the water in contact with the iron, but likewise from that in contact with the silver.

### 4. *Of Compound Galvanic Circles or Galvanic Batteries.*

1. Galvanic batteries are composed by series of the substances which form simple circles; and these substances are arranged in such a manner, that the conductors of the same class in every series are in contact with each other in one point or more, at the same time that they are respectively connected with different conductors of the other class, so that a regular alternation is observed; the order being, conductor of the one class, conductor of the one class, conductor of the other class, and so on. Thus, if plates of zinc and of silver, and pieces of cloth of the size of the plates, moistened in water, be arranged in the order of zinc, silver, cloth; zinc, silver, cloth, and so on, till twenty series are connected together, the galvanic battery of Volta will be formed. Likewise a galvanic battery will be formed if pieces of tin, iron, or charcoal, be introduced into glasses filled some with water, and some with nitric acid, and connected in pairs by siphons, in the order of metal, or charcoal, acid, water; metal, or charcoal, acid, water, and so on, till twenty series are constructed.

2. The substances most active in the simple circles are likewise most active in the compound circles. And in all

cases, the relative quantities of galvanic power exhibited by equal numbers of different series, are in some measure proportional to the intensity of the peculiar primary chemical agencies, exerted by the different conductors composing them, on each other. The tables of the simple circles will indicate, with the necessary changes of arrangement, the powers of such compound circles as are composed of similar parts.

### 5. *Of the Agencies of Galvanic Batteries.*

1. The galvanic influence in its accumulated state in compound circles, produces very singular physical and chemical effects, and exhibits many of the appearances of common electricity.

2. It produces shocks, when made to act upon the human body, which are very analogous to those occasioned by the electrical battery.

3. It passes through air and certain other nonconductors in the form of sparks; and in this state it is capable of burning charcoal, and metallic bodies, when they are in contact with the atmosphere; and likewise of inflaming mixtures of oxygene gas and hydrogene gas.

4. It affects the electrometer; and is capable of communicating weak charges to the condenser, and Leyden phial.

5. In passing through common water from perfect conductors, it effects chemical changes very analogous to those taking place in the different primary series, in which it was excited; producing in its positive state, oxygene and an acid; and in its negative state, hydrogene and an alkali.

### 6. *General Observations on Galvanic Circles.*

1. Provided those points of contact, in both the simple and compound galvanic circles, in which the chemical agencies of the different conductors on each other are more particularly exerted, remain permanent, the parts of

the series, which do not immediately act chemically on each other, may be connected together by means of conductors of their own class, without any other change in the agencies of the circle than a diminution of their intensity. This diminution, with regard to perfect conductors, is barely perceptible; though in the case of imperfect conductors it is evidently, in some measure, correspondent to the increase of the length, or, what is apparently equivalent, the diminution of the surface of the chain that they compose.

2. The agency of the galvanic influence which occasions chemical changes in water, and communicates shocks to the living body, is probably, in some measure, distinct from that agency which produces sparks, and the combustion of bodies. The one appears, all other circumstances being similar, to have little relation to surface in compound circles; but to be great in some unknown proportion as the series are numerous. The intensity of the other seems to be as much connected with the extension of the surfaces of the series, as with their number.

3. A measure of the intensity of that agency in galvanic batteries, which produces chemical changes in water, may be derived from the quantity of gas it is capable of evolving in a given time; or from the length of the fluid chain through which it can be transmitted. The comparative forces of different batteries may be determined by connecting them in an order different from that of the regular alternation, so as to produce a certain annihilation of power; for in all instances when the most oxidable part of one series is connected, by means of a fluid, with the analogous part of another equal series, the galvanic powers of both are destroyed.

## 7. *Theories concerning Galvanism.*

1. The obscurity of the galvanic facts which were first noticed, and their apparent insulation, gave rise at an early period of the science, to many different theories con-

cerning galvanism. It was supposed, 1. That it was a peculiar ethereal fluid. 2. That it depended upon hydrogene, disengaged during the decomposition of water by metals. 3. That it was the electrical fluid existing in a peculiar state.

2. Since the discovery of the agencies of the accumulated galvanic influence, the last of these suppositions has been adopted by the greater number of those philosophers who have studied the subject with accuracy. Galvanism is now generally believed to be electricity; and the chief difference that prevails in theory, is with respect to the manner in which this electricity is excited.

3. M. Volta has supposed, that an electrical current is always produced by the mere contact of certain different conductors of electricity. But many of the British philosophers have denied this position; accounting for galvanism from the destruction of the equilibrium of electricity in galvanic circles, in consequence of the chemical agencies of the different bodies composing them.

### 8. *Of the Appearance of Galvanism in Animal Organs.*

1. The well known facts relating to the torpedo, electrical eel, &c. prove that galvanic electricity is capable of being excited by the agencies of living organs. These facts, compared with the phenomena of the production of muscular contractions by galvanism, lead to interesting inquiries concerning the relation of this influence to living action. The general connexion of electricity with physiology and with chemistry, which is at present involved in obscurity, is probably capable of experimental elucidation; and the knowledge of it would evidently lead to novel views of the philosophy of the imponderable substances.

# SYLLABUS

# OF A COURSE OF LECTURES.

## PART III.

## THE CHEMISTRY OF THE ARTS.

### DIVISION I.

#### OF AGRICULTURE.

#### 1. *Of the Growth of Vegetables.*

1. Vegetables derive their component principles, which have been described in Part. I. Div. V. and which are, for the most part, hydrogene, carbon, oxygene, and nitrogene, either from the atmosphere by which they are surrounded, or from the soil in which they grow.

2. They are capable of being produced from seeds; and the process of vegetation appears to depend upon the perpetual assimilation of various substances to the organs of the plant, in consequence of the exertion of their living powers, and of their chemical affinities.

#### 2. *Of the Influence of the Atmosphere on Vegetation.*

1. The atmosphere is chiefly composed of about 78 parts of nitrogene gas, 21 parts of oxygene gas, and 1 part of carbonic acid gas. But these aëriform fluids always hold in solution a considerable quantity of water; and at the surface of the earth, many vapours, and different solid and fluid bodies, are perpetually suspended in them.

2. Plants are incapable of vegetating when deprived of air. The changes they effect in the atmosphere are intimately connected with the agencies of light: for, though they evolve oxygene gas from their leaves, when exposed to the direct rays of the sun; yet, in the shade, and in darkness, they seem to absorb this principle; and at the same time to give out carbonic acid.

3. The vegetation of plants is much assisted by putrid vapours floating in the atmosphere. Air saturated with moisture is much more favourable to the process than dry air. Portions of the carbonic acid in the atmosphere, are perpetually absorbed in the light, by the fluids in the vessels of plants; and from this substance is probably derived much of the carbon they contain.

4. Oxygene gas, or oxygene in a state of loose combination, is absolutely essential to the germination of seeds. By means of it, the mucilage they contain, is probably converted into sugar; which appears to be the first food of the plant. Oxygenated muriatic acid is a substance very active in producing the evolution of germs.

### 3. *Of Soils.*

1. Alumine, silex, and carbonate of lime, mingled or combined in different quantities, and in different states of cohesion, constitute the greater portion of soils. These substances appear, however, to contribute very little immediately to the nourishment of plants; but, from the peculiar form of their mixture, they enable them to grow, so as to be exposed in the best possible manner to the influence of the atmosphere; and, at the same time, they supply them in a proper manner with water and other fluid substances, which are perpetually deposited or formed on the surface of the earth, and which are essential to their existence.

2. Almost all soils contain certain portions of decomposing vegetable matter, which, when acted upon by water, and the oxygene of the atmosphere, produce compounds, capable of being absorbed by the organs of plants, so as to

form part of their nourishment. Likewise, soils in general contain oxide of iron, and various neutral salts: and these compounds, under certain circumstances, appear to accelerate vegetation; either by their agency on the living powers of plants, or by producing such changes in other substances, as enable them to become the food of plants.

3. As different vegetables are nourished by different food, and as they require to be supplied with food in various manners, so they vegetate to the greatest advantage in different soils.

The nature of the soils, however, which different vegetables demand, must, in some measure depend upon the state of the surrounding atmosphere.

In countries where the air is dry, and where very little rain falls, the soil should be extremely retentive of moisture; and in this case, it should contain a very considerable proportion of aluminous earth.

Sandy, and silicious soils are the least tenacious and retentive of water; and of course they are extremely pernicious to vegetation in dry climates.

4. The constituent principles of soils may be easily discovered by chemical analysis; and their relative powers of absorbing and retaining moisture by means of the hygrometer.

### 4. *Of the Action of Water on Vegetables.*

1. Water is absolutely essential to the life of vegetables. It is absorbed by them in great quantities from the atmosphere, and from the soil in which they grow. It almost wholly composes the sap contained in their vessels, and contributes materially to their nourishment.

2. There is every reason to believe that the hydrogene, which in different compounds forms so considerable a portion of the organized matter of plants, is obtained in a great measure, from the decomposition of water; and the oxygene, which they evolve when exposed to the solar light, is probably derived from the same source.

3. The water absorbed by plants, not only holds in solution certain portions of carbonic acid, and of atmospheric air, but likewise often mucilage, gelatine, and other substances, the products of spontaneous vegetable and animal decomposition, which are in a state eminently adapted to become parts of living vegetables.

### 5. *Of the Influence of Heat and Light on Vegetables.*

1. A certain degree of heat is absolutely essential to the preservation of the life of plants. At temperatures much below the freezing point, the living action of their vessels is destroyed, and the fluids that they contain are frozen.

2. The greater number of plants grow and evolve new organs only during the spring and summer months. After they have produced seeds, their excitability is exhausted by the heats of autumn: and during the cold of winter those decompositions, and new combinations, which are connected with the process of vegetation, cease altogether.

3. Plants when deprived of light soon become pale coloured and unhealthy, the fluids accumulate in their vessels in more than their just proportions, and they are rendered incapable of producing seeds.

4. There is every reason to believe, that the presence of light is connected with the decomposition of water and of carbonic acid by plants; and so far, it may contribute to the formation of their solid parts. The production of resin, gum, and tannin, in the epidermis and cortical layers of plants, appears to be materially influenced by this agent.

### 6. *Of Manures.*

1. Manures are substances used for accelerating the process of vegetation; and they are either mingled with the soil, or strewed over it.

2. The most useful manures are those which immediately supply nourishment to the plant. Amongst them, are vegetable, and animal matters, that have undergone putrefac-

tion; dung of different kinds; and various substances given out as excrementitious by animals, which contain carbon, hydrogene, and oxygene, in such combinations as readily enable them, under certain circumstances, to be absorbed by plants, and to be combined with their organs.

3. The manures of secondary use are such, as without supplying immediate nourishment to plants, hasten their growth; either by rendering their common food more nutritive in consequence of their chemical agencies upon it; or by stimulating the vegetable organs, so as to enable them to act with greater energy upon this food.

Various preparations of lime, gypsum, and different neutral salts, are considered for the most part, as manures of secondary importance: and in consequence, these substances are employed with advantage in such soils as contain much slowly decomposing vegetable matter.

## 7. *Of the Cultivation of Lands.*

1. To understand the mode of procuring from a given quantity of land, the greatest possible proportion of such vegetables as are necessary for human food, the food of animals, or for other purposes connected with human wants, is the great desideratum in agriculture.

To obtain this desideratum, it is necessary to study with accuracy, the nature of the different soils which are the subjects of agricultural operations; to discover by experiments what vegetable substances they are best calculated to support; and to determine how far their nature may be modified, by successions of crops of different vegetables, or improved, by fallowing, liming, or other analogous processes.

2. The knowledge of the proper mode of cultivating the earth, is connected with almost all the physical sciences; and the phenomena of vegetation, constitute a great part of what is known concerning the philosophy of living nature. Agriculture, as it has been hitherto practised, is an art very little assisted by theory. From the modern discoveries in chemistry, there is every reason to believe, that it

is eminently susceptible of improvement; and we may venture to hope, that inquiries concerning it will become generally interesting, as they are intimately related to the well being of society.

## DIVISION II.

### OF TANNING.

#### 1. *Of the Nature of Tanning.*

1. Tanning is that art by which the skins of animals are impregnated with tannin or the tanning principle, in such a manner as to be rendered tenacious, durable, and impermeable to water.

2. The processes by which skins are tanned, are extremely various in different countries, and even in different provinces of the same country. When, however, the theory of the art is examined, they may be easily generalised, and considered under two heads. 1. The depilation and preparation of skin for tanning. 2. The impregnation of prepared skin with the tanning principle.

#### 2. *Processes of Tanning.*

1. Depilation and preparation of skin. The depilation of skins is usually effected; either by an incipient putrefaction, or by the action of lime water on the epidermis. After depilation, they are prepared for combination with tannin, in one case by the action of a very diluted solution of sulphuric acid upon them; and in the other by the agency of certain weak alkaline lixivia, formed by the action of water upon certain animal excrements.

2. Impregnation of skin with tannin. The solutions employed for impregnating skins with tannin, are made by the infusion of various barks, and other substances

in water. They are used of different degrees of strength; and in common operations, the skins are first exposed to the action of weak solutions, and are afterwards introduced into stronger ones. The time required for tanning different skins is very different, and depends in a great measure upon the quantities of tannin dissolved in the solutions employed.

### 3. *Of the Composition and Texture of Skin.*

1. The skin, as taken from the animal by mechanical means, is evidently composed of three distinct membranes. 1. The cuticle or epidermis. 2. The mucous membrane. 3. The cutis or true skin.

2. The *epidermis* is a membrane possessed of very little organization. It is formed by the union of a number of small semitransparent plates. It is composed chiefly of albumen combined with a little gelatine, and phosphate of lime. It is very little acted upon by water, but is extremely soluble in fixed alkaline solutions. See Part I. Div. IV. Sect. 4.

3. The *mucous membrane*, which is situated immediately under the epidermis, upon the true skin, is composed chiefly of nervous papillæ, and of a soft gelatinous substance, which is supposed to contain the matter that gives to the skin its peculiar colour.

4. The *cutis* or true skin, which forms by far the greatest and most important part of the skin, is a thick, firm, elastic substance, constituted by a number of fibres interwoven with each other and intersected by small blood vessels and nerves. It is composed of gelatine combined with a small portion of fibrine, albumen, and phosphate of lime. It is acted upon by boiling water, and its gelatine is dissolved. The aqueous solution of this gelatine by evaporation forms glue. See Part I. Div. V. Sect. 5.

### 4. *Of Barks and other Substances employed for forming Tanning Lixivia.*

1. In Britain, the oak bark is generally used for producing the tanning lixivium. It is stripped from the trees in spring, and is rendered dry by exposure to light and air. The tanning lixivium is formed by introducing it in small fragments, or in coarse powder, into cold water, when its soluble parts are slowly dissolved.

2. The barks of the willow, the hazel, the chesnut, the ash, the poplar, and of many other trees, are equally proper with that of the oak, for forming tanning lixivia; but in general they contain a smaller quantity of the tanning principle. In all barks, the epidermis contains the least proportion of tannin. And even in the cortical layers this substance is most abundant, in proportion as they are nearer to the woody fibre.

3. Besides tannin, the aqueous infusions of barks generally contain gallic acid, mucilage, and colouring matters. And the different proportions of these substances may be known from a chemical analysis. The quantity of tannin in any infusion may be discovered by means of solution of glue, with the gelatine of which it forms an insoluble precipitate: and after the separation of the tannin, the presence of the gallic acid is denoted, by its striking agency upon solution of red sulphate of iron.

4. Many substances have been used in tanning, which contain a much larger proportion of tanning principle than any of the common barks. Amongst them are sumach, aleppo galls, and common galls.

### 5. *Of the Theory of Tanning.*

1. The depilation of skins by lime water, appears to be simply owing to the action of the lime upon the albumen of the epidermis, by which, its texture is destroyed in such a

manner, that the hairs can easily be separated from the mucous membrane and the skin.

2. The chief use of the preparatory weak alkaline lixivium is probably to free the skin from fat, oil, and other matters insoluble in water, and incapable of combining with tannin; and these purposes are effected by means of its free alkali, which forms with such matters in general soluble soaps.

3. The prepared skin is tanned in the infusions of bark, probably, in consequence of the combination of its gelatine and albumen in their organized form with the tanning principle, in such a manner, and so slowly, that the primitive shape and fibrous texture of the skin are preserved, at the same time that it becomes insoluble in water, and gains a different appearance and new strength. Whether the gallic acid, and colouring matter of bark, are of any use in tanning, has not been yet ascertained. The gallic acid, by its action upon water, increases the solubility of tannin; but it is not apparently altered during the conversion of skin into leather.

### 6. *Of Improvements which may probably be made in the Processes of Tanning.*

1. The lixivia of bark employed in this country are in general extremely weak, and in consequence the operation of tanning is performed only in a great length of time. Much expense and labour may probably be saved by the use of stronger lixivia, according to the method adopted in France by M. Seguin. These lixivia, however, as in the common practice, should contain different quantities of tannin; and that in which the skin is last immersed, for the completion of the process, should be uniformly the strongest.

2. The tanning principle may be easily obtained in a solid form, and nearly in a pure state, by evaporation of the strongest infusions of barks: and in such a form it might be easily made an article of commerce, so as to be

imported into Europe from those newly discovered countries in which forests abound, and in which they impede so materially the progress of cultivation.

3. From some experiments lately made, it is probable that certain vegetables which do not originally give out tannin to water, may be made to evolve, or produce that principle in its soluble state, by particular chemical operations. This discovery, if it be confirmed by new facts, will admit of very important and extensive applications.

## DIVISION III.

### OF BLEACHING.

#### 1. *Of the Bleaching of Wool, and Silk.*

1. Wool is generally bleached by the action of weak ammoniacal solutions, and of sulphureous acid. It is first immersed in the ammoniacal solution, which combines with the oil, or grease diffused over its surface. It is then washed, and exposed to the agency of sulphureous acid, which is sometimes employed in the liquid, but oftener in the aëriform state. By means of this substance the colouring matters combined with it are speedily destroyed, or rendered easily soluble in water.

2. Silk, in its native state, is rendered white by immersion in a weak solution of soda, and a subsequent exposure to the action of sulphureous acid dissolved in water. The theory of the process is very little known, but it appears to be the same as that of the process for bleaching wool.

#### 2. *Of the Bleaching of Linen and Cotton.*

1. Linen, and cotton were formerly bleached by a long exposure to the action of light and air; but the modern discoveries in chemistry, have given rise to new methods, which are now almost universally adopted.

2. Oxygenated muriatic acid, destroys the greater number of vegetable colours. It was first applied to the process of bleaching, by M. Berthollet, and it is now in common use. It is prepared in manufactories by the action of sulphuric acid upon a mixture of muriate of soda and black oxide of manganese; and it is made to act upon the substances to be bleached, in the form of a weak aqueous solution.

3. The oxygenated muriates of potash, lime, &c. are indeed often preferred to the pure oxygenated muriatic acid; which sometimes alters the texture of the cloth and diminishes its strength. They are prepared by passing oxygenated muriatic acid into solution of caustic potash, or of lime, and they are employed in a very diluted state.

4. The solution of hydrogenated sulphuret of lime has been applied with considerable advantage, to certain of the processes of bleaching, by Mr. Higgins; and it may be used in common with alkaline solutions for preparing linen for the action of oxygenated substances.

5. A method of bleaching, by means of steam, has been lately proposed by M. Chaptal. It consists in the application of the vapour disengaged from a heated fixed alkaline lixivium to the substances to be acted upon; and it is said to be in many respects superior to the common process.

### 3. *Of the Theory of Bleaching, by Oxygenated Muriatic Acid.*

1. The colouring matters destroyed in bleaching appear to be chiefly oxides, with bases compounded of carbon and hydrogene, insoluble in water; and it is probable that they are converted by the action of the oxygenated muriatic acid into carbonic acid and water.

2. But the theory of the different processes of bleaching is as yet very imperfectly known. And the smallness of the quantity of colouring matters, and their susceptibilities of change render it very difficult to make them the subjects of accurate experiments.

## DIVISION IV.

### OF DYEING.

#### 1. *Of the Nature of Dyeing.*

Dyeing is the art of impregnating cloths, stuffs, and other substances manufactured from vegetable, and animal products, with different permanent colouring matters.

The processes relating to this art are purely chemical, and they depend, in a great measure, upon the exertion of particular affinities by the substances to be dyed, and the different colouring matters.

#### 2. *Of the Substances usually Dyed.*

1. The substances usually dyed are articles of clothing, composed either of wool, silk, cotton, or linen.

2. Wool, and silk have a much stronger affinity for the colouring matters employed in dyeing, than cotton, or linen; their composition is less simple, and in consequence the attractions exerted by their elements, upon the principles of other bodies, are stronger and more numerous. See Part I. Div. VI.

3. In cases, when colouring matters cannot be immediately united with the substance to be dyed, the combination is effected by the operation of a third body, in consequence of intermediate affinity. Part I. Div. VI. Sect. 1.

The agents employed for fixing colours in cloths, stuffs, &c. are usually called mordants or bases.

#### 3. *Of Mordants or Bases.*

1. The most important mordants in common use are alumine, oxide of tin, and oxide of iron.

2. Alumine has a very strong attraction for wool, and silk, but a much weaker attraction for linen and cotton;

it is employed in two states, either combined with sulphuric acid, or with acetous acid which for this purpose, and for analogous purposes, is obtained in an easy manner from the decomposition of acetite of lead.

3. The oxide of tin at its maximum of oxidation, is applied to cloths, &c. in three forms of combination. 1. As nitromuriate of tin. 2. As acetite of tin; and 3. As tartrite of tin. These compounds are very powerful mordants, and act both on animal and vegetable substances.

4. Two preparations of iron are employed as mordants, the red acetite and the red sulphate.

5. Substances are occasionally used to facilitate the action of the common mordants, or to alter the shade of colour, such are tan, which itself is a species of mordant, tartar, acetite and sulphate of copper.

6. Mordants in general do not act simply by rendering the dye permanent, but have always an influence on the colour produced. And in fact, the colour may be considered as a simple property of the triple compound, containing the dye the cloth and the mordant.

## 4. *Of the Simplest Dyes, or Simple Colours.*

1. The colours denominated simple by dyers are four, blue, red, yellow, and black.

2. Indigo is the only colouring matter used for dyeing *blue.* It is procured from different plants, such as the indigoferia tinctoria, and the isatis tinctoria. It combines with all the substances usually dyed, without the intervention of a mordant; and it is generally applied to them either dissolved in its common state in sulphuric acid; or combined in its deoxygenated state with lime water. In cases when cloths, &c. are dyed with deoxygenated indigo, they are at first green, but soon become blue by exposure to the atmosphere.

3. The substances usually employed for dyeing *red,* are cochineal, archil, madder, brazil wood, and carthamus. And these colouring matters for the most part can only be

permanently combined with cloths, &c. through the intervention of mordants. The colouring matters of cochineal, archil, madder, and brazil wood, are soluble in water; and in processes of dyeing they are usually precipitated from their solutions upon cloths, by means of nitromuriate of tin, or sulphate of alumine. The red colouring matter of carthamus is not combinable with water, but it is speedily dissolved in solution of carbonate of potash; and in this form it is generally applied to the substance to be dyed. The tint it communicates is considerably heightened by acids.

3. The *yellow dyes* in common use are procured from weld, fustic, and quercitron bark, by the infusion of these substances in warm water, and they are generally combined with cloths, &c. by means of alumine. The red oxide of iron has been lately proposed as a yellow dye, by M. Chaptal.

4. The tannogallate of iron is almost the only known black dye. It is combined with cloths, &c. at the moment of its formation, during the decomposition of the red sulphate of iron by decoction of gallnuts. Its colour is considerably heightened by the infusion of logwood.

## 5. *Of Compound Colours.*

1. The dyes usually denominated compound colours, are formed by the mixture of simple colours. They are extremely numerous; and even when of the same class, differ in tinge according to the differences in their composition.

The most important of the compound colours, are mixtures of blue and red, of yellow and red, and of blue and yellow.

2. Cloths by being dyed successively with indigo, and cochineal or logwood, become violet, purple, or lilac, according to the intensity of the different dyes employed. When the blue dye prevails, violet is produced; and when the red, purple.

3. Various tints of orange are produced by means of dif-

ferent successive combinations of cloths, with the colouring matters of weld or fustic, and those of madder or cochineal.

4. Cloths are dyed of different shades of green, by means of indigo and quercitron bark. The colours are always applied to the cloth in succession; and oxide of tin is generally used as a mordant.

### 6. *Of Calico Printing.*

1. Calico printing is the art of dyeing cloths with different colouring matters, in such a manner as to produce upon them regular spots or figures. For this purpose the mordants necessary for the production of the different colours are applied to the surface of the cloths, &c. either by means of pencils, or wooden engravings in relief; and, after dyeing, the colouring matter is easily washed out from that part of the cloth not acted upon by the mordants.

2. The principal mordants employed in calico printing are acetite of alumine, and red acetite of iron. These substances are combined for application with a solution of gum or mucilage; and the cloth, after having received them, is washed with an infusion of cow dung.

3. The same colouring matter in calico printing is often made to produce several different colours, or shades of colour, according as the mordants applied differ in their nature or quantity. Thus, madder, with acetite of alumine, produces red, and with acetite of iron, brown; and quercitron bark, with the same mordants, in the same order, gives yellow, and olive.

### 7. *General Observations.*

1. The permanency of colours depends in a great measure upon the strength of the affinity between the cloths, &c. and the colouring matters, whether they are in states of simple combination, or of combination by means of mordants.

2. Colouring matters in general are compounded of many different principles, and they are for the most part decomposable by certain of the most powerful chemical reagents. In their combinations with cloths, however, they are seldom exposed to any other agencies than those of light, of air, and of alkaline substances; and those dyes are considered as durable which withstand the effects of washing, and of exposure to the atmosphere.

3. The blues and blacks generally used are very durable dyes; but yellows, reds, and all the brighter colours procured from vegetables, for the most part fade more speedily; though it is said, that the oxide of tungsten has been lately employed with great advantage for rendering them fixed and permanent.

## DIVISION V.

### OF METALLURGY.

#### 1. *Of the Modes of procuring Metals from their Ores.*

1. Metals are often found mineralised, either by sulphur, or oxygene, and in the last state they are often combined with the phosphoric, arseniac, or carbonic acids.

2. Sulphur is usually separated from metals by the application of heat, in a process called roasting; and they are deprived of oxygene by ignition with charcoal.

3. In cases when metallic substances are enveloped in, or mingled with, earthy substances, from which they cannot be obtained in a free state by mechanical agents; they are separated during fusion by means of certain compound salts, in consequence of their great specific gravity.

4. Acids, and other chemical reagents, are often used in operations upon the more precious metals, which in these cases are first exhibited in the states of oxides, and are

afterwards rendered metallic by the agency of heat and of inflammable substances.

## 2. *Of the Formation of Alloys, and other Metallic Compounds.*

1. Alloys are formed by bringing different metals together in a state of fusion, and they are much used for common purposes of life.

2. In general the alloys of gold, silver, and copper, are employed as the medium of exchange; and the standard gold of Britain is composed of 11 parts gold and 1 of copper; and the standard silver of 15 parts silver and 1 of copper.

3. The alloys of tin, and of copper are used for forming drinking vessels, lamps, mathematical instruments, bells, and different utensils employed for purposes in which fusibility, ductility, weight, durability, and impermeability to water are required.

4. But one of the most important of the metallic compounds is steel, which is employed for making all such instruments as demand great hardness, strength, and elasticity. The best steel contains about $\frac{1}{200}$ carbon. Its properties are wonderfully influenced by different applications of heat.

5. The alloys, as well as the pure metals, are made of regular forms, by being cast in moulds made of substances infusible, and unalterable by heat; and they are polished and ornamented by different mechanical compressions or abrasions of their useless parts.

## 3. *Of Soldering.*

1. Soldering is the art of fastening together different metals, by the application of some metallic compound in fusion, to the parts to be united.

2. Different alloys are generally employed as solders;

and they should be always more fusible than the metals to which they are applied, and possessed of a strong affinity for them.

3. Solders for lead, are composed of two parts of lead to one of tin. Pieces of copper are united by means of an alloy of copper and tin. Two parts of silver and one of brass compose silver solder.

4. Soldering is performed by means of the blow pipe, heated irons, &c.; and to prevent the metals from being oxydated, or to free them from impurities, resin, borax, and other substances are employed.

### 4. *Of Plating, Gilding, &c.*

1. The surface of one metal may be covered by a thin stratum of another metal, in many different ways.

2. Iron is plated with silver by means of hard solder; and silver is often made to cover the surfaces of copper and some other metals, by means of simple cementation; or by being rubbed or burnished upon them, when in a state of minute division.

3. Gold is made to adhere to other metals generally either by being amalgamated with mercury, or by being applied in a state of minute division. In the case of amalgamation the mercury is driven off by heat from the metallic surface, and the gold only remains. Finely divided gold becomes easily attached to a metallic surface by pressure, or by friction.

4. Iron and copper are readily covered with a coating of tin, by being immersed into that metal when in a state of fusion.

### 5. *Of the Analysis of Metallic Compounds.*

1. Metallic compounds are so numerous, that it is impossible to describe with accuracy, any general mode of discovering their constituent parts.

For the purpose of analysis, a number of reagents must be employed; and the greater part of the instruments of modern chemistry brought into action.

2. Different acids, and particularly the nitrous, are made use of for oxydating or dissolving metallic compounds. The prussiate of potash is a good test for the presence of red oxide of iron, and other metallic oxides in solutions.

3. Silver and lead are precipitated by means of muriatic acid; gold and platina are known by the facility with which they are revived. The quantity of tin, zinc, or iron, in any alloys, may be discovered from the quantity of hydrogene produced during their action upon diluted sulphuric acid.

4. But the habits of performing the processes relating to this part of metallurgy can only be attained by long experience, and by studying the works of the best writers on the subject. Kirwan, Klaproth, Vauquelin, Hatchett, &c.

## DIVISION VI.

### OF THE MANUFACTORY OF GLASS AND PORCELAIN, &c.

#### 1. *Of Glass Making.*

1. Glass is formed by the fusion of potash, or soda, with sand chiefly containing silicious earth. It is made of different degrees of density by means of oxide of lead; and it is rendered transparent and colourless by certain substances containing oxygene.

2. The best kind of flint glass is composed of about 120 parts of white silicious sand, 40 parts of pearl ash, 35 of red lead, 13 of nitre, and .25 of black oxide of manganese.

3. Glass is coloured blue by the oxide of cobalt; red by the oxide of gold; green by the oxide of copper, and yellow by the oxides of antimony and lead.

### 2. *Of the Manufactory of Porcelain, Earthenware, &c.*

1. The component parts in general of porcelain and earthenware are silex, alumine, lime, and, in certain cases, metallic oxides. The quantity of silex is commonly about two thirds; that of alumine, from a fifth to one third, and that of lime, from one fifth to one twentieth.

2. Alumine and silex, form, with water, a paste of softness and ductility capable of being easily kneaded; and by means of lime, they are rendered more susceptible of combining by incipient fusion, so as to form hard and permanent masses.

3. Porcelain and earthen ware, are glazed by means of different mixtures of earths with alkaline substances, oxide of lead, &c. and they are coloured nearly in the same manner, and by the same substances as glass.

## DIVISION VII.

## OF THE PREPARATION OF FOOD, DRINK, &c.

### 1. *Of the Preparation of Food.*

1. The food taken into the stomach should be capable of being easily digested and converted into chyle. The gelatine, fat, and fibrine, in animal compounds, are the most nutritive substances we are acquainted with; and after them follow the sugar, and mucilage in vegetable productions.

2. In the preparation of food by heat, great care should be taken to prevent any part of it from being decomposed. Stewing, by means of water, appears to be one of the most economical modes of preparing both animal and vegetable food; but in baking and roasting a portion of nutritive matter is always destroyed. As gelatine, mucilage, and sugar, are all soluble in hot water, they may be formed into soups, which are at once nutritive, and pleasant to the taste.

## 2. *Of the making of Wine, Beer, Alcohol, &c.*

1. Wines are procured by the fermentation of the juice of grapes; and in this process the saccharine matter of the fruit is slowly converted into alcohol, at the same time that much carbonic acid is evolved.

2. Ardent spirits are obtained by distillation, from substances containing saccharine matter, which has fermented so as to form alcohol; and they differ in quality chiefly in consequence of the different nature of the aroma and extractive matter combined with them.

3. Beer, porter, and ale are made from the fermented juice of barley and the infusion of hops; and they appear to consist chiefly of different proportions of water, mucilage, alcohol, sugar, and bitter principle.

# DIVISION VIII.

## OF THE MANAGEMENT OF HEAT AND LIGHT, ARTIFICIALLY PRODUCED.

### 1. *Of Combustion.*

1. In all processes of combustion, the fuel must be situated in such a manner, as to be constantly exposed to fresh atmospheric air.

2. The phenomena generally connected with combustion, are radiant heat, common communicated heat, and light; and these effects occur in very different degrees in different instances.

3. Coal, coke, charcoal, and wood, are the substances generally employed in purposes where heat only is required. But tallow, spermaceti, oil, wax, and other substances which burn with flames, are used for producing light.

## 2. *Of Open Fireplaces.*

1. The grates of such fireplaces as are chiefly designed for heating the air of appartments should project as much as possible, and their backs and sides ought to be formed by substances which are bad conductors of heat. Chimneys likewise should be composed of similar substances, and their lower orifices ought to be no larger than may be absolutely necessary for a free circulation of air.

2. For increasing the radiation of heat during the combustion of fuel, coals may be mingled with certain incombustible substances, so as to form fireballs.

3. The great principle in the management of common fires is to suffer as little as possible of the volatile parts of the fuel to pass off unconsumed by the chimney; and to communicate as much heat as possible in an equable manner to the air in every part of the room to be heated.

## 3. *Of Furnaces, and different closed Fireplaces for Culinary Purposes.*

1. Furnaces, and other similar fireplaces, should be constructed in such a manner as to enable as great a quantity as possible of the heat produced by the combustion of fuel to be applied immediately to the vessels to be heated. For this purpose they should be composed of non-conducting substances, and their form ought to be such as to cause the heated air, or flame, produced in them, to strike immediately against the bottoms of the vessels to be heated.

2. For culinary purposes these vessels ought to be composed of metallic substances, which are good conductors of heat; and their lower surfaces should be as large as possible, and of such a form as to enable the flame and heated air which strikes against them, to break, and to play over them with force in different currents and directions.

3. Steam may be employed with great advantage for

heating fluids, and for keeping them warm. It can easily be carried from place to place by means of tubes, and the apparatus required for applying it is light and simple.

### 4. *Of Candles, Lamps, &c.*

1. The wicks of candles and lamps seem to act, simply by conveying the inflammable matter in a fluid form regularly and slowly to the place of combustion, in consequence of capillary attraction.

2. In all lamps and candles the place of most intense combustion is a little above the point at which the oil is volatilized, and where the supply of air is greatest; and in all cases, the wick ought to extend but very little beyond that point.

3. During the combustion of candles, in consequence of the want of a supply of air to the middle of the flame, a small portion of inflammable matter is generally decomposed without being consumed, whence the production of smoke; but in the Argand lamp, in which the wick is exposed both externally and internally to air, this phenomenon does not take place.

4. The photometer described in Part II. Div. II. is of great use in all experiments upon artificial light; and by means of it, the intensity of the light produced during the combustion of different bodies may be ascertained, so as to be compared with their relative consumptions, in the process.

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