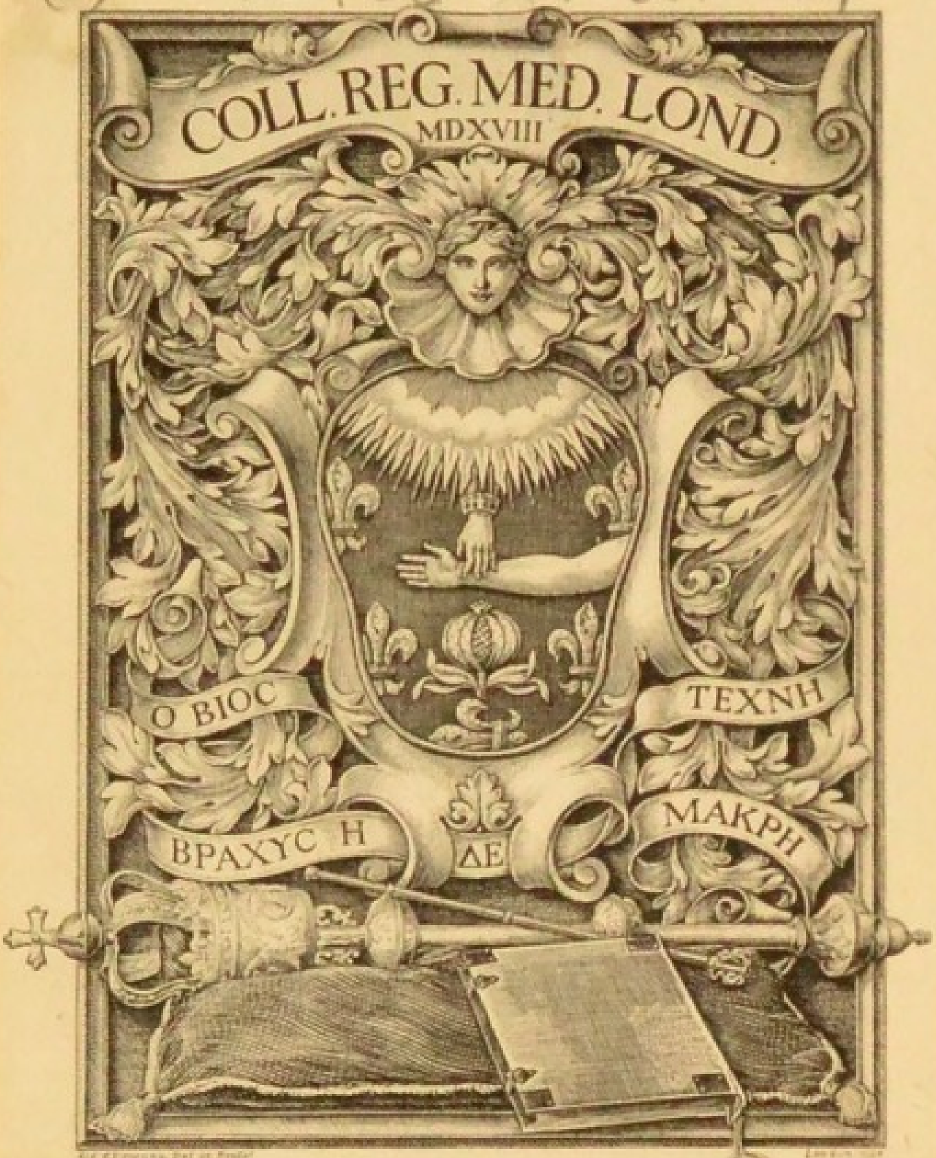
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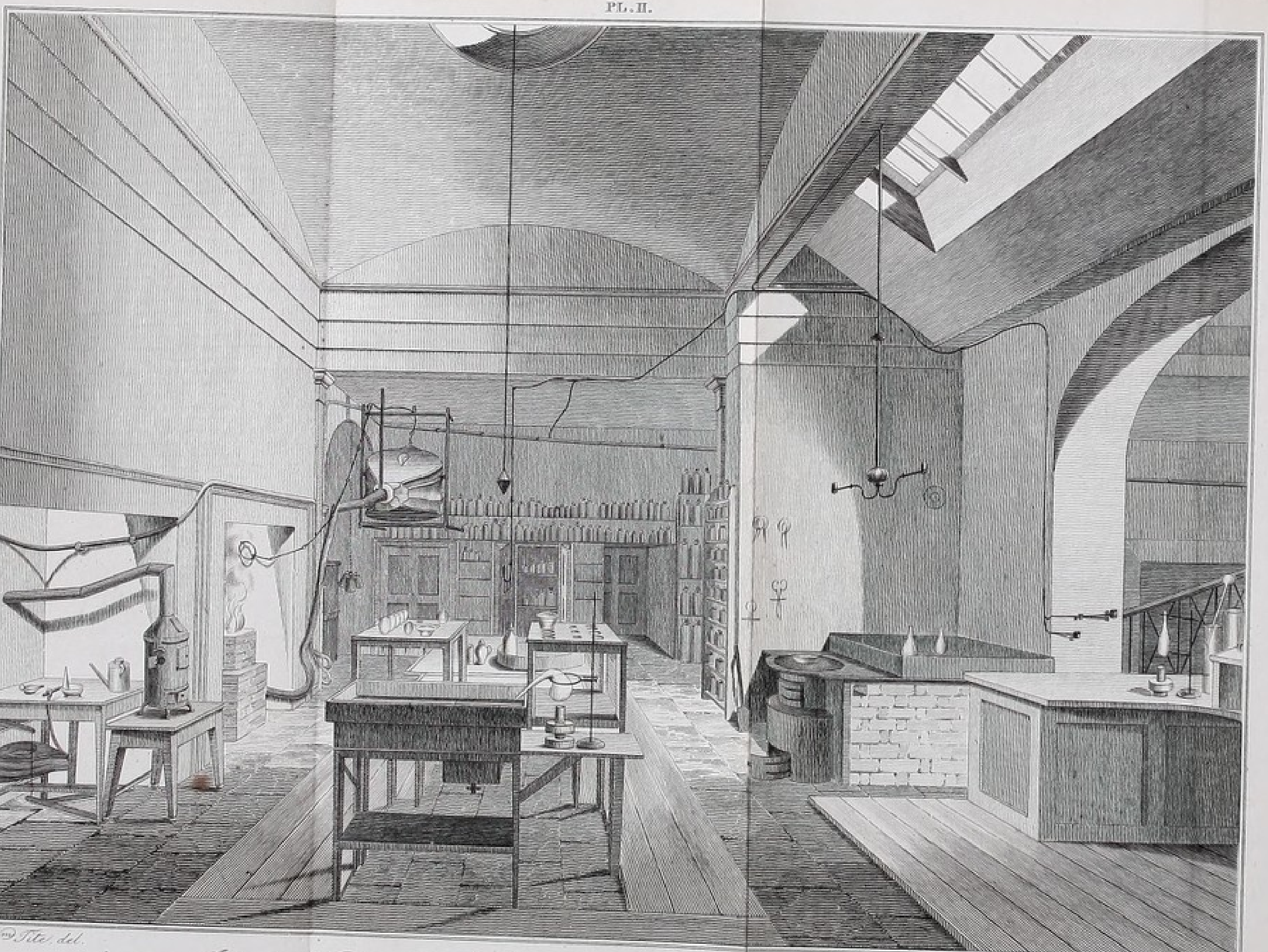

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Interior View of the Laboratory in the Royal Institution.

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Published by John Murray, Albemarle Street, London, 1816.

A

MANUAL OF CHEMISTRY;

CONTAINING

THE PRINCIPAL FACTS OF THE SCIENCE, ARRANGED IN THE ORDER IN WHICH THEY ARE DISCUSSED AND ILLUSTRATED IN THE LECTURES AT THE ROYAL INSTITUTION OF GREAT BRITAIN.

BY

WILLIAM THOMAS BRANDE,

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LONDON:

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1819.

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TO

CHARLES HATCHETT, Esq., F.R.S.,

&c. &c.

My Dear Sir,

TO You, as my first instructor in Chemistry, and as one whose researches in the Science have exalted your name to a high station among British Chemists, I beg leave to dedicate the following Work; trusting that you will receive it as a testimony of the gratitude and respect with which I shall always remain,

Your faithful Friend,

and affectionate Son-in-Law,

WILLIAM THOMAS BRANDE.

London, April 19, 1819.

CHAPTER VIII.

Geology.

APPENDIX.

Tabular View of Specific Gravities, Representative Numbers, &c.

Tables of Weights, Measures, &c.

Directions for placing the Plates.

PREFACE.

Though the following pages are chiefly intended for the use of students, it is trusted that the proficient will find them a useful compendium of Chemistry.

The arrangement of the materials differs from that sanctioned by our best elementary writers, but it has been adopted in consequence of some years' experience of its advantages in teaching the principles of the science.

In the first chapter the leading facts connected with the general laws of chemical changes are discussed under the separate heads of Attraction, Heat, and Electricity. The second chapter relates to the properties of radiant matter, and its influence upon the composition of bodies. In the third and fourth chapters I have detailed the sources and properties of the simple supporters of combustion, and of the elementary acidifiable substances, and their mutual combinations. The fifth chapter contains an account of the metals, and of their compounds with the bodies previously described, and with each other; some directions are also interspersed for the analysis of mineral substances, but I have in general preferred a reference to authorities, to any attempt at detailed instructions upon this head, by which the student cannot profit, and which are of little use to the practical operator, whose knowledge must be the result of experience. The sixth and seventh chapters are assigned to vegetable and animal products, and the concluding chapter contains the heads of geological inquiry.

In the Appendix will be found a table, chiefly useful as presenting a synoptic view of most of the simple and compound bodies, with their representative or equivalent numbers; these may easily be transferred to a logometric scale, as recommended by Dr. Wollaston, who has thus furnished the laboratory with one of its most useful implements.

The above materials have chiefly been drawn from the notes that I have employed in my different courses of lectures, and these are partly original, and partly compiled from various sources; although therefore I have in most instances scrupulously referred to the authorities quoted, it is possible that this may have been sometimes omitted, and for such omissions, I now beg to apologize.

The systematic and elementary works that I have chiefly relied on for assistance, are the systems of Dr. Thomas Thomson, of Dr. John Murray, and of M. Thenard; and the Elements of Sir Humphry Davy, and of Dr. William Henry. The Chemical Dictionary of Messrs. Aikin, I have also often consulted with much advantage, especially in relation to the Chemistry of the Arts.

Much of this work has been written in the Laboratory, where the results of experiments have been immediately transferred to its pages; and where I have uniformly received the active and able assistance of Mr. M. Faraday, whose accuracy and skill as an operator have proved of essential service in all my proceedings.

A view of the interior of the Laboratory of the Royal Institution forms the Frontispiece to this volume; I have selected it for description on account of its completeness and convenience; it comprises all that can be required in the pursuit of experimental chemistry, and by enlarging or diminishing the plan, it may be well adapted to any public or private establishment.

The following description of the ground plan (Plate I.) will serve to explain its general arrangement.

A is a part appropriated to an audience. B is the body of the Laboratory.

a The entrance.

b An open chimney for the reception of moveable furnaces.

c A wind furnace. (Plate III.)

d A reverberatory and assay furnace.

e A stove with a sunk flue, for warming the Laboratory.

f a table.

g A sand furnace. (Plate III.)

This has lately been transferred to the place of the centre table *p*, and communicates by a descending flue with the same chimney.

h A sink with a plentiful supply of water.

i A table with cupboards below it.

k A furnace for the production of gas from coal, *&c.*

l A cast-iron steam boiler for the abundant supply of hot water, and of steam when required.

m A recess lighted from above, containing a bellows-blowpipe, and communicating with three flues *n n n*, for the reception of the chimneys of portable furnaces. The gas purifiers also stand in this recess.

o A forge furnace placed in a similar recess, with flues for occasional purposes.

p p p Tables with drawers.

q A gasometer from which tubes issue for the supply of the Laboratory, and of the lecture room, with coal gas.

r A small store room and cellar for fuel, *&c.*

s s Recesses for apparatus.

t Doorway leading to an apartment for apparatus, *&c.*

Plate III. contains a representation of the most useful furnaces of the Laboratory.

Fig. 1. A sand furnace; *a* the larger bath; *b* the smaller one, which may occasionally be removed for the purpose of employing the fire-place for crucibles, or of inserting the boiler of a still.

Fig. 2. Section of the wind-furnace; *c* Plate I. *a* is a flue communicating with the exterior of the building, for the admission of cold air to the fire-place; *b* the ash-hole; *c c* two grates, the upper of which may be removed when a deep fire-place is wanted; *d* an aperture which may be closed by a moveable fire-brick ; *e* the chimney ; *f* a register.

Fig. 3. Knight's portable furnace, made of wrought iron, and lined with fire-brick. It is convenient for a variety of operations, conducted upon a small scale ; *a* is a door for the passage of the neck of a retort when distillation is performing in the open fire, as seen in the wood-cut at page 132; *b* is an aperture to which there is a corresponding one on the opposite side for the admission of a tube to pass through the furnace, as shewn at page 93.

Fig. 4. A portable assay-furnace ; *a* is the muffle represented in Fig. 5.

Fig. 6, 7, and 8, are evaporating basins ; 9, a Platinum crucible and cover ; 10, 11, Hessian crucibles ; 12, 13, 14, 15, the principal varieties of tongs useful in the Laboratory.

INTRODUCTION.

CHEMISTRY cannot be said to have existed, as a science, previous to the commencement of the seventeenth century; for although we find, in the writings of the earlier alchemists, many curious and important facts and discoveries, these remained useless and unapplied, so long as the minds of men were exclusively directed to the transmutation of the metals, and the fabrication of an universal elixir. Although, therefore, it may often be amusing, and sometimes profitable, to revert to the crude speculations and waking dreams of the voluminous writers upon these subjects who were eminent in the fourteenth and two successive centuries, the time of the student will be more profitably occupied in tracing the labours of those, who, discarding visionary hypotheses, proceeded to the investigation of truth; and who were led on, not by the vague glimmering of speculative notions, but by the steady day-light of real philosophy.

It is, I think, among our own countrymen that we discover the fathers of chemical philosophy: for Bacon, Boyle, Hooke, and Newton, present unequivocal claims to that distinctive title. As induction from experiment is exclusively the basis of chemical science, little progress could be made in it till the futility of the ancient philosophical systems had been shewn, and their influence annihilated; till the true end of science was rightly defined, and the road to it rendered straight and passable; till the necessity of well-digested experiment had been established, which "first procures the light, then shews the way by its means."

It may seem trite to quote Lord Bacon; but, as experience is constantly shewing the neglect of the invaluable doctrines inculcated in his works; and as students, especially, are too apt to throw off the burthen and responsibility of thinking for themselves, by adopting the notions of others, without either weighing their merit or appreciating their correctness, and often only because they are new, I shall beg leave to call their attention to one of the many relevant passages of this author.

"He who would come duly prepared, and fitted to the business of interpretation, must neither be a follower of novelty, custom, nor antiquity; nor indulge himself in a liberty of contradicting; nor servilely follow authority. He must neither be hasty in affirming, nor loose and sceptical in doubting; but raise up particulars to the places assigned them by their degree of evidence and proof. His hope must encourage him to labour, and not to rest; he must not judge of things by their uncommon nature, their difficulty, or their high character; but by their just weight and use. He must, in his own particular, carry on his view with concealment, and yet have a due regard for posterity. He must prudently observe the first entrance of errors into truths, and of truths into errors, without despising or admiring any thing. He must understand his own talents and abilities, or the advantages of his own nature. He must comply with the nature of others. He must, as with one eye, survey the natures of things, and have the other turned towards human uses. He must distinctly understand the mixed nature of words; which is extremely capable both of prejudicing and assisting. He must lay it down to himself, that the art of discovering will grow up, and improve, along with discoveries themselves. He must not be vain either in delivering or concealing the knowledge he has acquired; but ingenuous and prudent, and communicate his inventions without pride or ill-nature: and this in a strong and lively manner, well defended against the injuries of time, and fit for the propagation of knowledge, without occasioning errors; and, which is the principal thing of all, it must be such as may select and choose for itself a prepared and suitable reader*."

The following observations from the same source, will bring me back to my subject:

"And again; if any one should condescend to regard such things as are accounted rather curious than useful; and take a thorough view of the works of the alchemists, or the followers of natural magic; he might, perhaps, be at a difficulty which he should withhold, his tears, or his laughter. For the alchemist goes on with an eternal hope; and where his matters succeed not, lays the blame upon his own errors; and accuses himself as not having sufficiently understood either the terms of his art, or his author: whence he either hearkens out for traditions and auri-

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* *Prefatory Aphorisms of the Novum Organum Scientiarum.* No. XI.

cular whispers; or else fancies he made some mistake as to the exact quantity of the ingredients, or nicety of the experiment; and thus repeats the operation without end. And if, in the mean time, among all the chances of experiments, he throws any which appear either new or useful, he feeds his mind with these as so many earnests; boasts and extols them above measure; and conceives great hopes of what is behind. It must, indeed, be allowed that the alchemists have made many discoveries, and obliged mankind with useful inventions; but they are well represented in that fable of the old man, who left an estate to his children, (buried somewhere or other, he told them, in his vineyard;) which they, therefore, fell to dig for with great diligence; whereby, though they found no gold in substance, yet they received a better vintage for their labour."

"But such as apply to natural magic, and explain every thing by sympathies and antipathies, have, by supine and indolent conjectures, placed strange virtues and operations in things; and if, at any time, they have produced works, they are rather suited to admiration and strangeness, than to fruit and advantage*."

* *Novum Organum.* Section V.

The Honourable Robert Boyle*, who was born in the year in which Lord Bacon died, wrote upon many subjects, and among them upon chemistry, such as it was in his time. The perusal of his chemical works, however, impresses us rather with the benevolence and excellent moral character of the author, than with his skill or sagacity as an experimental philosopher. Yet Newton thought very highly of his philosophical attainments; and, with such evidence in his favour, it seems presumptuous to question their value.

Mr. Boyle's name is closely connected with the foundation and early proceedings of the Royal Society, a body from which the chief lights of British science have directly emanated, and which received its charter on the 15th of July, 1662, from the hands of Charles II†. Of this society he was chosen President in the year 1680, but, in consequence of some peculiarity in his notions respecting the administration of oaths, he declined taking those required upon the occasion, and, consequently, never ascended the chair; upon this account the celebrated Sir Christopher Wren was his substitute.

* Born in Ireland, 1627; died 1691.

† Thomson's *History of the Royal Society*.

The name of Robert Hooke * stands pre-eminent among the founders of modern chemical science; and, although his moral character is not of so amiable a description, he certainly went before his patron and contemporary, Boyle, as a theoretical and experimental philosopher. His contributions to science are of various degrees of merit; but it is his theory of combustion that principally fixes the attention of the chemical reader. Of this process the phenomena are so striking and peculiar, as to have excited the notice of philosophers in all ages. Fire was regarded, by the earliest chemists, as a principle resident in all forms of matter, and capable, under certain circumstances, of being separated or rendered evident. This notion, which, under various modifications, forms the basis of all their hypotheses, was first formally combated with experimental weapons, by John Rey †, a physician of Perigord. In 1629, Brun, an apothecary of Bergerac, having melted two pounds six ounces of tin, found the whole was converted into a calx, weighing seven ounces

* Born in the Isle of Wight, 1635; died in London, 1702.

† *Essays de Jean Rey, Docteur en Médécine, sur la Recherche de la Cause pour laquelle l'Estain et le Plomb, augmentent de poids quand on les calcine.* Paris, 1777.

more than the tin employed; a fact at variance with the separation of fire. Upon this he consulted Rey, who, in 1630, published a tract upon the subject, in which he refers the increase of weight to the absorption and solidification of air.

Hooke, in his *Micrographia,* published in 1664, has sketched a beautiful theory of combustion, in which he dwells chiefly upon the influence and necessity of air to the process, and refers the power of supporting combustion to a principle existing in saltpetre. The following are the principal passages relating to this subject:

"From the experiment of charring of coals (whereby we see that, notwithstanding the great heat, and the duration of it, the solid parts of the wood remain, whilest they are preserved from the free access of the air undissipated,) we may learn that which has not, that I know of, been published or hinted, nay, not so much as thought of, by any; and that, in short, is this.

"*First,* That the air in which we live, move, and breathe, and which encompasses very many, and cherishes most bodies it encompasses; that this air is the menstruum, or universal dissolvent, of all sulphureous bodies.

"*Secondly,* That this action it performs not, till the body be first sufficiently heated, as we find requisite also to the dissolution of many other bodies by several other menstruums.

"*Thirdly*, That this action of dissolution produces or generates a very great heat, and that which we call fire; and this is common also to many dissolutions of other bodies, made by menstruums, of which I could give multitudes of instances.

"*Fourthly*, That this action is performed with so great a violence, and does so minutely act, and rapidly agitate the smallest parts of the combustible matter, that it produces, in the diaphanous medium of the air, the action, or pulse of light; which what it is, I have elsewhere already shewn.

"*Fifthly*, That the dissolution of sulphureous bodies is made by a substance inherent, and mixt with the air, that is like, if not the very same, with that which is fixt in saltpetre, which, by multitudes of experiments that may be made with saltpetre, will, I think, most evidently be demonstrated."

In the *Lampas*, published in 1677, he has somewhat extended these views and their applications, and has offered suggestions respecting the nature of flame, which are equally creditable to the acumen of his genius.

In 1674, John Mayow's* *Tracts* were published at Oxford. In these he adopts the views previously divulged by Hooke, but extends and embellishes them. He contends that there exists in the atmosphere a spirit necessary to life and fire, identical with that pent up in saltpetre; that when metals are burned they absorb it, and therefore increase in weight; that a similar change may be effected in them by nitric acid; that the same principle is also an acidifying principle, and concerned in converting sulphur into an acid; that it is necessary to the vegetation of plants, and respiration of animals, as well as combustion. Mayow's writings abound in these and similar anticipations of modern discoveries; and, although he may be supposed to have borrowed his notion of the nitro-aërial spirit from Hooke, his claims to originality upon other equally important topics, must always remain indisputable.

Newton, to whom all science lies under deep obligation, made two capital contributions to chemistry. He subverted the ancient doctrines concerning the cause of chemical affinity; and, instead of referring the tendency which bodies have to combine to pe-

* Born in Cornwall, 1645; died in London, 1697.

culiar forms and attributes of their atoms, he referred it simply to attractions belonging to their ultimate particles. His queries upon this subject attached to the book on Optics, are so explicit and distinct, as to be creditable even to the sagacity of Newton. To him we are also indebted for the discovery of a mode of graduating thermometers, so as to render them correspondent with each other; thus was that real utility conferred upon the instrument, by which philosophers were afterwards enabled to carry on their researches in a very difficult department of chemistry with remarkable facility and precision. It is a question to whom the invention of the thermometer is due; perhaps it is most justly given to Santorio, of Padua *; it was, however, considerably improved by the academicians del Cimento, who, in the year 1651, united themselves into a body under the patronage of the Grand Duke of Tuscany. To this active and zealous association of experimentalists we owe the curious and important discovery of the expansion of water previous to its freezing (p. 24); they were also the first who observed the reflection of cold (p. 66.)

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* Born, 1561, at Capo d'Istria; died, 1636, at Venice.

In 1666, the Royal Academy of Sciences was instituted at Paris, under the protection of Louis XIV.; in its annals the names of Homberg, Geoffroy, and the two Lemerys, soon became celebrated for their various discoveries and improvements in chemistry. Homberg *, under the auspices of the Regent Duke of Orleans, was an active and successful experimentalist. He discovered the boracic acid, which he prepared under the name of sedative salt (244.) He was also the discoverer of pyrophorus (689.)

Geoffroy deserves mention as an active and scientific contributor to pharmaceutical chemistry; he was also, I believe, the first compiler of the *Paris Pharmacopœia*.

In 1674, the elder Lemery acquired considerable fame as a teacher and an author. In his lectures he brought the science to the level of ordinary understandings, and in his writings the leading doctrines of the chemistry of his day are perspicuously and unaffectedly set forth.

It now may be right to revert to the hypothesis respecting the cause and phenomena of combustion, which, as has already been shewn,

* Born at Batavia, in Java, 1652; died at Paris, 1715.

engaged the attention of the earlier chemists, and was philosophically discussed by Rey, Hooke, and Mayow.

Beccher*, who wrote in 1669, referred the changes which natural substances undergo, to the mutual agencies of a few elementary principles, and insists upon the powers of art as adequate to the performance of the various operations of nature. In his *Physica Subterranea*, and *Œdipus Chemicus*, these notions are set forth, and they are certainly very extraordinary productions. Much of his time was spent in visiting mines, and examining mineral bodies. He allowed the existence of five elementary substances; water, air, and a vitrifiable, an inflammable, and a mercurial earth; he considers acids as derived from the union of earth and water; stones, as produced by the combinations of two earths; and metals by the union of the three earths in variable proportions. Beccher also added to the instruments of chemical research, and simplified many of the very complex operations then prevalent in the laboratory. As a practical chemist, he is perfectly intelligible, but his theories are involved in so much contradiction and mystery, that it

* Born at Spires, in 1625; died in England, 1685.

is barely possible to understand the ends he aims at.

He was succeeded by Ernest Stahl *, whose name, as coupled with the once prevailing and generally, received phlogistic theory, is familiar to chemists. Stahl's doctrines are ably and perspicuously set forth in his *Fundamenta Chemiæ*, published at Nuremberg in 1723. He refers combustion to the separation of a highly subtile and elastic matter, which, under certain circumstances, is thrown into violent agitation, and then constitutes flame, or fire. This principle he terms *phlogiston*. He asserts that, when substances are burned, they throw off phlogiston; and that by its addition to the residuary matter, the original substance is reproduced; and endeavours to demonstrate this assertion by reference to the combustion of sulphur, and some of the metals. When antimony, for instance, is exposed to the open fire, it burns, and is converted into a white earth-like matter; it consists, therefore, of earth and phlogiston; when this earth is heated with charcoal, which abounds in phlogiston, antimony is regenerated.

It may here be observed, that the necessity of

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* Born in Franconia, 1660; died at Berlin, 1734.

air to combustion, and the increase of weight sus tained by the combustible, are entirely overlooked; and that, although this hypothesis was universally received and promulgated, under the name of the Stahlian, or Phlogistic Theory, it was, in fact, a mere revival of the erroneous surmises of the alchemical writers, and amply disproved by the experiments and arguments of Rey, Hooke, and Mayow, as above quoted.

The last writers of this period, whose names I shall here record, are Hermann Boerhaave*, and Dr. Stephen Hales†. The former was a clear, and often eloquent writer, but his experimental investigations were not crowned with much success.

Hales, on the contrary, was a diligent and acute inquirer; his researches into the physiology of vegetation, and his "*Specimen of an Attempt to analyze the Air, by Chymio-Statical Experiments,*" are deserving of perusal, in consequence of the ingenuity in the contrivance of experiments and apparatus which they display, as well as for the justness of some of his conclusions. He may be regarded as the founder of that department of chemistry which relates to

* Born near Leyden, 1668; died, 1738.

† Born in Kent, 1677; died at Teddington, 1761.

aëriform bodies, and which was so ardently and successfully prosecuted soon after he retired from the field.

The discoveries of Dr. Joseph Black * come next in order; and, whether with reference to their immediate importance, or indirect influence upon other branches of chemistry, may be considered as forming an era in the science. His first experiments refer to the cause of causticity in the earths and alcalis. It was long known that chalk, which is a mild insipid substance, after having been heated red-hot, became converted into quicklime, which is caustic and acrid; but the cause of this change, though it had been looked for by Macquer and others, remained unknown: it was generally referred to the absorption of fire. Black's attention was drawn to this subject by the discovery of magnesia, which, in 1720, was first distinguished from lime by the celebrated Hoffmann†, who also obtained it from sea-water.

Dr. Black's researches led him to ascertain the existence of a peculiar aëriform matter in the mild earths and alcalis, which was driven off by heat

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* Born in France, 1728; died at Edinburgh, 1799.

† Born at Halle, in Saxony, 1660; died, 1742.

and expelled by acids, and which he called *fixed air*. In 1764, Dr. Macbride*, of Dublin, ascertained many other interesting matters relating to fixed air, and completely verified and established the views of his predecessor. In 1765, Dr. Brownrigg also threw out some curious hints upon the same subject: in a communication to the Royal Society, printed in the *Transactions* for that year, he remarks, "that a more intimate acquaintance with those noxious airs in mines, called *damps*, might lead to a discovery of that subtile principle of mineral waters, known by the name of their *spirit*; that the mephitic exhalations termed *choak-damp*, he had found to be a fluid permanently elastic; and that, from various experiments, he had reason to conclude that it entered the waters of Pyrmont, Spa, and others, imparting to them that pungent taste, whence they are called *acidulæ*, and likewise that volatile principle in which their virtues chiefly depend;" and in 1769 †, Mr. Lane remarked the solubility of iron in water impregnated with fixed air.

Thus was it shewn, that one and the same prin-

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* Macbride's *Experimental Essays*, 1764. This author also improved the art of tanning. He was born in 1726, and died in 1778.

† *Phil. Trans.*

ciple renders the caustic alcalis mild, forms the choak-damp of mines, communicates briskness to mineral waters, and renders them capable of dissolving a portion of iron.

But the inquiries which have generally been considered as the main foundation of Dr. Black's scientific eminence, are those relating to the operation of heat in changing the state of bodies, as in converting solids into liquids, and liquids into vapours. The leading points of this investigation are amply detailed in the text, and an attentive consideration of the various difficulties it presented, of the simple means by which he overcame them, and of its intimate bearings upon a series of previously unexplained and ill understood appearances, gives it the stamp of a masterpiece of experimental philosophy.

The history of pneumatic chemistry next leads us to speak of the composition of the atmosphere, the first step to which was the discovery of nitrogen, made by Dr. Rutherford in 1772. He had found that when animals were confined in a portion of atmospheric air, they produced fixed, or mephitic air: this being removed by a caustic alcaline lixivium, he found the remainder to consist, in part, of an air which extinguished flame and destroyed life, though it did not, like fixed air, occasion a precipitate in lime-water.

The existence of two aëriform fluids, differing from common air, namely fixed or mephitic air, and nitrogen or azote, had now been established by Black and Rutherford: and various persons were engaged in prosecuting inquiries into this new branch of science, and slowly adding to our information upon it, when Dr. Priestley* entered this field of research, and with surprising rapidity gathered an abundant crop of curious and important discoveries. His attachment to chemistry seems to have been formed at Leeds, about 1768, where his attention was directed to the *doctrine of air*, in consequence of residing near a brewery, in which he used to amuse himself with experiments on the fixed air produced by fermentation. "When I removed from that house," says he (*Memoirs of His Own Life*, p. 60,) "I was under the necessity of making the fixed air for myself; and one experiment leading to another, as I have distinctly and faithfully noted in my various publications on the subject, I by degrees contrived

* Born at Fieldhead, near Leeds, 1733; died in Pennsylvania, 1804.

a convenient apparatus for the purpose, and of the cheapest kind." Dr. Priestley's first publication on this subject was in 1772, and related to the impregnation of water with fixed air; and in 1773, his *Observations on Different Kinds of Air* were read before the Royal Society. In this paper, which is crowded with new facts, he makes known the important influence of growing vegetables upon the purity of the atmosphere. Mayow and Hales had perhaps anticipated the discovery of nitrous gas, but its application to eudiometry was the sole invention of Priestley.

The importance of these researches now justly attracted the consideration of the council of the Royal Society, and in 1773 he was presented with Sir Godfrey Copley's medal, as a mark of the high opinion which that learned body entertained of them. Sir John Pringle, who was then President, delivered, on this occasion, an elaborate discourse on the different kinds of air, in which, alluding to the purification of a tainted atmosphere by vegetables, he thus expresses himself:

"From these discoveries we are assured that no vegetable grows in vain, but that, from the oak of the forest to the grass of the field, every individual plant is serviceable to mankind; if not always distinguished by some private virtue, yet making a part of the whole which cleanses and purifies our atmosphere. In this the fragrant rose and deadly nightshade co-operate; nor is the herbage, nor the woods that flourish in the most remote and unpeopled regions, unprofitable to us, nor we to them, considering how constantly the winds convey to them our vitiated air, for our relief and for their nourishment. And if ever these salutary gales rise to storms and hurricanes, let us still trace and revere the ways of a beneficent Being, who, not fortuitously, but with design, not in wrath, but in mercy, thus shakes the water and the air together, to bury in the deep those putrid and pestilential effluvia, which the vegetables on the face of the earth had been insufficient to consume."

Dr. Priestley entertained the idea that all factitious airs were noxious and unrespirable, and subsequent investigations have shewn that he was nearly correct. He also had remarked that they generally extinguished flame. In the year 1774, however, he disproved this opinion by the capital discovery of oxygen gas, which he procured from *red precipitate* and *red lead*. "What surprised me more than I can well express," he says, "was, that a candle burned in this air with a remarkably vigorous flame, very much like that enlarged flame with which a candle burns in nitrous air, exposed to iron, or liver of sulphur; but as I had got nothing like this remarkable appearance from any kind of air, besides this peculiar modification of nitrous air, and I knew no nitrous acid was used in the preparation of mercurius calcinatus, I was utterly at a loss how to account for it*." Priestley called this, *dephlogisticated* air, and to azote he gave the name of *phlogisticated* air, imagining that the former was deprived of, and the latter saturated with, phlogiston. Besides oxygen, Dr. Priestley discovered several other gases, and he was the first who collected ammonia, and sulphurous, and muriatic acid, over quicksilver.

In 1779, Bergman† published his "*Opuscula*," at Upsal, consisting of a collection of communications to various learned bodies, part of which have been translated into English, under the name of "*Physical and Chemical Essays*." Bergman was one of

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* *Experiments and Observations on Different Kinds of Air*. Vol. II. p. 107.

† Born in Sweden, 1735; died, 1784.

the first who prosecuted analytical chemistry with success; in his researches he entirely divested himself of every hypothetical consideration, and directed his undisturbed attention to the discovery of truth; his favourite motto was,

"Quod verum—curo et rogo, et omnis in hoc sum."

This principle he instilled into his very eminent pupil, Scheele*, to whom chemistry is doubly indebted; he was not only an original discoverer, but a sagacious theorist, as every one must readily allow who has perused his "*Chemical Observations and Experiments on Air and Fire*," and his numerous dissertations on insulated chemical subjects. He was the discoverer of baryta; of the existence of nitrogen in ammonia; of the method of obtaining citric and tartaric acids; and of chlorine; he obtained oxygen and nitrogen independent of any knowledge of the prior researches of Priestley and Rutherford; and in his Essays on Prussian Blue, on Milk, on the Acid Matter of Fruits, and on Ether, has shewn superior skill as an analyst, and great invention as an experimental chemist.

From the numerous inquiries of Priestley and Scheele, we turn to the important investigations of

* Born at Stralsund, 1742; died, 1786.

their contemporary, Cavendish*, a philosopher whose contributions to science have justly exalted his name to a high rank among the distinguished men of Britain, and who attained his eminence not so much from the number of his discoveries, as from their intrinsic value and unimpeachable accuracy. His experiments were subjected to numerous repetitions, and his opinions to the strictest examination, before he ventured to present them to the public eye, and as such they have remained unshaken and unimpaired, amidst the various revolutions which new and improved methods of investigation have lately brought upon chemistry. He furnishes a useful example to those who aim at distinction by the number, rather than the merit, of their contributions to science; who are led by novelty rather than truth; and who are continually obliged to retrace their steps, in consequence of the thoughtless haste of their proceedings.

Hydrogen, in its pure state, was first examined by Mr. Cavendish, and its properties described with a precision which at that time was peculiarly his own. In 1784, he gave a paper to the Royal Society, describing the results of the combustion of hydrogen

* Born in London, 1731; died, 1810.

with atmospheric air, and with oxygen, in which he shews that pure water is the only product, provided proper precautions be taken to ensure the purity of the gases, and the exclusion of foreign matters. In 1785, he proved, in a second communication, published in the *Philosophical Transactions,* that nitric acid consists of oxygen and azote, or, as it has since been termed, in consequence of this discovery, nitrogen. Thus, independent of their indirect influence and collateral importance, two great steps in chemistry were made by Mr. Cavendish; the discovery of the composition of water, and of nitric acid.

While the eminent persons whose discoveries have now been briefly recited, were thus actively employed in extending the boundaries of chemical science, it was receiving a most important accession of new facts from the celebrated, but unfortunate, Lavoisier*, a man whose active diligence tended to his success as an experimentalist, and whose discerning genius enabled him to employ to the utmost advantage, that which was discovered by his associates and contemporaries.

Lavoisier's principal contributions to chemistry

* Born in 1743; died, 1794.

will be found in his investigations respecting the nature of fixed air, which he proved to consist of charcoal and oxygen; and, by demonstrating the similarity of the results of the combustion of the diamond and charcoal, he shewed the identity of those apparently dissimilar bodies. In the year 1775, he collected the scattered and contradictory results of the numerous experiments that had been made respecting the nature of the atmosphere, and by new and severe investigation, proved the correctness of some, and the futility of others; he shewed it to consist of about eight parts, by measure, of oxygen gas, and forty-two of nitrogen; and found that a candle burned, and an animal breathed, in such an artificial mixture, precisely as in common air.

Lavoisier's fame has usually been erected upon his views of the phenomena of combustion, which he combined into what was termed the *Antiphlogistic Theory;* he asserted, that oxygen was necessarily present in every case of combustion, and referred the evolution of heat and light to the solidification of that gas; and he imagined that acidity could not exist without the presence of the same element; but these assumptions were not original, and subsequent inquiries have amply demonstrated their insufficiency and incorrectness.

The statical accuracy which Lavoisier introduced into chemical inquiry, the many original discoveries and inventions which he made, the zeal which he displayed in his philosophical pursuits, and the liberality with which he assisted and patronised those followers of science whom fortune had less favoured than himself, afford ample materials for those who would write a panegyric upon this eminent person.

Connected with the labours of Lavoisier is the celebrated reform of chemical nomenclature effected by him and his associates, among the most eminent of whom we may enumerate Guyton Morveau*, and Fourcroy†. The difficulties of such a task may be well imagined, and they were encountered with considerable address; and, it must be confessed, that, while it particularly tended to the dissemination of the antiphlogistic doctrines, it facilitated the general acquisition of the science; the ludicrous terms of the alchemists were rejected, and names founded upon the nature of compound bodies, and upon the leading qualities of elementary substances, became

* Born at Dijon, 1737; died, 1815.

† Born at Paris, 1755; died, 1809.

their more sensible substitutes. Had chemistry remained stationary, or nearly so, the French nomenclature, if not unobjectionable, would, at least, have been efficient: but, independent of those imperfections evinced by a reference to the philosophical principles of language, the plan was quite unsuitable to a branch of knowledge so eminently and rapidly progressive. The consequence is, that many of the terms, once unexceptionable, are now become, not merely objectionable, but absurd, and are only retained in consequence of the very serious inconvenience to which innovation necessarily tends. I have consequently, in the following pages, checked myself whenever I felt inclined to change old and accepted terms for those of more recent coinage; and, in the selection of names necessarily new, I have preferred such as are most analogous to those previously in use, being convinced that a partial reform would be useless; and a radical one, mischievous. For these reasons I have declined the adoption of Sir Humphry Davy's principles of nomenclature, to whose subjoined opinion, however, upon this subject I entirely subscribe *.

"Simplicity and precision ought to be the cha-

* *Elements of Chemical Philosophy*, pp. 46, 47.

racteristics of a scientific nomenclature; words should signify things, or the analogies of things, and not opinions. If all the elements were certainly known, the principle adopted by Lavoisier would have possessed an admirable application; but a substance in one age supposed to be simple, in another is proved to be compound; and *vice versâ*. A theoretical nomenclature is liable to continued alterations; *oxygenated muriatic acid* is as improper a name as *dephlogisticated marine acid*. Every school believes itself in the right; and if every school assumes to itself the liberty of altering the names of chemical substances, in consequence of new ideas of their composition or decomposition, there can be no permanency in the language of the science; it must always be confused and uncertain. Bodies which are similar to each other should always be classed together; and there is a presumption that their composition is analogous. Metals, earths, alcalies, are appropriate names for the bodies they represent, and independent of all speculative views; whereas, oxides, sulphurets, and muriates, are terms founded upon opinions of the composition of bodies, some of which have been already found erroneous. The least dangerous mode of giving a systematic form to a language, seems to be, to signify the analogies of substances by some common sign affixed to the beginning, or the termination of the word. Thus, as the metals have been distinguished by a termination in *um*, as *aurum*, so their calciform, or oxidated state, might have been denoted by a termination in *a*, as *aura*; and no progress, however great, in the science, could render it necessary that such a mode of appellation should be changed. Moreover, the principle of a composite nomenclature must always be very limited. It is scarcely possible to represent bodies consisting of five or six elements in this way, and yet it is in such difficult cases that a name implying a chemical truth would be most useful."

To those who will cast an eye upon chemical science, as left by Lavoisier, and upon its present improved state, I need offer no remarks upon its extraordinary and rapid advancement, upon the unremitting industry and penetrating research with which it has been lately pursued, nor upon the genius that has been displayed in its fertile and fascinating fields. The above sketch has been limited and succinct, in consequence of the bulk which this volume has acquired; but the student who wishes further details will find them in the sources I have quoted, and in a more extended view, which I have elsewhere published*.

The discoveries of contemporaries are, I hope, accurately enumerated in their proper places; in these prefatory remarks I have, for obvious reasons, declined even their enumeration; to do justice to their merits, and set forth in due terms their respective claims to the gratitude of their country and the respect of mankind, is a task to which many circumstances render me inadequate; one among them I am proud to acknowledge, which is the intimacy, friendship, or acquaintance, of the principal individuals alluded to.

* *Dissertation*, prefixed to the *Supplement of the Encyclopædia Britannica*.

A

MANUAL OF CHEMISTRY.

CHAPTER I.

Of the Powers and Properties of Matter, and of the general Laws of chemical Changes.

1. CHEMISTRY takes cognizance of all changes in the constitution of matter, whether effected by heat, mixture, or other means. Its general range, therefore, is so extensive, and the individual cases, requiring explanation, so numerous, that *Arrangement* is of the first consequence to its successful study; and, in the present state of our knowledge, it will be found most convenient to begin with the discussions relating to the general powers or properties of matter, and afterwards to proceed to the examination of individual substances, and to the phenomena which they offer when presented to each other under circumstances favourable to the exertion of their mutual chemical agencies.

2. The powers and properties of matter, connected with chemical changes, may be considered under the heads of

1. Attraction.
2. Heat.
3. Electricity.

Section I. ATTRACTION.

3. Attraction may be regarded as acting at sensible and at insensible distances. In the former case, it is called *gravitation.* It is the power by which substances are propelled towards the earth; it exists in all known forms of matter, and acts directly as the mass, and inversely as the square of the distance: And, when restrained by *inertia*, it preserves the planetary bodies in their orbits, presides over their movements, and tends to confer upon the system of the universe that consummate harmony which the genius of Newton has unveiled.

4. Attraction is also exerted at insensible distances, and among the minutest atoms of matter. It thus preserves the form and modifies the texture of solids, gives a spherical figure to fluids, and influences the mechanical characters of bodies; and, when it operates upon *dissimilar* particles, it produces their union, giving rise to new and infinitely varied productions.

5. The results of attraction, as relating to the forms of matter, are influenced by the circumstances under which it has taken place. Sometimes the particles are, as it were, indiscriminately collected; in other cases they are beautifully arranged, giving rise to regular and determinate figures. In this case, bodies of the same composition invariably affect the same form; hence we are often enabled to infer the composition of a substance from accurate inspection of its external or mechanical characters.

6. The regular polyhedral solids thus resulting from the influence of attraction upon certain kinds of matter, are usually called *crystals,* and the bodies are said to be susceptible of *crystallization.*

7. To enable the particles of bodies to assume that regular form which crystals exhibit, it is obvious, that they must have freedom of motion; and, accordingly, the first step towards

obtaining a body in its crystalline form, is to confer upon it either the liquid or aëriform state. The former is usually effected by solution in water; the latter by exposure to heat. When common salt is dissolved in water, its particles may be regarded as disposed at regular distances throughout the fluid; and if the quantity of water be considerable, the particles will be too far asunder to exert reciprocal attraction; in other words, they will be more powerfully attracted by the water than by each other. If we now slowly get rid of a portion of the water by evaporation, the saline particles will gradually approach each other, and they will aggregate according to certain laws, producing a regular solid of a cubic form.

8. The regularity of this figure will be influenced by the rapidity of the evaporation; if the process be slowly conducted, the particles unite with great regularity; if hurried, the crystals are irregular and confused. In common cases, the evaporation may be continued till a pellicle forms upon the surface of the solution, which indicates, that the attraction of the saline particles for each other, is becoming superior to their attraction for the water. The formation, therefore, of a superficial pellicle is the common criterion of the fitness of a solution for crystallization; but where the object is to obtain very regular and very large crystals, the evaporation must be much slower, and carried to much less extent; even spontaneous evaporation, or that which takes place at common temperatures, must be resorted to.

9. There are certain bodies which may be dissolved or liquefied by heat, and during slow cooling, may be made to crystallize. This is the case with many of the metals, and with sulphur. Some other substances, when heated, readily assume the state of vapour, and, during condensation, present regular crystalline forms, such as iodine, benzoic acid, camphor, *&c.*

10. The hardness, brilliancy, and transparency of crystals, often

depend upon their containing water, which sometimes exists in them in large quantities. Thus, sulphate of soda, in the state of crystals, contains more than half its weight. This is called *water of crystallization.* Some salts part with it by simple exposure to a dry air, when they are said to *effloresce*; but there are other salts which *deliquesce,* or attract water from the atmosphere.

11. Crystallization is accelerated, by introducing into the solution a nucleus, or solid body, upon which the process begins; and manufacturers often avail themselves of this circumstance. Thus we see sugar-candy crystallized upon strings, and verdigris upon sticks. There are cases in which it is particularly advantageous to put a few crystals of the dissolved salt into the solution, which soon cause a crop of fresh crystals; and in some instances, if there be two salts in solution, that will most readily separate, of which the crystals have been introduced.

12. A strong saline solution, excluded from the air, will frequently crystallize the instant that air is admitted,—a circumstance referred to atmospheric pressure. In other cases, agitation produces the same effect. These phenomena seem connected with the doctrine of latent heat.

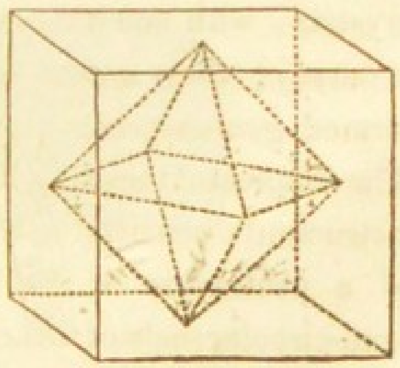
13. The presence of light also influences the process of crystallization. Thus we see the crystals collected in camphor bottles in druggists' windows always most copious upon the surface exposed to light; and if we set a solution of nitre in a room which has the light admitted only through a small hole in the window-shutter, crystals will form most abundantly upon the side of the basin exposed to the aperture through which the light enters.

14. We may now proceed to examine the structure of crystallized bodies, upon which the *Theories of Crystallization* are founded. This inquiry exposes a connecting link between Chemical and Mechanical properties of bodies.

It is commonly observed, that crystallized bodies affect one form in preference to others. The fluor spar of Derbyshire crystallizes in cubes: so does common salt. Nitre assumes the form of a six-sided prism, and sulphate of magnesia that of a four-sided prism. These forms are liable to vary. Fluor spar and salt crystallize sometimes in the form of octoëdra, and there are so many forms of carbonate of lime, that it is difficult to select that which most commonly occurs.

Romé de Lisle referred these variations of form to certain truncations of an invariable primitive nucleus; and Gahn afterwards observed, that when a piece of calcareous spar was carefully broken, all its particles were of a rhomboidal figure. This induced Bergman to suspect the existence of a primitive nucleus in all crystallized bodies*. When Haüy† entered this field of inquiry, he not only corroborated the opinions of Bergman, and submitted former hypotheses to experimental proof, but traced with much success the laws of crystallization, and pointed out the modes of transition from primitive to secondary figures.

Those who are in the habit of cutting and polishing certain gems, have long known that they only afford smooth surfaces when broken in one direction; and that in others the fracture is irregular and uneven. This is the case with crystallized bodies in general. If we attempt to split a cube of fluor spar with the blade of a knife, assisted by a hammer, we shall find that it will only yield kindly in the direction of the solid angles; and pursuing the division in these directions, an octoëdron will be the resulting figure, as in this diagram.

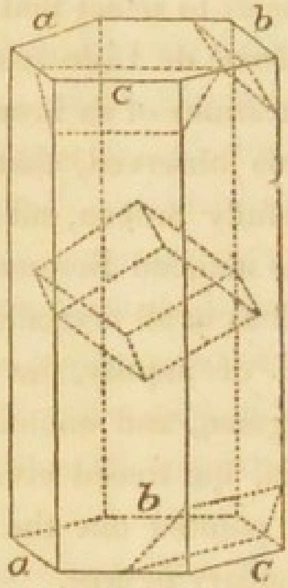


In splitting a six-sided crystal of calcareous spar, we find that, of the six edges of the superior base, three alternate

* *Physical and Chemical Essays.* Vol. II. p. 1.

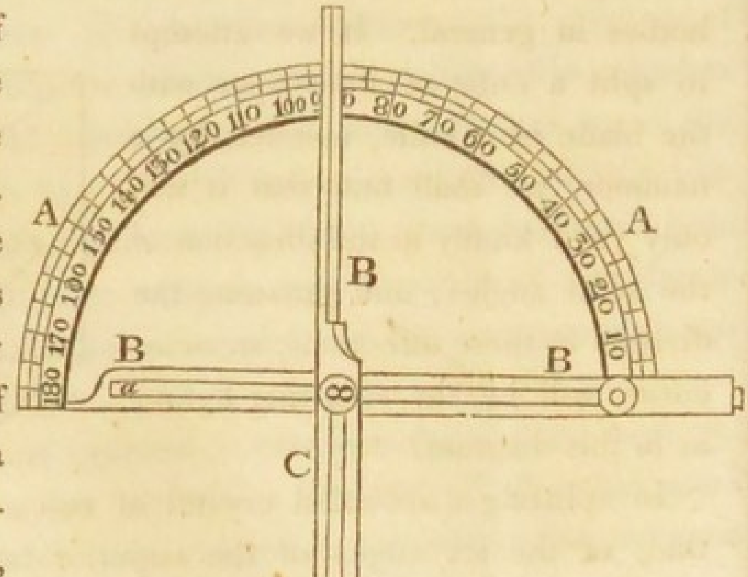
† *Traité de Mineralogie.* Paris, 1801.

edges only will yield to the blow: those, for instance, marked *a, b, c;* and the division will take place in a plane inclined at an angle of 45°. The three intermediate edges resist this division. But in dissecting the inferior base of the crystal, the intermediate edges will alone yield, namely, *a, b, c*. If we continue this dissection in the same directions, we shall at length obtain the obtuse rhomboid, which is seen in this diagram in its relative situation to the including prism.



We thus then arrive at the *primitive form* of the calcareous spar, and from whatever secondary form it has been obtained, it is always a rhomboid, having obtuse angles of 105° 5′. But an obtuse rhomboid is also the primitive form of other bodies, as of pearl spar, iron spar, and tourmalin. But here the inclination of the surface points out a difference. Thus the primitive angle of pearl spar is 106° 5′, of iron spar 107°*, and of tourmalin 113° 10′.

15. These instances show the necessity of being provided with instruments for measuring the angles of crystals with nice accuracy; they are termed *goniometers.* The simplest of these instruments consists of a protractor or semi-circular scale of degrees, A A, and a small pair of compasses or nippers, B B B B, destined to receive the crystal.



* Wollaston. *Phil. Trans.* 1812.

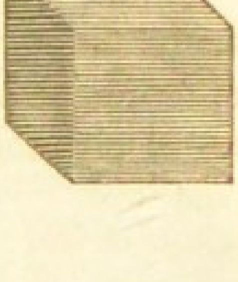
The centre of the pair of compasses is made moveable like those of the common proportional compasses, so as to permit the legs B B, and B C B, to be considerably lengthened or shortened, when the two pieces are applied to each other. The fixed leg B B, is represented as beneath the moveable one B C B, or radius, measuring 90 degrees, and the lower end of the centre pin, which could not be shown in the wood cut, is made to fit the hole or centre in the protractor precisely at the same time that the stud or projecting piece of brass, being admitted into the long perforation *a* of the leg B B, the piece becomes steadily attached to the protractor or semi-circle, as is seen in the Figure.

The application of this instrument is obvious. The crystal to be measured is applied between the compasses, which being thus set, are applied to the protractor, and the value of the angle may be read off at the fiducial edge of the leg B C B.

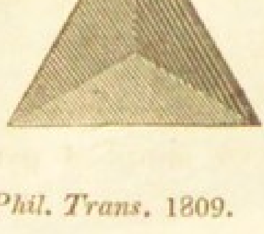
The reflective goniometer, invented by Dr. Wollaston *, is the most useful of these instruments. It enables us to determine the angles even of minute crystals with great accuracy; a ray of light reflected from the surface of the crystal being employed as radius, instead of the surface itself.

16. In following the method above described, Haüy obtained six *primitive* forms.

1. The cube, parallelopipedon, &c.

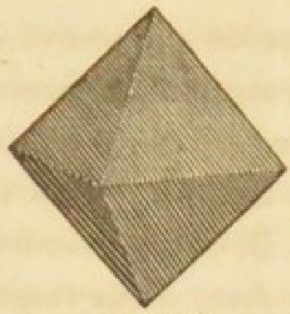


2. The tetraëdron.



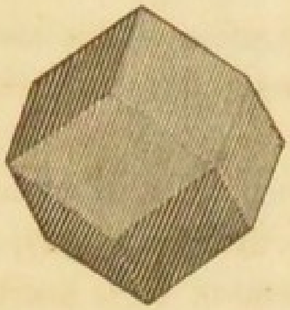
* *Phil. Trans.* 1809.

3. The octoëdron.

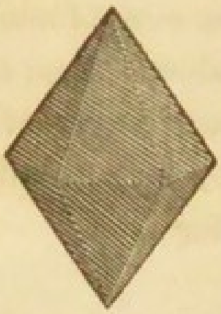


4. The hexangular prism.

5. The rhombic dodecaëdron.



6. The dodecaëdron with triangular faces.



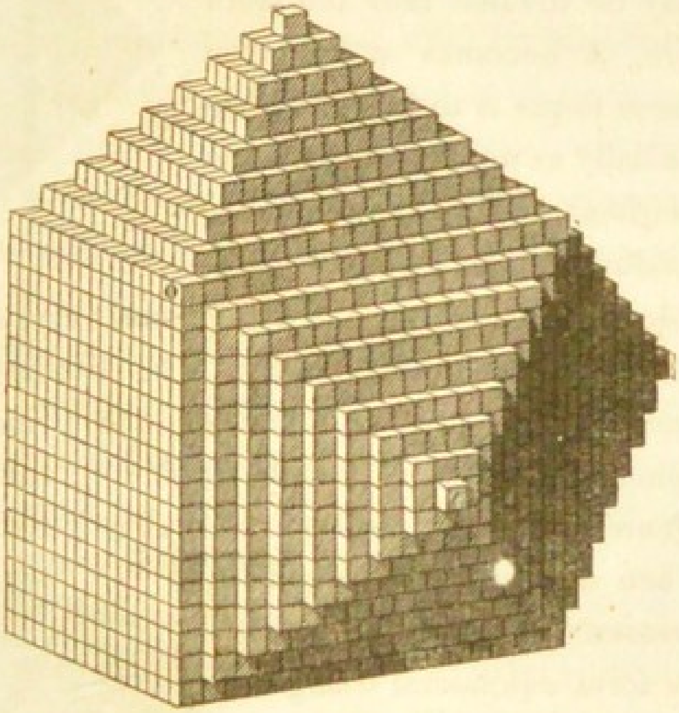
These primitive forms, by further mechanical analysis, may be reduced to three *integral elements.*

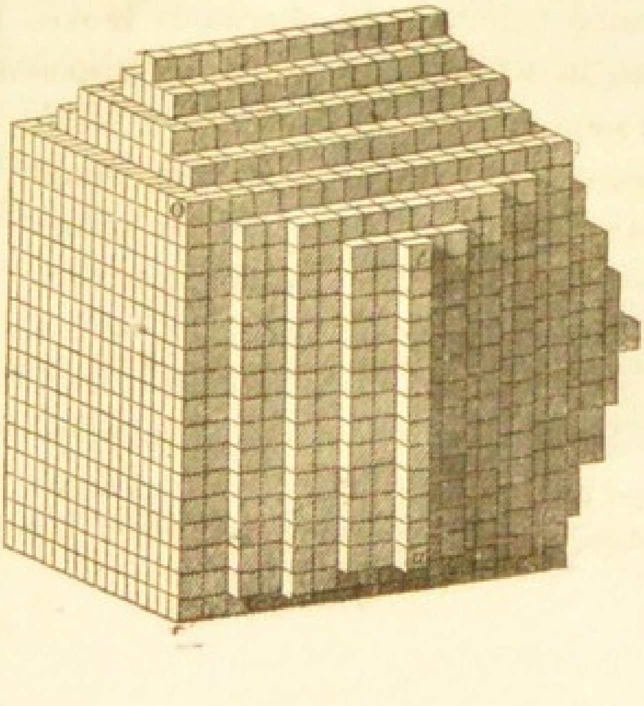
1. The parallelopiped, or simplest solid, having six surfaces, parallel two and two.

2. The triangular, or simplest prism, bounded by five surfaces.

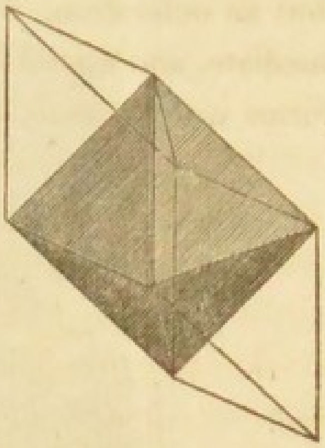
3. The tetraëdron, or simplest pyramid, bounded by four surfaces.

17. The *secondary* forms are supposed to arise from decrements of particles taking place on different edges and angles of the primitive forms. Thus a cube, having a series of decreasing layers of cubic particles upon each of its six faces, will become a dodecaëdron, if the decrement be upon the edges; but an octoëdron, if upon the angles; and by irregular, intermediate, and mixed decrements, an infinite variety of secondary forms would ensue, as the annexed figures shew.

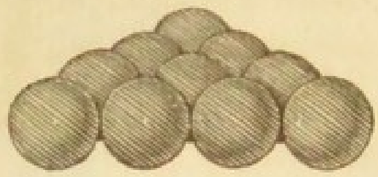


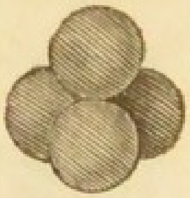


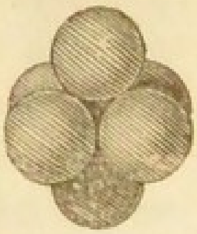
18. But in crystallography we meet with appearances which Haüy's theory but imperfectly explains. A slice of fluor spar, for instance, obtained by making two successive and parallel sections, may be divided into acute rhomboids; but these are not the primitive form of the spar, because by the removal of a tetraëdron from each extremity of the rhomboid an octoëdron is obtained. Thus, as the whole mass of fluor may be divided into tetraëdra and octoëdra, it becomes a question which of these forms is to be called primitive, especially as neither of them can fill space without leaving vacuities, nor can they produce any arrangement sufficiently stable to form the basis of a permanent crystal.



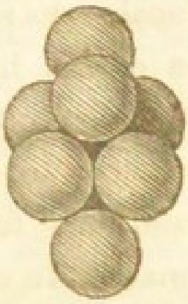
19. To obviate this incongruity, Dr. Wollaston * has very ingeniously proposed to consider the primitive particles as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. When a number of similar balls are pressed together in the same plane, they form equilateral triangles with each other; and if balls so placed were cemented together and afterwards broken asunder, the straight lines in which they would be disposed to separate, would form angles of 60° with each other. A single ball, placed any where on this stratum, would touch three of the lower balls, and the planes touching their surfaces would then include a regular tetraëdron. A square of four balls, with a single ball resting upon the centre of each surface, would form an octoëdron, and upon applying two other balls at opposite sides of this octo





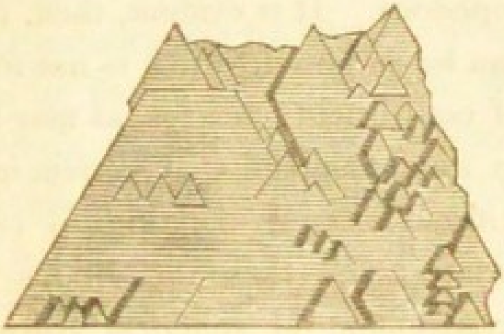


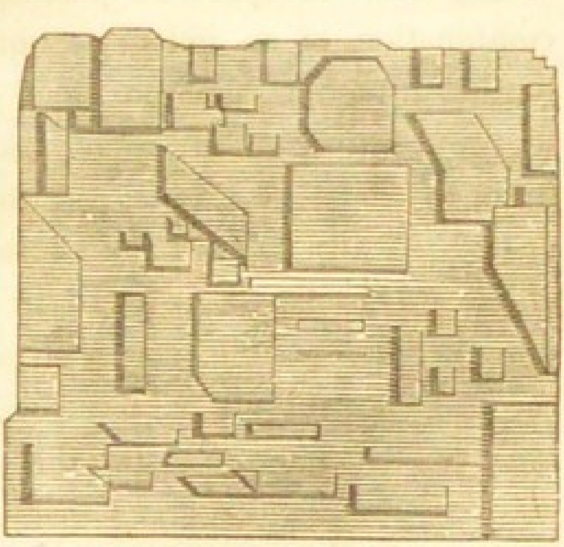
* *Phil. Trans.* 1813.



ëdron, the group will represent the acute rhomboid. Thus the difficulty of the primitive form of fluor, above alluded to, is done away, by assuming a sphere as the ultimate molecula. By oblate and oblong spheroids other forms may be obtained.

20. The subject of crystallization has more lately engaged the attention of Mr. J. F. Daniell *, and his researches have produced some singular confirmations of Dr. Wollaston's hypothesis. If an amorphous piece of alum be immersed in water, and left quietly to dissolve, at the end of about three weeks we shall observe that it has been unequally acted upon by the fluid: the mass will present the forms of octoëdra, and sections of octoëdra, as it were carved or stamped upon its surface, as seen in these figures:





This appearance is produced when the attraction of the water for the solid is nearly counterbalanced by its mechanical texture. The crystals produced by this species of dissection, are highly curious from their modifications and relative positions, as the same group presents the primitive form as well as its truncations and decrements. Other salts yield other figures, and by more complicated chemical action, as of acids upon carbonate of lime, the metals, *&c.*,

* *Quarterly Journal of Science and the Arts*, Vol. 1.

analogous results are obtained. Here, then, instead of dividing a crystal by mechanical force, its structure is gradually developed by the process of solution. In these cases two circumstances are particularly remarkable: the crystals are different; and their forms vary with the different faces of the original mass. In one direction we observe octoëdra and sections of octoëdra; in another, parallelograms of every dimension, modified with certain determinate intersections.

If, in either of these positions, we turn the mass upon its axis, the same figures will be perceived at every quadrant of a circle; and, if we suppose the planes continued, they will mutually intersect each other, and various geometrical solids will be constructed. In this way, alum alone furnishes octoëdrons, tetraëdrons, cubes, four and eight-sided prisms either with plain or pyramidal terminations, and rhombic parallelopipedons. It is evident, then, that no theory of crystallization can be admitted, which is not founded upon such a disposition of constituent particles, as may furnish all these modifications, by mere abstraction of certain individuals from the congeries, without altering the original relative position of those which remain; and these conditions may be fulfilled by such an arrangement of spherical particles, as would arise from the combination of an indefinite number of balls endued with mutual attraction, and no other geometrical solid is adequate to the purpose; and where bodies afford crystals differing from the octoëdral series, an analogous explanation is furnished, by supposing their constituent particles to consist of oblate spheroids, whose axes bear different proportions to each other in different substances. Hence we may also conclude, that the internal structure of all crystals of the same body is alike, however the external shapes differ. In corroboration of the above hypothesis, we may remark, that the hexaëdron is, of all geometrical figures, that which includes the greatest capacity under the least surface. If, therefore, the ultimate particles of crystalline bodies be spheres or spheroids, the greatest possible number in the least space will be included in this form. It is probable that the exterior shape of every crystal is determined by the nucleus first formed by a certain definite number of particles, which, by the power of mutual attraction, overcome the resistance of the medium in which they were suspended, or from which they were separated. This number may vary with the solvent, or other contingent circumstances. Four spherical particles, thus united, would balance each other in a tetraëdral group, six in an octoëdral group, and each would present particular points of attraction to which all subsequent deposits would be directed. Now, let us imagine two nuclei formed in the same solution, whose axes run in contrary directions; their increase will consequently be in contrary directions, and each will attract a particular system of particles from the surrounding medium. If these two systems should cross each other in their course, a greater number will be brought within the sphere of mutual reaction at the point of junction, and they ought to arrange themselves in the least possible compass. The facts here answer to the theory. If we select any crystals, having others crossing them nearly at right angles, and separate them, the points of junction invariably present an hexaëdral arrangement.

21. In connexion with chemistry, the theory of crystallization opens a new avenue to the science, and frequently enables us to ascertain directly, that which independent of such aids, could only be arrived at by an indirect and circuitous route. We frequently read the chemical nature of substances in their mechanical forms. To the mineralogist, an intimate acquaintance with the crystalline forms and modifications of natural bodies is essentially requisite. Indeed, the theory of crystallization may be considered as one of the great supports of that useful branch of natural history, and it is to the indefatigable exertions of Haüy that much of its present perfection is to be

referred. In the arts, the process of crystallization is turned to very valuable account, in the separation and purification of a variety of substances.

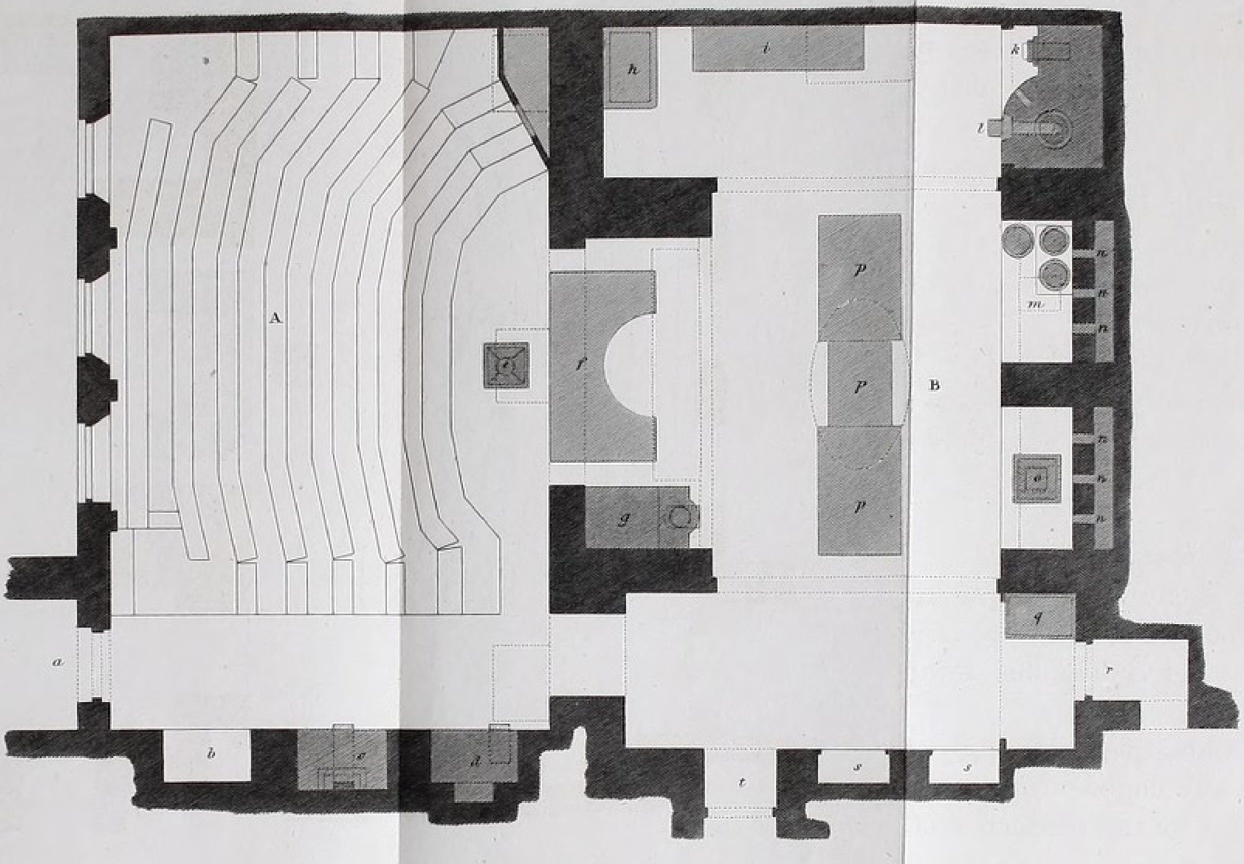
22. We have hitherto considered Attraction as disposing the particles of bodies to adhere, so as to form masses or aggregates, and, in many instances, to arrange themselves according to peculiar laws, and to assume regular geometrical figures. We are now to regard this power as operating upon dissimilar particles, as presiding over the composition of bodies, and as producing their chemical varieties. This is Chemical Attraction or Affinity.

23. If, into a glass vessel, exhausted of air, be introduced some sulphur, and copper filings, and heat be applied so as to melt the former, it will presently combine with the latter. We observe, as the results of this attraction between the sulphur and copper, 1. That the substance produced has not the intermediate properties of its elements, but that it presents new characters. 2. That much heat and light are evolved during the mutual action. 3. That sulphur and copper will unite in certain proportions only.

In liquids and gases, similar changes of properties may be exhibited, and, in many cases, a change of form or state results. Thus the combination of aëriform bodies produces a solid, as when muriatic and ammoniacal gases produce the solid salt called muriate of ammonia. Solids also produce liquids, as is shewn by triturating crystals of Glauber's salt with nitrate of ammonia; and liquids produce gases, as when one part of nitric acid is mixed with two of alcohol.

24. In some cases of chemical combination, the resulting compound differs but little from its component parts, and their leading characters are still obvious in it. This is often remarked in the mixture of different gaseous bodies, and in solutions of different substances in water and other fluids.

In other cases, the properties of the compound differ essen-



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Plan of the Laboratory in the Royal Institution.

Published by John Murray, Albemarle Street, London, 1818.

tially from those of its component parts, and a series of new bodies, possessed of distinct and peculiar characters, are produced. Such operations are not confined to art. Nature presents them on an extended scale; and, in connexion with the functions of life, renders them subservient to the most exalted purposes.

25. The new chemical powers, therefore, that bodies acquire in consequence of combination, are often extremely remarkable, and can only be learned by *experiment*. It frequently happens that inert bodies produce inert compounds, and that active substances remain active when combined; but the reverse often occurs. Thus oxygen, sulphur, and water, in themselves tasteless and comparatively inert, produce *oil of vitriol* when chemically combined; and potash, which is a powerful caustic, when combined with oil of vitriol forms a *salt* possessed of little activity. The colours, and specific gravity and temperature of bodies are also commonly altered by chemical action. Thus the *blue* infusion obtained by macerating violets in warm water is rendered *red* by acids, *green* by alcalis, and its *colour is wholly destroyed* by chlorine. When equal parts of oil of vitriol and water are mixed, the resulting liquid has a specific gravity much above the mean; the temperature is also much increased; and ignition frequently attends chemical action. (23.)

26. As chemical action takes place among the ultimate or constituent elements of bodies, it must obviously be opposed by the cohesion of their particles, and chemical attraction is often prevented by mechanical aggregation. A piece of the metal antimony, put into the gas called chlorine, is only slowly and superficially acted upon; but if the mechanical aggregation be previously diminished, by reducing the metal to powder, it in that state rapidly unites with the gas, and burns the instant that it is introduced.

27. Heat increases the chemical energies of bodies. Its effects are sometimes only referable to the diminution of adhesion by expansion, but in other cases are peculiar and complicated, as will be shown under the sections on HEAT and ELECTRICITY.

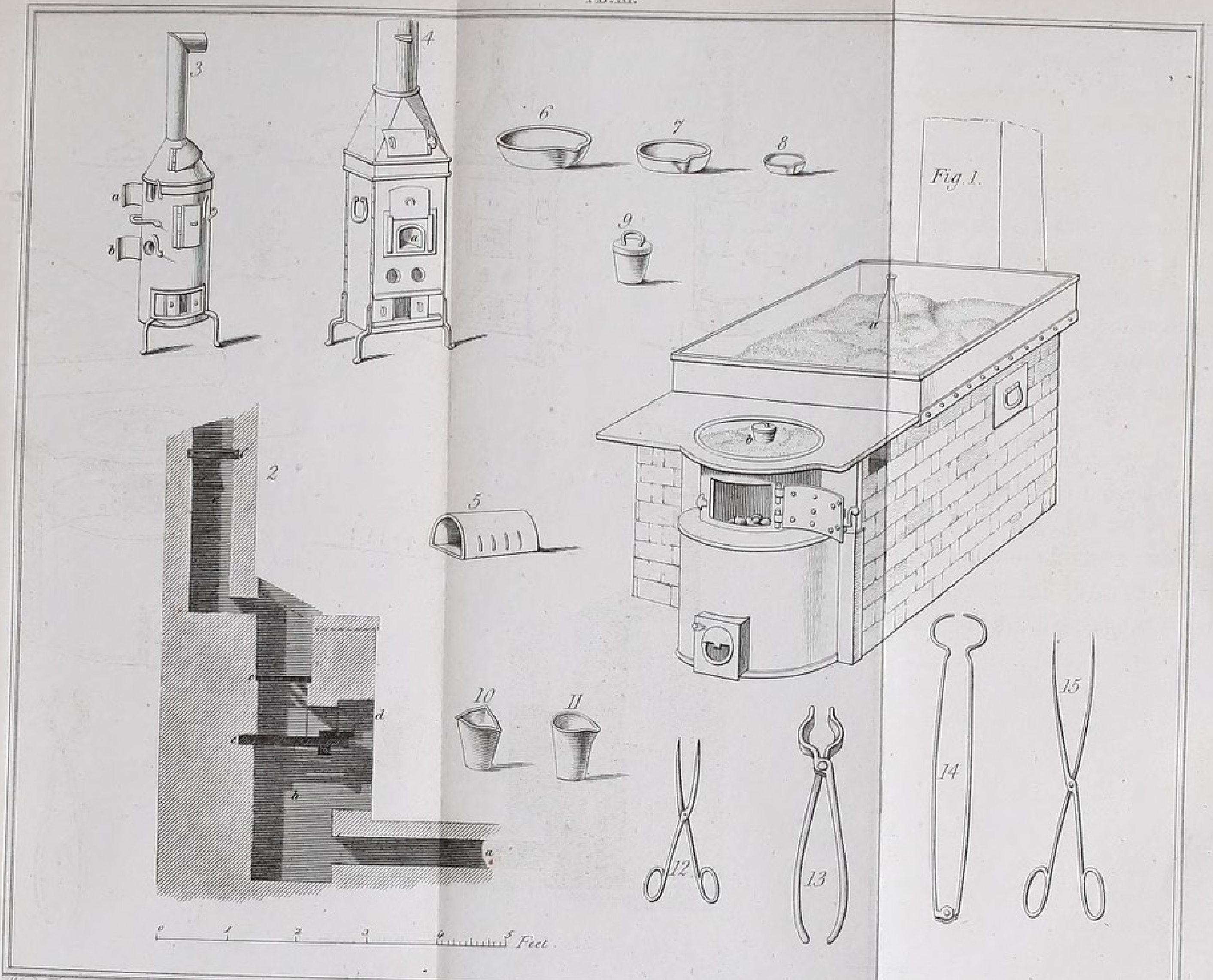
28. Different bodies are possessed of different attractive powers, and if several be brought together, those which have the strongest mutual affinities enter first into union. Thus, if nitric acid be poured upon a mixture of lime and magnesia, it dissolves the former in preference to the latter earth. The knowledge of this fact enables us to separate bodies when united, or to perform the process of *decomposition*. Thus, if I add an aqueous solution of lime to a solution of magnesia in nitric acid, the latter earth is thrown down or precipitated, and the lime occupies its place in the acid.

29. Decomposition is effected under a variety of circumstances, and by many methods; but it is commonly described by chemists as SIMPLE and COMPLEX, or SINGLE and DOUBLE.

In cases of simple attraction or affinity, one body separates another from its combination with a third. Thus, when potash is added to a solution of sulphate of zinc (composed of sulphuric acid and oxide of zinc), the oxide of zinc is separated, and sulphate of potash is produced.

In cases of double decomposition, two new compounds are produced; as when a solution of nitrate of baryta is mixed with solution of sulphate of soda, the results are a precipitate of sulphate of baryta, and a solution of nitrate of soda.

These cases of double decomposition are sometimes conveniently illustrated by diagrams which may either be constructed so as merely to shew the result of the change, or where required, they may also exhibit the composition of the acting bodies. In the case just alluded to, the substances



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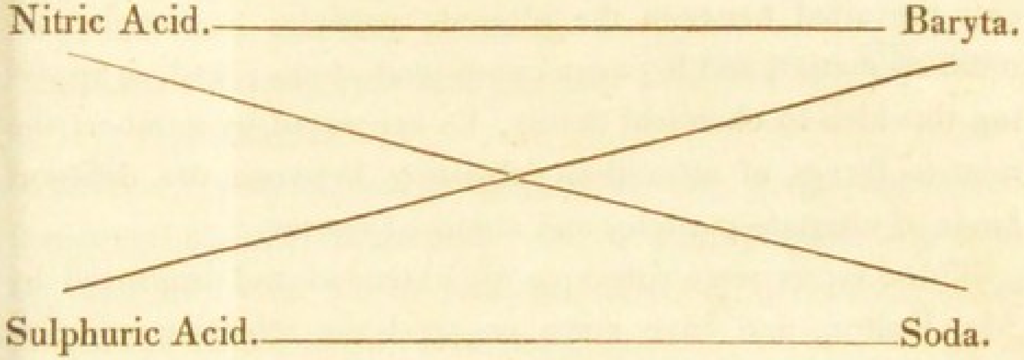
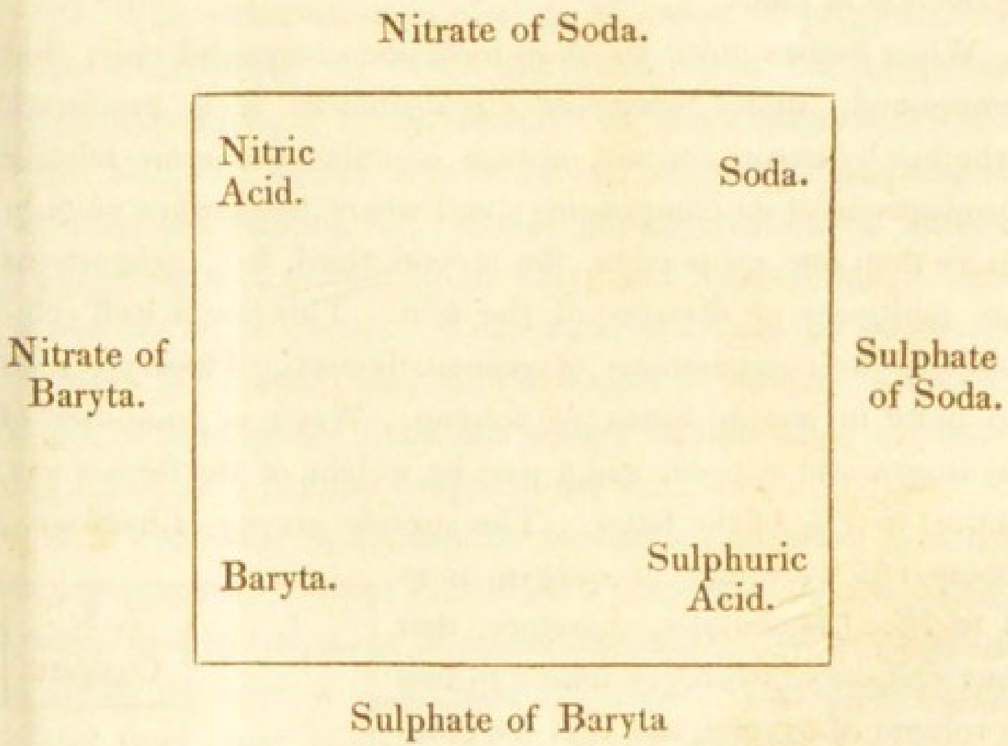
before mixture are shewn by parallel lines, and after mixture by diagonal lines.



Or a more complete view of the change is given in the following diagram, where the bodies before mixture are placed upon the outside of the perpendicular lines; their component parts are shewn within them, and the new results on the outside of the horizontal lines.



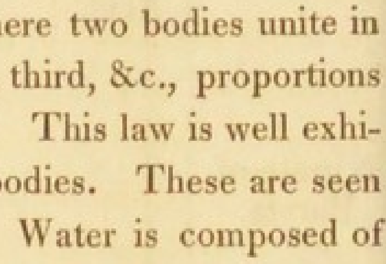
30. It is obvious, from the uniform results of chemical action, that affinity must be governed by certain definite laws,

by which its results are determined, and upon which its uniformity depends. Attention was first called to this subject by Mr. Higgins in 1789. He conceived that chemical attraction only prevailed between the ultimate particles of simple elementary matter, and between compound atoms; and, in applying this idea to chemical theory, he expressed by numbers the relative forces of attraction subsisting between the different kinds of ultimate particles and atoms of matter.

These views were subsequently extended and improved by Mr. Dalton, and have since engaged the attention of some most eminent chemical philosophers; among whom we may enumerate Gay Lussac and Berzelius, Davy, Wollaston, and Thomson.

The atomic doctrine, or theory of definite proportionals, has been much blended with hypothetical views; but it will be most satisfactorily and usefully considered as an independent collection of facts.

When bodies unite so as to form one compound only, that compound, under whatever circumstances it is produced, whether by nature or art, always contains the same relative proportions of its components; and where two bodies unite in more than one proportion, the second, third, &c., proportions are multiples or divisors of the first. This law is well exhibited in the combinations of gaseous bodies. These are seen to unite in simple ratios of volume. Water is composed of hydrogen and oxygen, and 1 part by weight of the former gas, unites to 7,5 of the latter. The specific gravity of hydrogen, compared with that of oxygen, is as 1 to 15: it is obvious, therefore, that one volume of hydrogen unites to half a volume of oxygen, and that the composition of water will be represented by weight and volume thus:



Muriatic acid gas consists of 1 part by weight of hydrogen, and 33,5 by weight of chlorine. The relative specific gravities of these gases are as 1 to 33,5. It is obvious, therefore, that they combine in equal volumes, and that muriatic acid gas may be thus represented.

1.	3 3, 5.
Hydrogen.	Chlorine.

Carbonic acid unites to potash in two proportions, and forms two definite compounds. In the one, 70 parts of potash are combined with 30 of carbonic acid; in the other, 70 of potash are united to 60 of carbonic acid.

Lead combines with oxygen in three proportions; the first compound consists of 100 lead + 8 oxygen, the second of 100 + 12, the third of 100 + 16.

Bodies are always obedient to these laws of union; and, in whatever way they are produced, their component parts exist in the same relative proportions.

31. This observation applies to all cases of energetic chemical combination, in which the qualities of the component parts are no longer to be detected in the compound; for in some instances bodies may be said to unite in all proportions, as water and alcohol, &c. Other bodies combine in all proportions up to a certain point only, and beyond that, combination no longer ensues. Thus water will take up successive portions of common salt, until at length it refuses to take up more, or is *saturated;* and this always occurs when the water has dissolved a definite weight of the salt.

32. The term *neutralization* is applied to cases in which bodies mutually disguise each other's properties, as is especially exemplified in the union of acids with alcalis; as of sulphuric acid, for instance, with solution of potash. The acid reddens violet juice, and is sour. The potash converts the blue to green, and is acrid. If the acid solution be gradually added to the alcaline, we shall find that at a certain point the taste will neither be acid nor acrid, but slightly saline and bitter, nor will there be any effect produced upon the vegetable blue.

Thus the acid is neutralized by the alcali, and the compound has been termed a *neutral salt*.

33. When we have ascertained the proportion in which any two or more bodies of one class, A. B. C., neutralize another body X of a different class, it will be found that the same relative proportion of A. B. C. &c., will be required to neutralize any other body of the same class as X. Thus since 100 parts of sulphuric acid, and 68 (omitting fractions) of muriatic acid, neutralize 118 of potash, and since 100 of sulphuric acid neutralize 71 of lime, we may infer that 68 of muriatic acid will also neutralize 71 of lime.

34. If the quantities of two bodies A and B, that are necessary to saturate a given weight of a third body, be represented by q and r, these quantities may be called *equivalents*. Thus in the above example (33), 100 parts of sulphuric acid and 68 of muriatic acid, are *equivalents* of each other. A column of equivalent numbers, of great use in chemical calculations, will be found in the tables inserted in another part of this work. By adapting a table of this sort to a moveable scale, on the principle of Gunter's sliding rule, Dr. Wollaston has constructed a logometric scale of chemical equivalents, which is capable of solving with great facility, many problems of chemistry. (Phil. Trans. 1814.)

35. By prosecuting chemical analysis, we arrive at a certain number of *principles* or *elements*, that is, of bodies which have not hitherto been decomposed.

The nature of compound bodies is demonstrated by two kinds of proof—*synthesis* and *analysis*. Synthesis consists in effecting the chemical union of two or more bodies, which by analysis are again separated from each other. The term *proximate analysis* has been applied to the separation of two bodies which are themselves compounded; and *ultimate analysis* to the farther separation of these compounds into their components. The composition of blue vitriol is *synthetically* demonstrated by *uniting* sulphuric acid to oxide of copper—

analytically, by *separating* these *proximate* elements from each other. But the sulphuric acid consists of sulphur and oxygen; and oxide of copper consists of copper and oxygen. Consequently, we should say that the *ultimate* component parts of blue vitriol are copper, sulphur, and oxygen.

Section II. HEAT.

36. Heat may be considered as a power opposed to attraction, for it tends to separate the particles of bodies; and whenever a body is heated, it is also expanded. Expansion is the most obvious and familiar effect of heat; and it takes place, though in different degrees, in all forms of matter. Solids are the least expansible,—liquids expand more readily than solids,—and gases or aëriform bodies more than liquids. When a body has been expanded by heat, it regains its former dimensions when cooled to its former temperature.

37. Different bodies expand differently when equally heated. The metals are the most expansible solids; but among them, zinc expands more than iron, and iron more than platinum.

The following Table shews the relative expansibility of some of the metals, when their temperature is raised from the freezing to the boiling point of water.

Temperature.	Platinum.	Steel.	Iron.
32°	120000	120000	120000
212°	120104	120147	120151
Temperature.	Copper.	Brass.	Tin.
32°	120000	120000	120000
212°	120204	120230	120290
Temperature.	Lead.	Zinc.	
32°	120000	120000	
212°	120345	120360	

38. Liquids differ also in their relative expansibilities: ether is more expansible than spirit of wine, and spirit more than water, and water more than mercury. Those liquids are generally most expansible which boil at the lowest temperature.

The following Table shews the rate of expansion of several liquids :

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpen.	Alcohol.
32°	100000	100000	—	—	—	—	100000
40	100081	—	99752	99514	—	—	100539
50	100183	—	100000	100000	100023	100000	101105
60	100304	—	100279	100486	100091	100460	101688
70	100406	—	100558	100990	100197	100993	102281
80	100508	—	100806	101530	100332	101471	102890
90	100610	—	101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104162
110	100813	—	101540	103196	—	102943	—
120	100915	—	101834	103776	101404	103421	—
130	101017	—	102097	104352	—	103954	—
140	101119	—	102320	105132	—	104573	—
150	101220	—	102614	—	102017	—	—
160	101322	—	102893	—	—	—	—
170	101424	—	103116	—	—	—	—
180	101526	—	103339	—	—	—	—
190	101628	—	103587	—	103617	—	—
200	101730	—	103911	—	—	—	—
212	101835	107250	—	—	104577	—	—

39. In all pure gaseous bodies, the rate of expansion for similar increase of temperature is similar: 100 measures of air, when heated from the freezing to the boiling point of water, suffer an increase in bulk=37, 5 parts at mean pressure.

The experiments of Gay Lussac have proved that steam, and all vapours, are subject to laws of expansion similar to those of air—hence the following Table, shewing the changes of bulk suffered by 100000 parts of air at all temperatures between 32° and 212°, will apply equally to all gases and vapours, and will often be found useful to the practical Chemist.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	59°	105616	86°	111232
33	100208	60	105824	87	111440
34	100416	61	106032	88	111648
35	100624	62	106240	89	111856
36	100833	63	106448	90	112064
37	101040	64	106656	91	112272
38	101248	65	106864	92	112480
39	101459	66	107072	93	112688
40	101666	67	107280	94	112896
41	101872	68	107488	95	113104
42	102080	69	107696	96	113312
43	102290	70	107904	97	113520
44	102496	71	108112	98	113728
45	102708	72	108320	99	113936
46	102916	73	108528	100	114144
47	103124	74	108736	110	116224
48	103333	75	108944	120	118304
49	103536	76	109152	130	120384
50	103749	77	109360	140	122464
51	103952	78	109568	150	124544
52	104166	79	109776	160	126624
53	104368	80	109984	170	128704
54	104576	81	110192	180	130784
55	104791	82	110400	190	132864
56	104992	83	110608	200	134944
57	105200	84	110816	210	137024
58	105408	85	111024	212	137440

The expansion of liquids is not equable for equal additions of heat at different temperatures. Thus the addition of 5° of heat to alcohol at 40°, will produce a less relative increase of bulk than the same addition of heat to alcohol of 100°; and in general the nearer a liquid approaches its boiling point, the greater is its expansibility. Those liquids therefore appear most equably expansible which have the highest boiling points, and hence one of the great advantages of mercury, as will presently be seen, in constructing thermometers.

40. As heat increases the bulk of all bodies, it is obvious that change of temperature is constantly producing changes in their density or specific gravity, as may be easily demonstrated in fluids where there is freedom of motion among the particles. If I apply heat to the bottom of a vessel of water, the heated part expands and rises, while a cold or denser stratum occupies its place. In air, similar currents are continually produced, and the vibratory motion observed over chimney pots, and slated roofs which have been heated by the sun, depends upon this circumstance. The warm air rises, and its refracting power being less than that of the circumambient colder air, the currents are rendered visible by the distortion of objects viewed through them.

41. There is only one strict exception to the general law of expansion by heat, and contraction by cold; this is in the case of water, which expands considerably when it approaches its freezing point. Water has attained its maximum of density at 40°, and if it be cooled below 40° it expands as the temperature diminishes, as it does when heated above 40°; and the rate of this expansion is equal for any number of degrees above or below this maximum of density, so that the bulk of water at 32° and at 48° will be the same. Accordingly, if two thermometer tubes, one containing spirit of wine, and the other water, be immersed into melting snow, the former will sink till it indicates 32°; but the latter when it has attained 40° begins to expand, and continues so to do till it freezes.

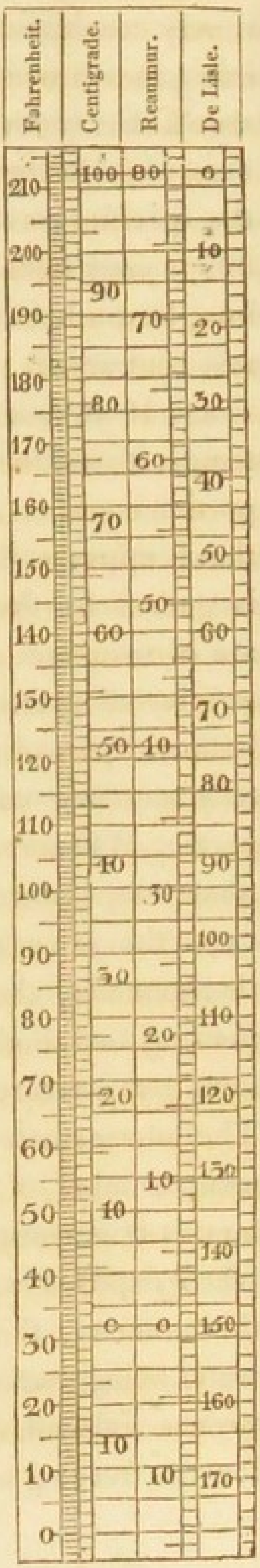
This anomaly in respect to water is productive of very important consequences, in preserving the depths of rivers and lakes of a temperature congenial to their inhabitants. (See Preface).

42. There are many liquids which suffer considerable expansion in passing into the solid state. This is the case with

the greater number of saline solutions, and remarkably with water, and seems connected with the phenomena of crystallization, and is referable to a new arrangement of particles. That the force with which water expands in the act of freezing, is very considerable, is shewn by the rupture of leaden and iron pipes in which it is suffered to freeze. Dr. Thomson has shewn that water in freezing suffers a much greater expansion than when heated from the freezing to the boiling point; for the specific gravity of water at 60° being = 1, that of ice at 32° is only 0,92. Of the metals, Reaumur found that cast iron, bismuth, and antimony, expanded in becoming solid; the rest contracted.

43. If we mix equal quantities of the same fluid at different temperatures, the cold portion will expand as much as the hot portion contracts, and the resulting temperature is the mean; so that it appears, that as much heat as is lost by the one portion is gained by the other. Upon this principle, *thermometers* are constructed. A common thermometer consists of a tube terminated at one end by a bulb, and closed at the other. The bulb and part of the tube are filled with a proper liquid, generally mercury, and a scale is applied, graduated into equal parts. Whenever this instrument is applied to bodies of the same temperature, the mercury, being similarly expanded, indicates the same degree of heat. In dividing the scale of a thermometer, the two fixed points usually resorted to are the freezing and boiling of water, which always take place at the same temperature, when under the same atmospheric pressure. The intermediate part of the scale is divided into any convenient number of degrees; and it is obvious, that all thermometers thus constructed will indicate the same degree of heat when exposed to the same temperature. In the centigrade thermometer, this space is divided into 100°; the freezing of water being marked 0°, the boiling point 100°. In this country we use Fahrenheit's scale, of which the 0° is placed at 32° below the freezing of water, which, therefore, is marked 32°, and

the boiling point 212°, the intermediate space being divided into 180°. Another scale is Reaumur's; the freezing point is 0°, the boiling point 80°. These are the principal thermometers used in Europe. Each degree of Fahrenheit's scale is equal to $\frac{4}{9}$ of a degree on Reaumur's; if, therefore, the number of degrees on Fahrenheit's scale, above or below the freezing of water, be multiplied by 4, and divided by 9, the quotient will be the corresponding degree of Reaumur.



Fahrenheit.	Reaumur.

$$68°-32°= 36\times4=144\div9=16°$$
$$212°-32°=180\times4=720\div9=80°$$

To reduce the degrees of Reaumur to those of Fahrenheit, they are to be multiplied by 9, and divided by 4.

Reaumur.	Fahrenheit.

$$16°\times9=144\div4= 36°+32°= 68$$
$$80°\times9=720\div4=180 +32 =212$$

Every degree of Fahrenheit is equal to $\frac{5}{9}$ of a degree on the Centigrade scale; the reduction, therefore, is as follows:—

Fahrenheit.	Centigrade.

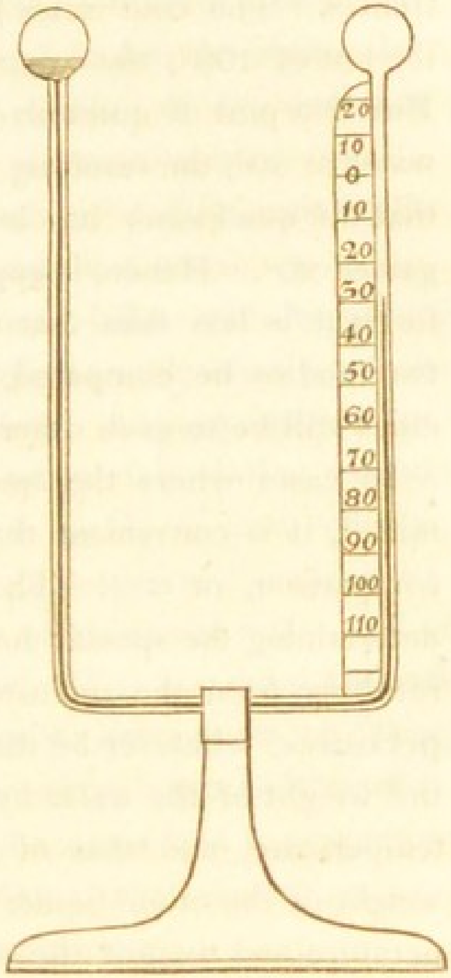
$$212-32=180\times5=900\div9=100°$$

Centigrade.	Fahrenheit.

$$100\times9=900\div5=180+32=212°$$

The annexed is a comparative table of the different thermometrical scales, (including de Lisle's, in which the graduation commences with the boiling point which is marked 0°, and the freezing 150°).

When a thermometer is intended to measure very low temperatures, spirit of wine is employed in its construction, as that fluid has never been frozen, whereas the low temperature at which it boils, renders it unfit for measuring high temperatures. Quicksilver will indicate 500°, but freezes at 40°. Air is sometimes resorted to as indicating very small changes of temperature; and of air thermometers, that described by Professor Leslie*, under the name of the *Differential Thermometer*, is the best. It consists of two large glass bulbs containing air, united by a tube twice bent at right angles, containing coloured sulphuric acid. When a hot body approaches one of the bulbs, it drives the fluid towards the other. The great advantage of this instrument in delicate experiments is, that general changes of the atmosphere's temperature do not affect it, but it only indicates the *difference* of temperature between the two balls.



44. The relative quantities of heat which different bodies in the same state require to raise them to the same thermometric temperature, is called their *specific heat*, and those bodies which require most heat are said to have the greatest *capacity* for heat. That the quantity of heat in different bodies of the same temperature is different, was first shewn by Dr. Black, in his lectures at Glasgow, in 1762.

It has been stated as a proof of the accuracy of the ther-

* *Experimental Inquiry into the Nature and Propagation of Heat*, by John Leslie, London, 1804, p. 9, &c.

mometer, that equal volumes of the same fluid, at different temperatures, give the arithmetical mean, on mixture. Thus, the temperature of a pint of hot and a pint of cold water is, after mixture, as near as possible half-way between the extremes. The cold water being of a temperature of 50°, and the hot of 100°, the mixture raises the thermometer to 75°. But if a pint of quicksilver at 100° be mixed with a pint of water at 50°, the resulting temperature is not 75°, but 70°; so that the quicksilver has lost 30°, whereas the water has only gained 20°. Hence, it appears, that the capacity of mercury for heat is less than that of water; and if the *weight* of the two bodies be compared, which are as 13,3 to 1, their capacities will be to each other as 19 to 1.

In cases where the specific heat of bodies is to be ascertained, it is convenient that water should be the standard of comparison, or = 1. The following is a general formula for determining the specific heat of bodies, from the temperature resulting from the mixture of two bodies at unequal temperatures, whatever be their respective quantities. Multiply the weight of the water by the difference between its original temperature, and that of the mixture. Also, multiply the weight of the other liquid, by the difference between its temperature and that of the mixture; divide the first product by the second, and the quotient will express the specific heat of the other substance, that of water being = 1. Thus, 20 ounces of water at 105°, mixed with 12 ounces of spermaceti oil at 40°, produce a temperature of 90°. Therefore, multiply 20 by 15 (the difference between 105 and 90) = 300. And multiply 12 by 50 (the difference between 40 and 90) = 600. Then 300, ÷ 600, = ½, which is the specific heat of oil; that is, water being 1, oil is 0,5.

The capacities of bodies for heat have considerable influence upon the rate at which they are heated and cooled. Those bodies which are most slowly heated and cooled have generally the greatest capacity for heat. Thus, if equal quantities of water and quicksilver be placed at equal distances from the fire, the quicksilver will be more rapidly heated than the water, and the metal will cool most rapidly when carried to a cold place. Upon this principle, Professor Leslie ingeniously determined the specific heat of bodies, observing their relative times of cooling a certain number of degrees, comparatively with water, under similar circumstances.

The calorimeter, invented by Lavoisier* for determining the specific heat of bodies, is an inaccurate instrument.

The capacity of gases and vapours differs with the nature of the gas, and with its density. In gases, dilatation produces cold, and compression excites heat. A thermometer suspended in the receiver of the air-pump sinks during exhaustion, and sudden compression of air produces heat sufficient to inflame tinder. In liquids too, condensation diminishes capacity for heat; hence the mixture of spirit and water, and of oil of vitriol and water, evolves heat. The increased capacity which air acquires by rarefaction has its influence in modifying natural temperatures. The air, becoming rarer as it ascends, absorbs its own heat, and hence becomes cold in proportion as it recedes from the earth's surface: thus moisture, rain, or snow, are thrown down on the mountain-tops.

45. When different bodies are exposed to the same source of heat, they suffer it to pass through them with very different degrees of velocity, or they have various *conducting powers* in regard to heat. Among solid bodies, metals are the best conductors; and silver, gold, and copper, are better conductors than platinum, iron, and lead. Next to the metals, we may, perhaps, place the diamond, and topaz, then glass, then siliceous and hard stony bodies in general, then soft and porous earthy bodies, and wood; and lastly, down, feathers, wool, and other porous articles of clothing.

* *Lavoisier's Elements*, vol. i.

Liquids and gases are very imperfect conductors of heat, and heat is generally distributed through them by a change of specific gravity, as before stated.

If we apply heat to the upper surface of any fluid, it will with great difficulty make its way downwards. Count Rumford considered fluids as non-conductors of heat; but the more accurate researches of Dalton, Hope, Murray *, and Thomson †, have demonstrated that they do conduct, though very imperfectly. Experiments on the conducting power of air are complex and difficult, and the results hitherto obtained are unsatisfactory. They are interfered with by several circumstances presently to be noticed.

The different conducting powers of bodies are shown in the application of wooden handles to metallic vessels, or a stratum of ivory or wood is interposed between the hot vessel and the metal handle. The transfer of heat is thus prevented. Heat is confined by bad conductors; hence clothing for cold climates consists of woollen materials; hence, too, the walls of furnaces are composed of clay and sand. Confined air is a very bad conductor of heat; hence the advantage of double doors to furnaces, to prevent the escape of heat; and of a double wall, with an interposed stratum of air, to an ice-house, which prevents the influx of heat from without. From the different conducting powers of bodies in respect to heat, arise the sensations of heat and cold experienced upon their application to our organs, though their thermometric temperature is similar. Good conductors occasion when touched a greater sensation of heat and cold than bad ones. Metal feels cold because it readily carries off the heat of the body; and we cannot touch a piece of metal immersed in air of a temperature moderate to our sense.

46. Heat has great influence on the *forms* or *states* of bodies. When we heat a solid, it becomes fluid or gaseous;

* *System of Chemistry*, vol. i.

† *System of Chemistry*, vol. i.

and liquids are converted into aëriform bodies or vapours. Dr. Black investigated this effect of heat with singular felicity, and his researches rank among the most admirable efforts of experimental philosophy*. During the liquefaction of bodies, a quantity of heat is absorbed, which is essential to the state of fluidity, and which does not increase the sensible or thermometric temperature. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it; much of the heat of the hotter body being consumed in rendering the colder solid, *liquid*, before it produces any effect upon its *sensible temperature*.

47. Equal parts of *water* at 32°, and of *water* at 212°, will produce on mixture a mean temperature of 122°. But equal parts of *ice* at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the heat of the water being employed in thawing the ice, before it can produce any rise of temperature in the mixture. To heat thus *insensible* or *combined*, Dr. Black applied the term *latent heat*. The actual loss of the thermometric heat in these cases was thus estimated: a pound of ice at 32° was put into a pound of water at 172°; the ice melted, and the temperature of the mixture was 32°. Here the water was cooled 140°, while the *temperature* of ice was unaltered; that is, 140° of heat disappeared, their effect being not to increase temperature, but to produce fluidity.

48. The same phenomena are observable in all cases of liquefaction, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water. Upon this principle the action of freezing mixtures depends, some of which may frequently be conveniently and œconomically applied to the purpose of cooling wine or water in hot

* Black's *Lectures*, edited by John Robison, LL.D.

climates, or where ice cannot be procured. The following Table shews the results of some of Mr. Walker's experiments on this subject.

Mixtures.	Thermometer sinks.
Muriate of ammonia .. 5 parts Nitre .... 5 Water 16	From 50° to 10°
Nitrate of ammonia .. 1 Water 1	From 50° to 4°
Sulphate of soda...... 5 Diluted sulphuric acid 4	From 50° to 3°
Snow .... 1 Common salt 1	From 32° to 0°
Muriate of lime ...... 3 Snow.............. 2	From 32° to—50°
Snow .... 2 Diluted sulphuric acid 1 Diluted nitric acid.... 1	From —10° to —56°
Snow or pounded ice..12 Common salt .... 5 Nitrate of ammonia .. 5	From—18° to—25°
Muriate of lime ...... 3 Snow 1	From—40° to—73°
Diluted sulphuric acid 10 Snow 8	From—68° to—91°

In order to produce these effects, the salts employed must be fresh crystallized, and newly reduced to a very fine powder. The vessels in which the freezing mixture is made should be very thin, and just large enough to hold it, and the materials should be mixed together as quickly as possible.

In order to produce great cold, they ought to be first reduced to the temperature marked in the table, by placing them in some of the other freezing mixtures; and then they are to be mixed together in a similar freezing mixture*.

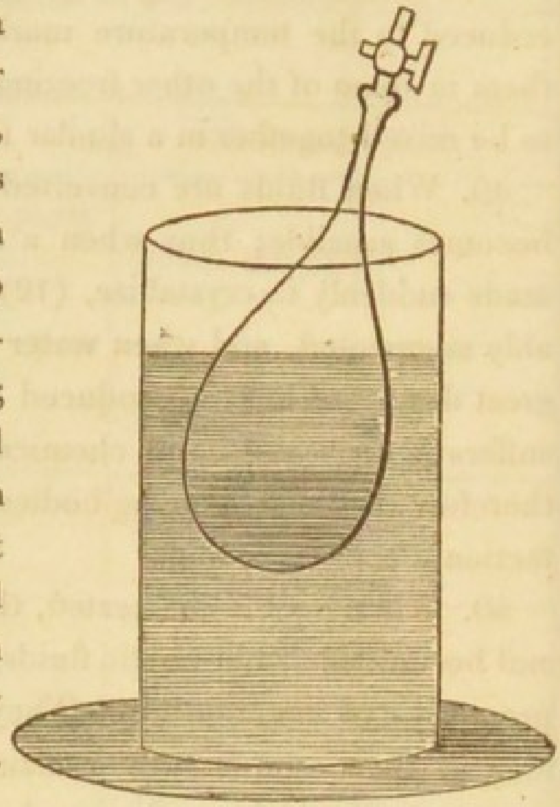
49. When fluids are converted into solids, their latent heat becomes sensible; thus when a solution of Glauber's salt is made suddenly to crystallize, (12) its temperature is considerably augmented, and when water is poured upon quicklime, a great degree of heat is produced by the solidification which it suffers in consequence of chemical combination; congelation, therefore, is to surrounding bodies a heating process, and liquefaction a cooling process.

50. When liquids are heated, they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. They retain this form or state as long as their temperature remains sufficiently high, but reassume the liquid form when cooled again. Different fluids pass into the aëriform state at different temperatures, or their boiling points are different; these are also regulated by the density of the atmosphere. If we diminish atmospheric pressure, we lower the boiling point. When the barometer is at 28 inches, water will boil at a lower temperature than when it is at 31 inches. Water under mean atmospheric pressure boils at 212°. At the top of Mont Blanc, Saussure found that it boiled at 187°, so that the heights of mountains, and even of buildings, may be calculated by reference to the temperature at which water boils upon their summits. The Reverend Mr. Wollaston has described to the Royal Society the method of constructing a thermometer of extreme delicacy, applicable to these purposes†. In the vacuum of an air-pump, fluids boil at temperatures considerably below their ordinary boiling points.

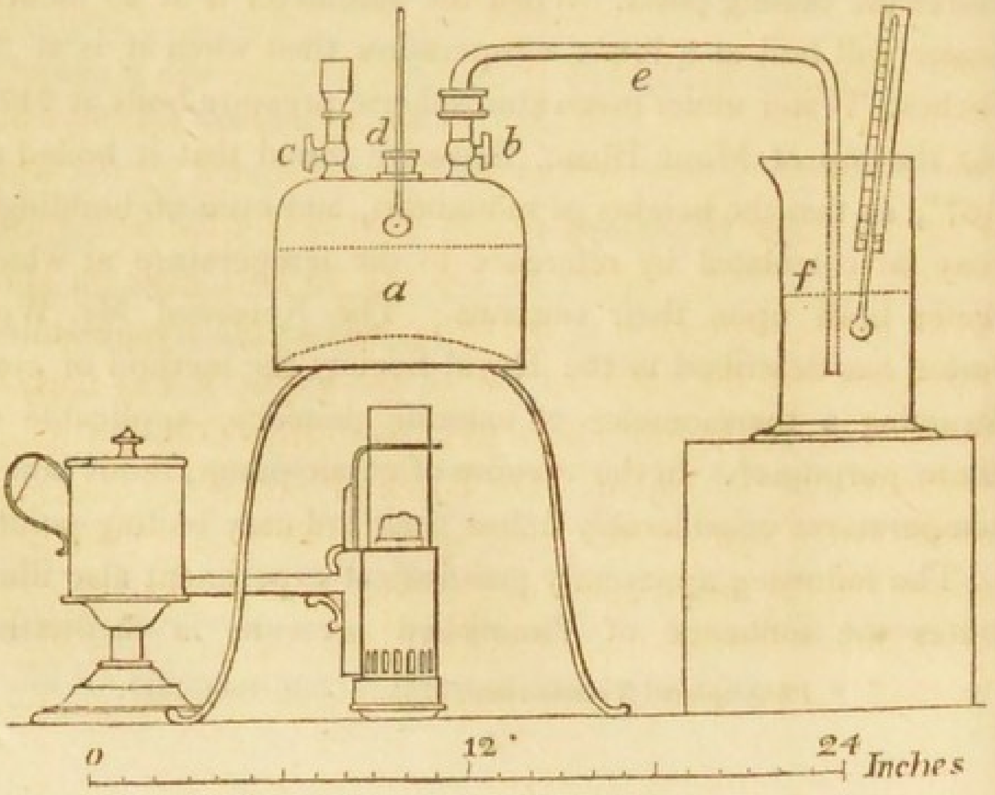
The following apparently paradoxical experiment also illustrates the influence of diminished pressure in facilitating

* *Philosophical Transactions*, 1795. † Ibid. 1817.

ebullition. Insert a stopcock securely into the neck of a Florence flask, containing a little water, and heat it over a lamp till the water boils, and the steam freely escapes by the open stopcock; then suddenly remove the lamp and close the cock. The water will soon cease to boil; but if plunged into a vessel of cold water, ebullition instantly re-commences, but ceases if the flask be held near the fire: the vacuum in this case being produced by the condensation of the steam.



Under increased pressure, on the contrary, fluids require a higher temperature to produce their ebullition, as may be shewn by inserting a thermometer *(d)* into a small boiler *(a)*, as represented in the annexed cut, copied from Dr. Henry's Elements.



As soon as the water boils the stopcock *(b)* being closed and *(c)* open, the steam will escape, and the thermometer remain at 212° (50). If we now close the stopcock *(c)* it will be found, that in consequence of the increased pressure occasioned by the included steam, the thermometer will rise several degrees above the boiling point. In this experiment a safety valve should be screwed on at *(b)*.

51. The conversion of a liquid into vapour is always attended with great loss of thermometric heat; and as liquids may be regarded as compounds of solids and heat, so vapours may be considered as consisting of a similar combination of heat with liquids; in other words, a great quantity of heat becomes latent during the formation of vapour. This is easily illustrated by immersing a thermometer into an open vessel of water placed over a lamp. The quicksilver rises to 212°, the water then boils, and although the source of heat remains, neither the water nor the steam acquire a higher temperature than 212°; the heat then becomes latent, and is consumed in the formation of steam.

52. To ascertain the absolute loss of thermometric heat in this case, Dr. Black instituted the following experiments: he noted the time required to raise a certain quantity of water to its boiling point; he then kept up the same heat till the whole was evaporated, and marked the time consumed by the whole process; it was thus computed to what height the temperature would have risen, supposing the rise to have gone on above 212°, in the same ratio as below it; and as the temperature of the steam was the same as that of the water, it was fairly inferred that all the heat above 212° was essential to the constitution of aqueous vapour. Dr. Black estimated this quantity at about 810°, that is, the same quantity of heat which is required for the total evaporation of boiling water at 212° would be sufficient to raise the water 810° above its boiling point, or to 1022° had it continued in the liquid state. There are other

means of ascertaining the latent heat of steam, which lead us to place it between 900° and 1000°.

53. When steam is again condensed, or when vapours re-assume the liquid state, their latent heat becomes sensible, and in this way it is obvious that a small quantity of steam will, during its condensation, communicate heat sufficient to boil a large quantity of water.

The small boiler just mentioned may be conveniently employed in experiments on the latent heat of steam: for this purpose the tube *(e)* must be screwed on the stopcock *(b)*, and immersed into the glass of water *(f)*. The cock *(c)* being closed, the steam will then pass into the water, the temperature of which will be much augmented by its condensation. Ascertain the increase of temperature and weight, and the result will shew how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, of the same weight and temperature as that in the jar at the outset of the experiments, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparing the resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature than the same quantity of boiling water. *(Henry, vol. i. p.* 106, *7th edit.)*

In breweries and other manufactories, where large quantities of warm and boiling water are consumed, it is frequently heated by thus conveying steam into it, or by suffering steam pipes to traverse the vessels, or by employing double vessels— a plan adopted with particular advantage in the laboratories at Apothecaries' Hall.

54. The cold produced by evaporation is, under certain circumstances, very great. Spirit of wine and ether, which readily evaporate, produce considerable cold during that process. Upon this principle wine-coolers, and similar porous

vessels, refrigerate the fluids they contain; and thus, by accelerating the evaporation of water, by exposing it under an exhausted receiver, containing bodies that quickly absorb its vapour, Professor Leslie has contrived to effect its congelation; the heat required for the conversion of one portion of the water into vapour being taken from the other portion, which is thus reduced to ice. (See Supplement to Encyclopædia Brit. Art. Cold.)

55. The heat given off by steam during its condensation, is often advantageously applied to warming buildings, and is at once safe, salubrious, and economical. In many natural operations the conversion of water into vapour, and the condensation of vapour in the form of dew and rain, is a process of the utmost importance, and tends considerably to the equalization of temperature over the globe.

56. Nothing is known of the nature or cause of heat. It has been by some considered as a peculiar fluid, to which the term *Caloric* has been applied; and many phenomena are in favour of the existence of such a fluid. By others, the phenomena above described have been referred to a *vibratory motion* of the particles of matter, varying in velocity with the perceived intensity of the heat. In fluids and gases the particles are conceived to have a motion round their own axes. *Temperature*, therefore, would increase with the velocity of the vibrations, and increase of *capacity* would be produced by the motion being performed in greater space. The loss of temperature, during the change of solids into liquids and gases, would depend upon loss of *vibratory* motion, in consequence of the acquired *rotatory* motion.

Upon the other hypothesis, *temperature* is referred to the quantity of *caloric* present; and the loss of temperature, which happens when bodies change their state, depends upon the chemical combination of the caloric with the solid in the case of liquefaction, and with the liquid in the case of conversion into the aëriform state.

Section III. ELECTRICITY.

57. If a piece of sealing-wax and of dry warm flannel be rubbed against each other, they both become capable of attracting and repelling light bodies. Glass rubbed upon silk exhibits the same phenomena. In these cases the bodies are said to be *electrically excited.*

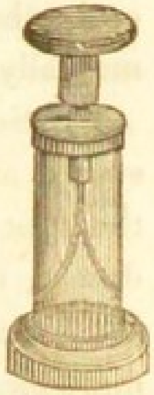
58. If two pith-balls be electrified by touching them with the sealing-wax or with the flannel, they repel each other; but if one pith-ball be electrified by the wax and the other by the flannel, they attract each other. The same applies to the glass and silk: it shews a difference in the electricities of the different bodies, and the experiment leads to the conclusion, that *bodies similarly electrified repel each other, but that when dissimilarly electrified they attract each other.*

If one ball be electrified by sealing-wax rubbed by flannel, and another by silk rubbed with glass, those balls will repel each other; which proves that the electricity of the silk is the same as that of the sealing-wax. But if one ball be electrified by the sealing-wax and the other by the glass, they then attract each other, showing that they are oppositely electrified.

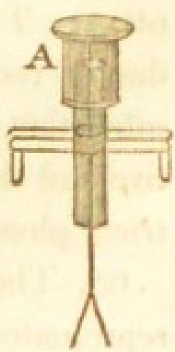
59. The terms *vitreous* and *resinous* electricity were applied to these two phenomena; but Franklin, observing that the same electricity was not inherent in the same body, but that glass sometimes exhibited the same phenomena as wax, and *vice versâ,* adopted another term, and, instead of regarding the phenomena as dependent upon two electric fluids, referred them to the presence of one fluid, in excess in some cases and in deficiency in others. To represent these states he used the terms *plus* and *minus, positive* and *negative.* When glass is

rubbed with silk, a portion of electricity leaves the silk and enters the glass. It becomes *positive,* therefore, and the silk *negative;* but when sealing-wax is rubbed with flannel, the wax loses and the flannel gains: the former, therefore, is negative, the latter positive. All bodies in nature are thus regarded as containing the electric fluid, and when its equilibrium is disturbed, they exhibit the phenomena just described.

60. Very delicate pith-balls, or strips of gold leaf, are usually employed in ascertaining the presence of electricity; and, by the way in which their divergence is affected by glass or sealing-wax, the kind or state of electricity is judged of. When properly suspended or mounted for delicate experiments, they form an *electrometer.* For this purpose the slips of gold leaf are suspended by a brass cap and wire in a glass cylinder; they hang in contact when unelectrified; but when electrified they diverge, as in the marginal wood cut.



When this instrument, as usually constructed, becomes at all damp its delicacy is much diminished, and it is rendered nearly useless. The following improvement in its construction by the late Mr. Singer renders it a much more sensible and useful instrument. It is constructed as usual, with a glass cylinder, surmounted by a brass cap. The insulation is made to depend upon a glass tube, about four inches long, and one-fourth of an inch internal diameter, covered both on the inside and outside with sealing-wax, and having a brass wire of a sixteenth or twelfth of an inch thick and five inches long, passing through its axis so as to be perfectly free from contact with any part of the tube, in the middle of which it is fixed by a plug of silk, which keeps it concentric with the internal diameter of the tube. A is a brass cap screwed upon the upper part of this wire; it serves to limit the atmosphere from free contact with the outside of the tube, and also defends its



inside from dust; to the lower part of the wire the gold leaves are attached, and the whole mounted as usual, and as represented above.

61. The kind of electricity by which the gold leaves are diverged may be judged of by approaching the cap of the instrument with a stick of excited sealing-wax; if it be *negative* the divergence will increase; if *positive*, the leaves will collapse, upon the principle of the mutual annihilation of the opposite electricities, or that bodies similarly electrified repel each other, but that when dissimilarly electrified they become mutually attractive. (58.)

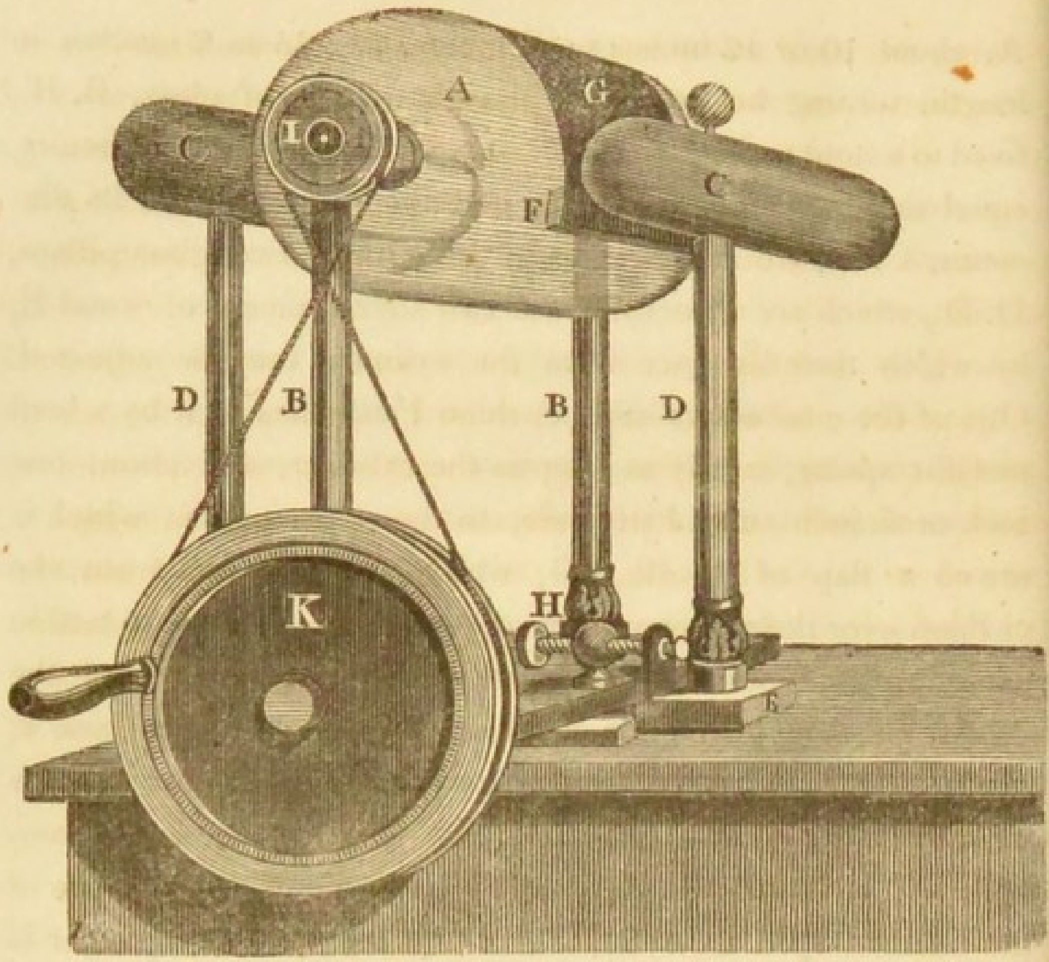
62. Some bodies suffer electricity to pass through their substance, and are called *conductors*. Others only receive it upon the spot touched, and are called *nonconductors*. The former do not, in general, become electric by friction, and are called *nonelectrics:* the latter, on the contrary, are *electrics*, or acquire electricity by friction. They are also called *insulators*. The metals are all conductors; glass, sulphur, and resins, are nonconductors. Water, damp wood, spirit of wine, and some oils, are imperfect conductors.

63. There are many mineral substances which shew signs of electricity when heated, as the tourmalin, topaz, diamond, boracite, &c.; and in these bodies the different surfaces exhibit different electrical states.

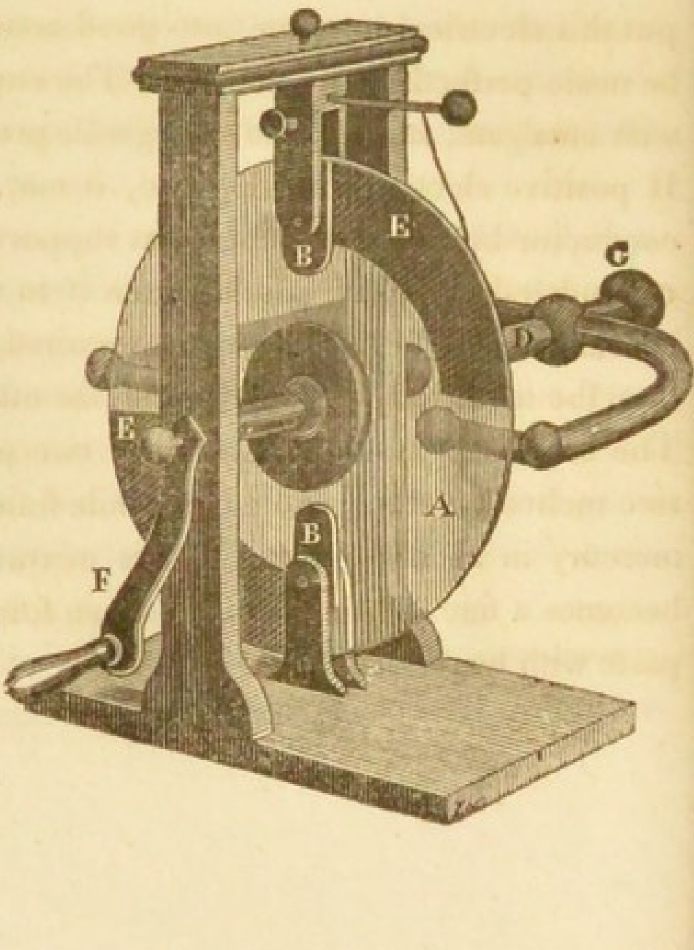
64. Whenever one part of a body, or system of bodies, is positive, another part is invariably negative; and these opposite electrical states are always such as exactly to neutralize each other. Thus, in the common electrical machine, one conductor receives the electricity of the glass cylinder, and the other that of the silk rubber, and the former conductor is positive and the latter negative; but if they be connected, all electrical phenomena cease.

65. The best electrical machine for experimental purposes is represented in the annexed sketch. It consists of a glass cylinder

A, about 10 or 12 inches in diameter, and 15 to 20 inches in length, turning between two upright pillars of glass, B. B., fixed to a stout mahogany base. Two smooth metal conductors, equal in length to the cylinder and about one-third of its diameter, C. C., are placed parallel to it upon two glass pillars, D. D., which are cemented into two sliding pieces of wood E, by which their distance from the cylinder may be adjusted. One of the conductors has a cushion F attached to it by a bent metallic spring, nearly as long as the cylinder, and about one inch or an inch and a half wide, to the upper part of which is sewed a flap of oil-silk, G, which should reach from the cushion over the upper surface of the glass cylinder, to within about an inch of a row of points attached to the side of the opposite conductor. The conductor to which the cushion is attached is called the negative conductor; the other collects the electricity of the glass, and is called the positive conductor. H is an adjusting screw to regulate the pressure of the cushion upon the cylinder. The motion of the cylinder is in the direction of the silk flap, and may be communicated by a handle attached at I, or by the multiplying wheel K. To put this electrical machine into good action, every part should be made perfectly clean and dry. The cushion is then anointed with amalgam, and applied by a gentle pressure to the cylinder. If positive electricity is required, it may be received from the conductor bearing the points, that supporting the cushion being uninsulated by a wire passing from it to the stand;—if, on the contrary, negative electricity is required, it may be obtained from the insulated cushion cylinder, the other being uninsulated. The best amalgam is composed of one part of tin and two of zinc melted together, and mixed while fluid with six parts of hot mercury in an iron mortar. This mixture is triturated till it becomes a fine powder, which is then formed into a tenacious paste with hogs' lard.



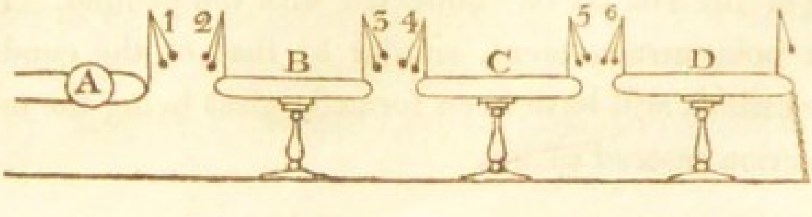
66. Another form of the electrical machine consists of a circular glass plate A, mounted upon an axis and rubbed by two pairs of cushions, as shewn at B. B. The brass conductor C has its points opposed to the plate, and is insulated by the glass stem D.—E. E. are double pieces of oil silk passing from the cushions to near the points. The whole is supported by a stout mahogany frame, and motion is given to the plate by the winch F.



These electrical machines have considerable power; they are sily cleaned and excited, and are more portable than the cy-lders; but as they cannot be conveniently insulated, the ne-tive electrical power cannot be well exhibited, so that for purposes of experimental research the former machines are eferable.

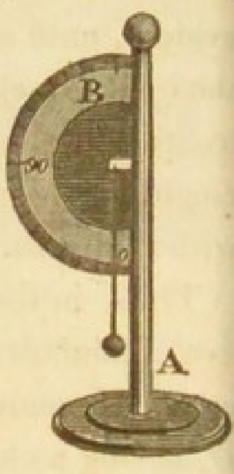
67. If an insulated conductor be electrified, and an uninsu-ed conductor be opposed to it, there being between the two thin stratum of air, glass, or other nonconductor, the unin-ated conductor, under such circumstances, acquires an op-site electrical state to that of the originally electrified insu-ed conductor. In this case, the uninsulated body is said to electrified by *induction;* and the induced electricity remains dent, until an explosion, spark, or discharge happens, when opposite electricities annihilate each other. Induced elec-city may thus be exhibited through a long series of insulated nductors, provided the last of the series be communicated th the earth.

Thus, in the following diagram, A, may represent the posi-e conductor of the electrical machine; B, C, and D, three ulated conductors, placed at a little distance from each other, having a chain touching the ground; then the balls 1, being sitive, will attract the balls 2, which are rendered negative induction. Under these circumstances, each of the con-ctors becomes polar, and the balls 3 are positive, while 4 are gative, 5 positive, 6 negative, &c. The central points of conductors, B, C, D, are neutral. When these opposite ctrical states have arrived at a certain intensity, sparks pass ween the different conductors, and the electrical phenomena se.

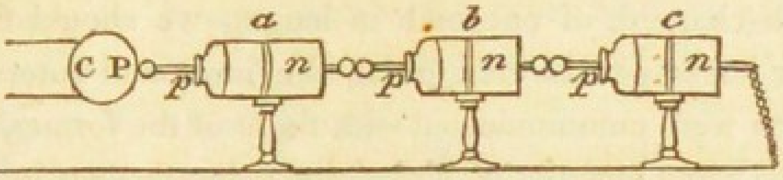


68. Upon the principle of induction it is that the accumulation of electricity in the *Leyden phial* is effected. It consists of a thin glass jar, coated internally and externally with tinfoil to within a short distance of its mouth. When the inner surface is rendered positive by union with the conductor of the electrical machine, the exterior, being connected with the ground, becomes negative by induction. When the inner and outer surfaces are united by a conductor, all electrical accumulation is annihilated by a spark, and the two opposite states are found to have been precisely equivalent.

69. To ascertain the relative *charge* which the jar has received, we employ the *quadrant electrometer*, contrived by Henly. It consists of a rounded stem of metal A, to the side of which is attached an ivory semi-circle B, to the centre of which is affixed a pin, upon which a very thin piece of cane or ivory, about 4 inches long, and with a pith ball at its lower extremity, turns freely and traverses the semicircle as an index. The lower half of the semicircle is divided into 90°. When not electrified, its index hangs parallel to the stem at 0°, but when electrified, the ball recedes and carries the index over the graduated circle to a greater or less extent, in proportion to the intensity of the electricity.



70. If one Leyden jar be insulated with its internal surface connected with the positive conductor, another jar may be charged from its exterior coating; and if this second jar be insulated, a third may be charged from its exterior coating, and so on for any number of jars, provided always that the exterior coating of the last jar be connected with the ground. In this case, a polar arrangement, similar to that of the conductors just described, will have been formed, glass being the medium of induction instead of air.



Let C P be the positive conductor of the electrical machine, and *a*, *b*, *c*, three insulated Leyden phials, the outer coating of *c* being connected with the ground; it is then obvious, that there will be the same polar state as in the conductors just noticed; that the insides of *a*, *b*, and *c*, will be positive, and the outsides negative; and that, consequently, on removing the jars from each other, they will all be similarly charged, and that if the three inner surfaces *p*, *p*, *p*, and the three outer surfaces *n*, *n*, *n*, be united, the whole may be discharged as one jar.

71. Upon this principle a jar may be charged by the transfer of its inherent electricity from one surface to the other, by insulating it and connecting its interior coating with the positive conductor, and its exterior with the negative;—thus the electricity received by the former is withdrawn from the latter, and the jar becomes charged. (59). This experiment well illustrates the nonconducting power of glass.

72. The use of the metallic coatings of the Leyden phial is equally to distribute the electricities over the opposite surfaces, for if the coatings be made moveable the jar remains charged when they are removed. In discharging the jar too, the annihilation is rendered simultaneous by the conducting coating suffering the transfer of the opposite electricities from every part of the glass surfaces at the same instant.

73. Electricians employ the term *quantity* to indicate the absolute quantity of electric power in any body, and the term *intensity* to signify its power of passing through a certain stratum of air or other ill-conducting medium.

If we suppose a charged Leyden phial to furnish a spark, when discharged, of one inch in length, we should find that another uncharged Leyden phial, the inner and outer coating of which were communicated with those of the former, would, upon the same quantity of electricity being thrown in, reduce the length of the spark to half an inch; here, the *quantity* of electricity remaining the same, its *intensity* is diminished by one-half, by its distribution over the larger surface.

74. There are many other sources of electricity than those just noticed. Whenever bodies change their forms, their electrical states are also altered. Thus the conversion of water into vapour, and the congelation of melted resins and sulphur, are processes in which electricity is also rendered sensible.

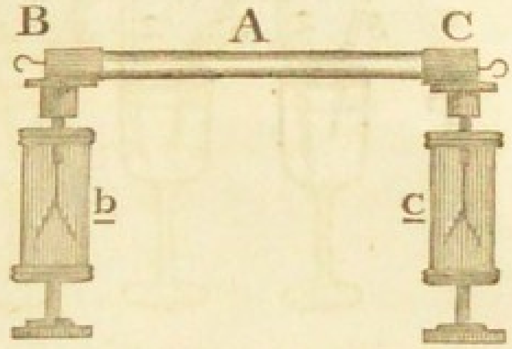
75. When an insulated plate of zinc is brought into contact with one of copper or silver, it is found, after removal, to be positively electrical, and the silver or copper is left in the opposite state. If the nerve of a recently killed frog be attached to a silver probe, and a piece of zinc be brought into the contact of the muscular parts of the animal, violent convulsions are produced every time the metals thus connected are made to touch each other; exactly the same effect is produced by an electric spark, or the discharge of a very small Leyden phial.

If a piece of zinc be placed upon the tongue, and a piece of silver under it, a peculiar sensation will be perceived every time the two metals are made to touch.

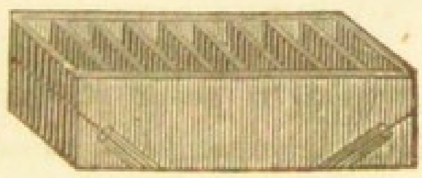
76. In these cases the chemical properties of the metals are observed to be affected. If a silver and a zinc wire be put into a wine-glass full of dilute sulphuric acid, the zinc wire only will evolve gas; but upon bringing the two wires in contact with each other, the silver will also copiously produce air bubbles.

77. If a number of alternations be made of copper or silver leaf, zinc leaf, and thin paper, the electricity excited by the contact of the metals will be rendered evident to the common

electrometer. A, represents a glass tube, in which are regularly arranged a number of alternating plates of silver, zinc, and thin paper. The metallic cap B is in contact with the silver plate, and C with the zinc plate, at the respective extremities of the pile. Upon examining the electrometers, it will be found that *b* is negatively diverged and *c* positively.



If the same arrangement be made with the paper moistened with brine, or a weak acid, it will be found, on bringing a wire communicating with the last copper plate into contact with the first zinc plate, that a spark is perceptible, and also a slight shock, provided the number of alterations be sufficiently numerous. This is the VOLTAIC *apparatus*. Several modes of constructing this apparatus have been adopted with a view to render it more convenient or active. Sometimes double plates of copper and zinc soldered together are cemented into wooden troughs in regular order, the intervening cells being filled with water, or saline or acid solutions.



78. Another form consists in arranging a row of glasses, containing dilute sulphuric acid, in each of which is placed a wire or plate of silver or copper, and one of zinc, not touching each other, but so connected by metallic wires, that the zinc of the first cup may communicate with the copper of the second; the zinc of the second with the copper of the third, and so on throughout the series as represented in the annexed cuts.

Fig. 1.

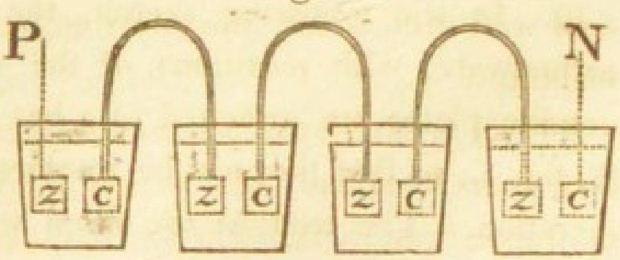
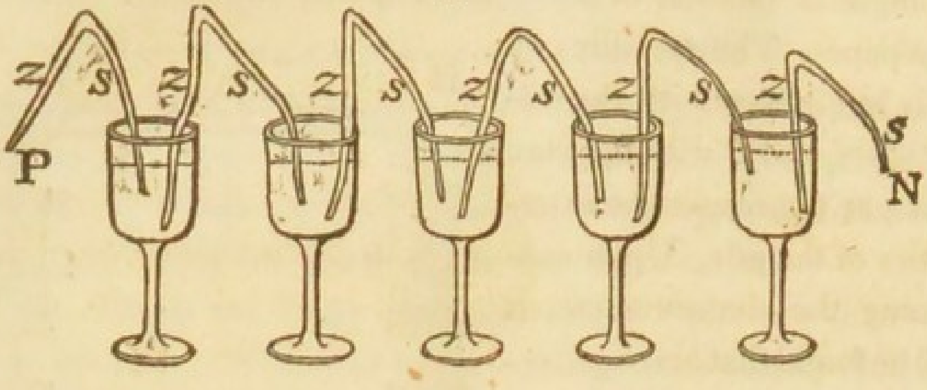
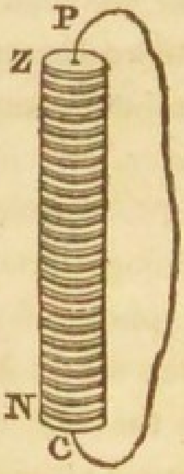


Fig. 2.

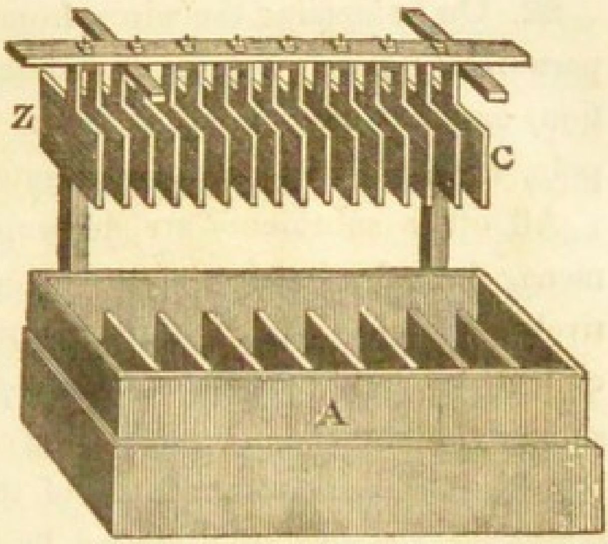


By applying the moistened fingers to the extreme wires P and N, a shock will be felt; and on making a communication between them by a wire, it will be found that the copper plates in fig. 1, and the silver wires in fig. 2, instantly acquire the power of decomposing the dilute sulphuric acid, and that the chemical action of the zinc is much augmented. One advantage of this arrangement over the former (77) is, that both surfaces of the metal are exposed; whereas in the other, by soldering the plates together, its action is diminished.



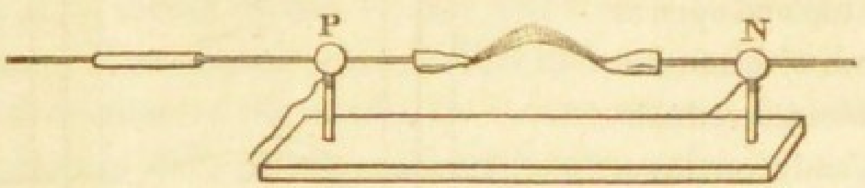
Also, if plates of zinc and copper be regularly arranged, with moistened flannel between each pair of plates, we shall observe that, having made 50 or 60 such alternations, the same effect will be produced, and that the zinc plate will give a positive, and the copper extreme a negative charge to the gold leaf electrometer.

79. In the following sketch, the trough A is made of earthenware, with partitions of the same material, and the metallic plates are attached to a bar of wood, arranged as in 78, fig. 1., so that they can be immersed and removed at one operation. The troughs are filled with dilute acid, and by



uniting them in regular order, the apparatus may be enlarged to any extent. This is, on the whole, the best form of the Voltaic instrument hitherto devised, and it is thus that the great apparatus of the Royal Institution is constructed.

80. When from 500 to 1,000 double plates are thus arranged and rendered active by immersion into a liquid, consisting of about sixty parts of water with one of nitric and one of sulphuric acid, very brilliant effects are produced when the opposite poles are properly united by conductors. Thus, if a piece of charcoal united with the negative wire be made to touch another piece united with the positive wire, a bright spark and intense ignition ensue, and by slowly withdrawing the points from each other, a constant current of electricity takes place through the heated air, producing a magnificent arc of intense light, in the form here represented.

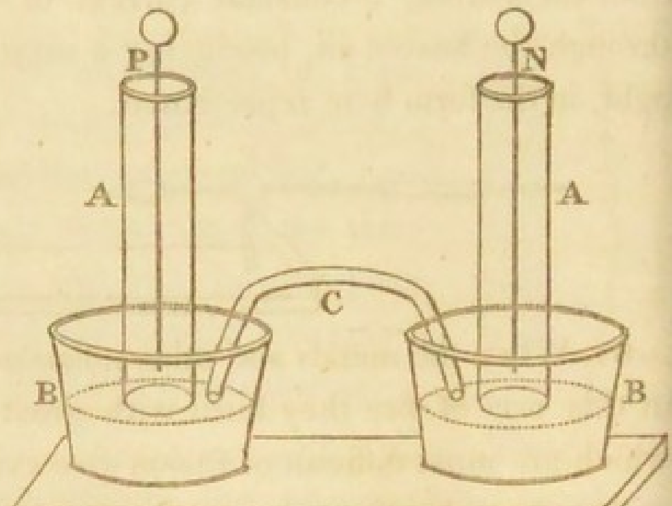


81. When the metals and other inflammable bodies are placed in this arc of fire they burn with great brilliancy, and those which are most difficult of fusion give evidence of the intensity of the heat by instantly melting; and some earthy and other bodies infusible by ordinary methods are liquified by the same means. The shock is painful and dangerous. When the communication between the points of charcoal is made in rarefied air, the annihilation of the opposite electricities takes place at some inches' distance, producing a stream of deep purple light.

82. On immersing the wires from the extremes of this apparatus into water, it is found that the fluid suffers decomposition, and that oxygen gas is liberated at the positive wire, or pole, and hydrogen gas at the negative pole.

All other substances are decomposed with similar phenomena, the inflammable element being disengaged at the negatively electrical surface; hence it would appear, upon the principle of similarly electrified bodies repelling each other, and dissimilarly electrified bodies attracting each other, (58) that the inherent or natural electrical state of the inflammable substances is *positive*, for they are attracted by the negative or oppositely electrified pole; while the bodies called supporters of combustion, or acidifying principles, are attracted by the positive pole, and, therefore, may be considered as possessed of the *negative* power.

83. When bodies are thus under the influence of electrical decomposition, their usual chemical energies are suspended, and some very curious phenomena are observed, which may be illustrated by the following experiments.



Fill the glass tubes A. A. which are closed at top and open at bottom with infusion of violets, or red cabbage, and invert them in the basins B. B., containing a solution of Glauber's salt, and connected by the glass tube C., also containing the blue infusion. P. and N. are platinum wires, which pass into the tubes nearly to the bottom, and which are to be connected with the positive and negative extremities of the Voltaic apparatus. It will be found that oxygen is evolved at the wire P., and hydrogen at N., derived from the decomposition of the water. The Glauber's salt, which consists of sulphuric acid and soda, will also be decomposed; and the blue liquor will be rendered red in the positive vessel, by the accumulation of sulphuric acid, and green in the negative, by the soda, while the acid and alcali will each traverse the tube C. without uniting, in consequence of being under the influence of electrical attraction.

84. The most difficultly decomposable compounds may be thus resolved into their component parts by the electrical agency; by a weak power the proximate elements are separated, and by a stronger power these are resolved into their ultimate constituents. (35).

85. All bodies which exert powerful chemical agencies upon each other when freedom of motion is given to their particles, render each other oppositely electrical when acting as masses. Hence Sir H. Davy, the great and successful investigator of this branch of chemical philosophy, has supposed that electrical and chemical phenomena, though in themselves quite distinct, may be dependent upon one and the same power, acting in the former case upon masses of matter, in the other upon its particles.

86. The theory of the Voltaic pile is involved in many difficulties. The original source of electricity appears to depend upon the contact of the metals, for we know that a plate of silver and a plate of zinc, or of any other difficultly and easily oxidable metals, become negative and positive on contact. The accumulation must be referred to *induction*, which takes place in the electrical column (77), through the very thin stratum of air or paper, and through water when that fluid is interposed between the plates. Accordingly we observe that the apparatus is in the condition of the series of conductors with interposed air (67)—and of the Leyden phials (70). When the electric column is insulated the extremities exhibit feeble negative and positive powers, but if either extremity be connected with the

ground, the electricity of its poles or extremities is greatly increased, as may be shewn by the increased divergence of the leaves of the electrometer which then ensues.

87. The power of the Voltaic apparatus to communicate divergence to the electrometer, is most observed when it is well insulated and filled with pure water; but its power of producing ignition and of giving shocks, and of producing the other effects observed when its poles are connected, are much augmented by the interposition of dilute acids, which act chemically upon one of the plates: here, the insulation is interfered with by the production of vapour, but the quantity of electricity is much increased, a circumstance which may, perhaps, be referred to the increase of the positive energy of the most oxidable metal by the contact of the acid. In experiments made with the great battery of the Royal Institution, it has been found that 120 plates rendered active by a mixture of one part of nitric acid and three of water, produced effects equal to 480 plates rendered active by one part of nitric acid and fifteen of water.

88. In the Voltaic pile, the *intensity* of the electricity increases with the number of alternations, but the *quantity* is increased by extending the surface of the plates. Thus, if a battery, composed of thirty pairs of plates two inches square, be compared with another battery of thirty pairs of twelve inches square, charged in the same way, no difference will be perceived in their effects upon bad or imperfect conductors; their powers of decomposing water and of giving shocks will be similar; but upon good conductors the effects of the large plates will be considerably greater than those of the small: they will ignite and fuse large quantities of platinum wire, and produce a very brilliant spark between charcoal points. The following experiment well illustrates the different effects of quantity and intensity in the Voltaic apparatus.

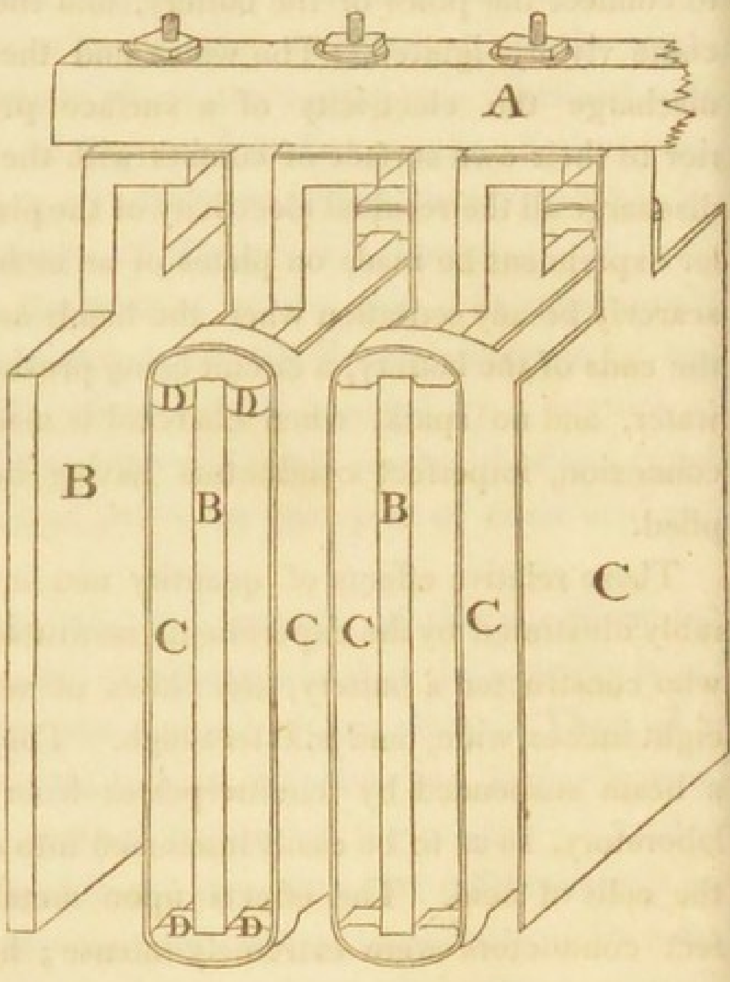
Immerse the platinum wires connected with the extremity of a charged battery composed of twelve-inch plates into water, and it will be found that the evolution of gas is nearly the same as that occasioned by a similar number of two-inch plates. Apply the moistened fingers to the wires, and the shock will be the same as if there were no connexion by the water. While the circuit exists through the human body and the water, let a wire attached to a thin slip of charcoal be made to connect the poles of the battery, and the charcoal will become vividly ignited. The water and the animal substance discharge the electricity of a surface probably not superior to their own surface of contact with the metals; the wires discharge all the residual electricity of the plates; and if a similar experiment be made on plates of an inch square, there will scarcely be any sensation when the hands are made to connect the ends of the battery, a circuit being previously made through water, and no spark, when charcoal is made the medium of connexion, imperfect conductors having been previously applied.

These relative effects of quantity and intensity were admirably illustrated by the experiments instituted by Mr. Children, who constructed a battery, the plates of which were two feet eight inches wide, and six feet high. They were fastened to a beam suspended by counterpoises from the cieling of his laboratory, so as to be easily immersed into or withdrawn from the cells of acid. The effects upon metallic wires and perfect conductors were extremely intense; but upon imperfect conductors, such as the human body, and water, they were feeble.

89. When the extremes of a battery composed of large plates are united by wires of different metals, it is found that some are more easily ignited than others, a circumstance which has been referred to their conducting powers—thus, platinum is more easily ignited than silver, and silver than zinc. If the ignition be supposed to result from resistance to the passage of electricity,

we should say that the zinc conducted better than silver, and the silver than platinum.

90. An important improvement has been suggested in the construction of the Voltaic apparatus by Dr. Wollaston *, by which great increase of *quantity* is obtained without inconvenient augmentation of the size of the plates—it consists in extending the copper plate, so as to oppose it to every surface of the zinc, as seen in the annexed cut. A is the rod of wood to which the plates are screwed. BB the zinc plates connected as usual with the copper plates CC, which are doubled over the zinc plates, and opposed to them upon all sides, contact of the surfaces being prevented by pieces of wood or cork placed at DD.



91. We have as yet no plausible hypothesis concerning the *cause* of electrical phenomena, though the subject has engaged the attention of the most eminent philosophers of Europe. They have been by some referred to the presence of a peculiar fluid existing in all matter, and exhibiting itself by the appearances which have been described, whenever its equilibrium is disturbed, presenting negative and positive electricity when de-

* *Annals of Philosophy*. Sept. 1815.

ficient and when redundant. Others have plausibly argued for the presence of two fluids, distinct from each other. Others have considered the effects as referable to peculiar exertions of the attractive powers of matter, and have regarded the existence of any distinct fluid or form of matter to be as unnecessary to the explanation of the phenomena, as it is in the question concerning the cause of gravitation.

92. When the flame of a candle is placed between a positive and negative surface, it is urged towards the latter; a circumstance which has been explained upon the supposition of a current of electrical matter passing from the positive to the negative pole;—indeed, it has been considered as demonstrating the existence of such a current of matter. But if the flame of phosphorus be substituted for that of a candle, it takes an opposite direction; and, instead of being attracted towards the negative, it bends to the positive surface. It has been shown that inflammable bodies are always attracted by negative surfaces, and acid bodies, and those in which the supporters of combustion prevail are attracted by positive surfaces (82). Hence the flame of the candle throwing off carbon, is directed to the negative pole, while that of phosphorus forming acid matter goes to the positive, consistently with the ordinary laws of electrochemical attraction (83)*.

93. There are many experiments which sanction the idea that electricity is "an exhibition of attractive powers acting in certain combinations." If we discharge a Leyden phial through a quire of paper, the perforation is equally burred upon both sides, and not upon the negative side only, as would have been the case if any material body had gone through in that direction. The power seems to have come from the centre of the paper, as if one-half of the quire had been attracted by the positive, and the other by the negative surface.

94. When a pointed metallic wire is presented towards the

* *Philos. Trans.* 1814.

conductor of the electrical machine, in a darkened room, a star of light is observed when the conductor is positive, but a brush of light when it is negative; a circumstance which has been referred to the reception of the electric fluid in the one case, and its escape in the other. In the Voltaic discharge the same appearances are evident upon the charcoal point—rays appearing to diverge from the negative conductor, while upon the positive a spot of bright light is perceptible. But these affections of light can scarcely be considered as indicating the emission or reception of any specific form of matter.

95. Small surfaces are much more rapidly electrified by induction than large ones, and are consequently unfit for the accumulation of electricity by induction; and when an uninsulated pointed wire is brought near an electrified surface, it quickly gains an opposite state, and a rapid annihilation of the electricity ensues; hence the advantage of pointed conductors as safeguards for lightning.

96. As general changes in the form and constitution of matter are connected with its electrical states, it is obvious that electricity must be continually active in nature. Its effects are exhibited on a magnificent scale in the thunder-storm, which results from the accumulation of electricity in the clouds. The coruscations of the aurora borealis are also probably electrical, and the phenomena of the water-spout may be referred to the same cause. In the *gymnotus* and in the *torpedo* are electrical arrangements, given to those remarkable animals for the purposes of defence, which certain forms of the voltaic apparatus much resemble, for they consist of many alternations of different substances. These electrical organs are much more abundantly supplied with nerves than any other part of the animal, and the too frequent use of them is succeeded by debility and death*. That arrangements of dif-

* *Todd. Phil. Trans.* 1817.

ferent organic substances are capable of producing electrical effects, has been shewn by various experimentalists. If the hind legs of a frog be placed upon a glass plate, and the crural nerve dissected out of one made to communicate with the other, it will be found, upon making occasional contacts with the remaining crural nerve, that the limbs of the animal will be agitated at each contact. These circumstances have induced some physiologists to suppose that electricity may be concerned in some of the most recondite phenomena of vitality, and Dr. Wollaston, Sir E. Home, and myself, have made some experiments tending to confer probability on this idea *.

* *Phil. Trans.* 1809.

CHAPTER II.

Of Radiant or Imponderable Matter.

97. OF the substances belonging to our globe, some are of so subtile a nature as to require minute and delicate investigation to demonstrate their existence; they can neither be confined nor submitted to the usual modes of examination, and are known only in their states of motion as acting upon our senses, or as producing changes in the more gross forms of matter. They have been included under the general term of RADIANT or IMPONDERABLE ETHERIAL MATTER, which, as it produces different phenomena, must be considered as differing either in its nature or affections. Respecting the nature of these phenomena, two opinions have been entertained, and each ably supported. It has been supposed by Huygens and Descartes, that they arise from vibrations of a rare elastic medium which fills space; while Newton has considered them as resulting from emanations of particles of matter.

The other forms of matter are tangible and ponderable, and, therefore, easily susceptible of accurate examination; they may be considered as resulting from the mutual agencies of heat and attraction, and are comprehended under the three classes of *Solids*, *Liquids*, and *Gases*.

SECTION I. *Of the Effects of Radiant Matter in producing the Phenomena of Vision.*

THE minute investigation of those laws of light which relate to its motion, and effects in producing vision, constitutes a branch of the science of Optics, and therefore belongs to Mechanical Philosophy; it is, however, requisite that some of them should partially be considered as bearing upon important questions of chemical inquiry.

98. The discoveries of Roemer* and of Bradley†, have shewn that light is about eight minutes in passing from the sun to the earth, so that it may be considered as moving at the rate of 200,000 miles in a second.

99. Some bodies intercept light, or are *opaque;* others allow its transmission, or are *transparent;* and there are gradations from perfect opacity to nearly perfect transparency. It is probable that opacity results from the attraction of the substance for light, and not from its density, for it can scarcely be supposed that the particles of bodies should not be far enough distant to allow of the passage of light. Newton supposes the particles of transparent bodies to be of uniform density and arrangement, and attracting the ray of light equally in every direction, they suffer it to pass through them without obstruction; whereas, in opaque bodies, the particles are either of unequal density or irregularly arranged, and the light being unequally attracted, cannot therefore penetrate the body.

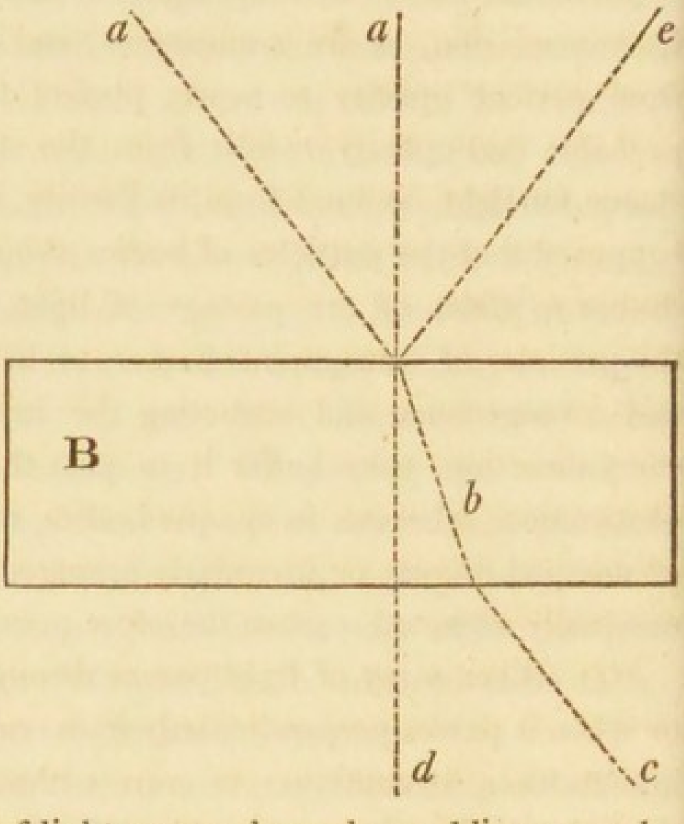
100. When a ray of light passes through the same medium, or when it passes perpendicularly from one transparent medium into another, it continues to move without changing its direction; but, when it passes obliquely from one medium into another of a different density, it is thrown more or less out of its old direction, and is said to be *refracted*. The refraction is *towards* the perpendicular when the ray passes into a denser medium, and *from* the perpendicular when it passes into a rarer medium. The medium in which the rays of light are caused to approach nearest to the line perpendicular to its surface, is said to have the greatest refractive density.

101. When the rays of light arrive at the surfaces of bodies,

* *Philos. Trans.* Vol. xii. † *Philos. Trans.* Vol. xxxv. and xlv.

a part of them, and sometimes nearly the whole, is thrown back, or *reflected,* and the more obliquely the light falls upon the surface, the greater in general is the reflected portion. In these cases the angle of reflection is always equal to the angle of incidence.

Let *a, a,* represent pencils of light falling upon the surface of a polished piece of glass B., the perpendicular pencil will pass on in a straight line to *d.* Of the oblique pencil, one portion will enter the glass and suffer refraction towards the perpendicular as at *b,* and re-entering the atmosphere, it will bend from the perpendicular, and reassume its former direction, as at *c.* Another portion of the oblique pencil will be reflected at an angle equal to that of its incidence, as at *e.*



102. When a ray of light passes through an oblique angular crystalline body, it exhibits peculiar phenomena; one portion is refracted in the ordinary way, another suffers extraordinary refraction, in a plane parallel to the diagonal joining the two obtuse angles of the crystal; so that objects seen through the crystal appear double. Transparent rhomboids of carbonate of lime, or Iceland crystal, exhibit this phenomenon particularly distinct.

If a ray of light, which has thus suffered double refraction, be received by another crystal, placed parallel to the first, there will be no new division of the rays; but, if it be placed in a transverse direction, that part of the ray which before suffered ordinary refraction will now undergo extraordinary refraction, and reciprocally that which underwent extraordinary refraction now suffers ordinary refraction.

If the second crystal be turned gradually round in the same plane, when it has made a quarter of a revolution there will be four divisions of the ray, and they will be reduced to two, in the half of the revolution; so that the refracting power appears to depend upon some relation of the position of the crystalline particles.

When light is reflected from bodies it retains, under many circumstances, its former relations to the refractive power of transparent media; but, in certain cases, at angles differing for different substances, the reflected rays exhibit peculiar properties, analogous to those which have suffered extraordinary refraction. Thus if the flame of a taper reflected at an angle of 52° 45′ from the surface of water, be viewed through a piece of doubly refracting spar, one of the images will vanish every time that the crystal makes a quarter of a revolution.

When a ray of light is made to fall upon a polished glass surface, at an angle of incidence of 35° 25′, the angle of reflection will be equal to that of incidence. Let us suppose another plate of glass so placed that the reflected ray will fall upon it at the same angle of 35° 25′; this second plate may be turned round its axis without varying the angle which it makes with the ray that falls upon it. A very curious circumstance is observed as this second glass is turned round. Suppose the two planes of reflection to be parallel to each other, in that case the ray of light is reflected from the second glass in the same manner as from the first. Let the second glass be now turned round a quadrant of a circle, so as to make the reflecting planes perpendicular to each other. Now, the whole of the ray will pass through the second glass, and none of it will be reflected. Turn the second glass round another quadrant of a circle, so as to make the reflecting planes again parallel, and the ray will again be reflected. When the second glass is turned round, three quadrants, the light will be again transmitted, and none of it reflected. Thus, when the reflecting planes are parallel, the light is reflected, but when they are perpendicular the light is transmitted. This experiment proves, that under certain circumstances, light can penetrate through glass when in one position, but not in another. This curious fact was first observed by Malus, who accounted for it by supposing the particles of light to have assumed a particular position, as a needle does when under the influence of a magnet, and hence he called this property of light, its Polarisation*. It has since been studied with laborious diligence by Dr. Brewster, and by M. M. Arago and Biot. (*Philos. Trans.* 1813, 1814, 1815, 1816, 1817. *Annales de Chimie, tom.* 94. *Traité de Physique.*)

103. That a sunbeam, in passing through a dense medium, and especially through a triangular prism of glass, gives rise to a series of brilliant tints similar to those of the rainbow, was known in the earliest ages, but it required the sagacity of Newton to develope the cause of the phenomenon. He proved, that light consists of rays differing from each other in their relative refrangibilities; and, guided by their colour, considered their number as seven: red, orange, yellow, green, blue, indigo, and violet. If the prismatic colours, or *Spectrum*, be divided into 360 equal parts, the red rays will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the violet 80. Of these rays, the red being least refrangible, fall nearest that spot which they would have passed to, had they not been refracted; while the

* *Thomson's System.* Vol. i. p. 16.

violet rays being most refrangible, are thrown to the greatest distance; the intermediate rays possess mean degrees of refrangibility.

These differently coloured rays are not susceptible of further decomposition, by any number of refractions, but when they are collected into a focus they re-produce white light. Upon these phenomena is founded the Newtonian theory of colours, which supposes them to depend upon the absorption of all rays, excepting those of the colour observed. Thus green bodies reflect the green rays and absorb the others. All the rays are reflected by white bodies, and absorbed by those which are black.

Section II. *Of the Operation of Radiant Matter in producing Heat.*

104. If a solar beam be refracted by a prism, and the coloured image received upon a sheet of paper, it will be found, on moving the hand gently through it, that there is an evident increase of temperature towards the red ray. This fact seems to have been first noticed by Dr. Hutton (*Dissertation on Light and Heat*, p. 39); but it is to Dr. Herschel (*Philos. Trans.* 1800) that we are indebted for a full investigation of the subject. If the coloured rays be thrown successively upon delicate thermometers, it will be found, that if the heating power of the violet rays be considered = 16, that of the green rays will be = 26, and of the red = 55. These circumstances suggested the possibility of the heating power of the spectrum extending beyond the red ray; and on applying a thermometer just out of the red ray, and beyond the limits of the visible spectrum, this was found to be the case. A thermometer in the red ray rose 7° in ten minutes, but just beyond the red ray the rise was = 9°. It is evident, therefore, that, independent of the

illuminating rays, there are others which produce increase of temperature, and these from their increase towards the red ray, and from the spot which they principally occupy in the refracted congeries, are possessed of less refrangibility than the visible rays.

That these calorific rays are susceptible of refraction and reflection is proved by the intense heat produced when the solar rays are concentrated into a focus by a lens, or by a concave mirror.

105. The radiant matter, emitted by terrestrial bodies at high temperatures, agrees in many of its properties with that constituting the solar rays, but in others it presents material differences, and the investigation of this subject constitutes a beautiful department of philosophic inquiry.

The effect we perceive in approaching a fire chiefly results from radiation ; and is little connected with the immediate conducting power of the air; and if a concave *metallic* mirror be held opposite the fire, a heating and luminous focus will be obtained. The affections of terrestrial radiant matter are best demonstrated by employing two concave mirrors of planished tin or plated copper, placed at a distance of about 10 feet asunder. (Pictet *Essais de Physique.*) Under these circumstances, when a thermometer is in the focus of one of the mirrors, it will be found sensible to the effects of a heated body placed in the focus of the opposed mirror; and that the effect is produced by reflection, and not by mere direct radiation, is proved, either by drawing the thermometer out of the focus towards the opposed mirror, or by placing a screen between the thermometer and its mirror, when diminution of temperature is in either case indicated. In these experiments the differential thermometer (43) is most advantageously employed, and the mirrors may be placed opposite each other on the ground, or vertically sus pended as in the woodcut, where *a*, *a*, represent the mirrors, *b*, a pan of hot charcoal, *c*, an air thermometer.

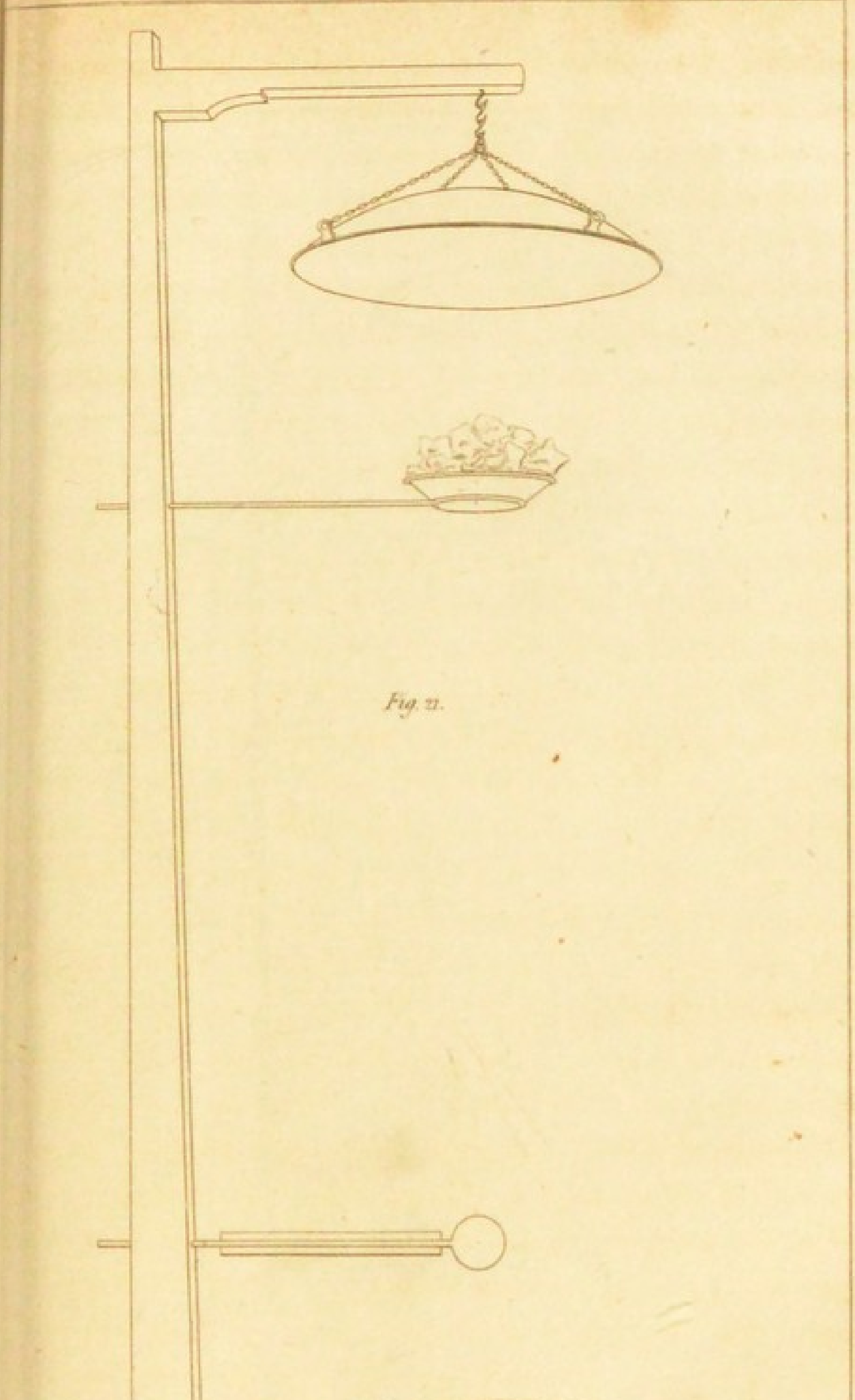
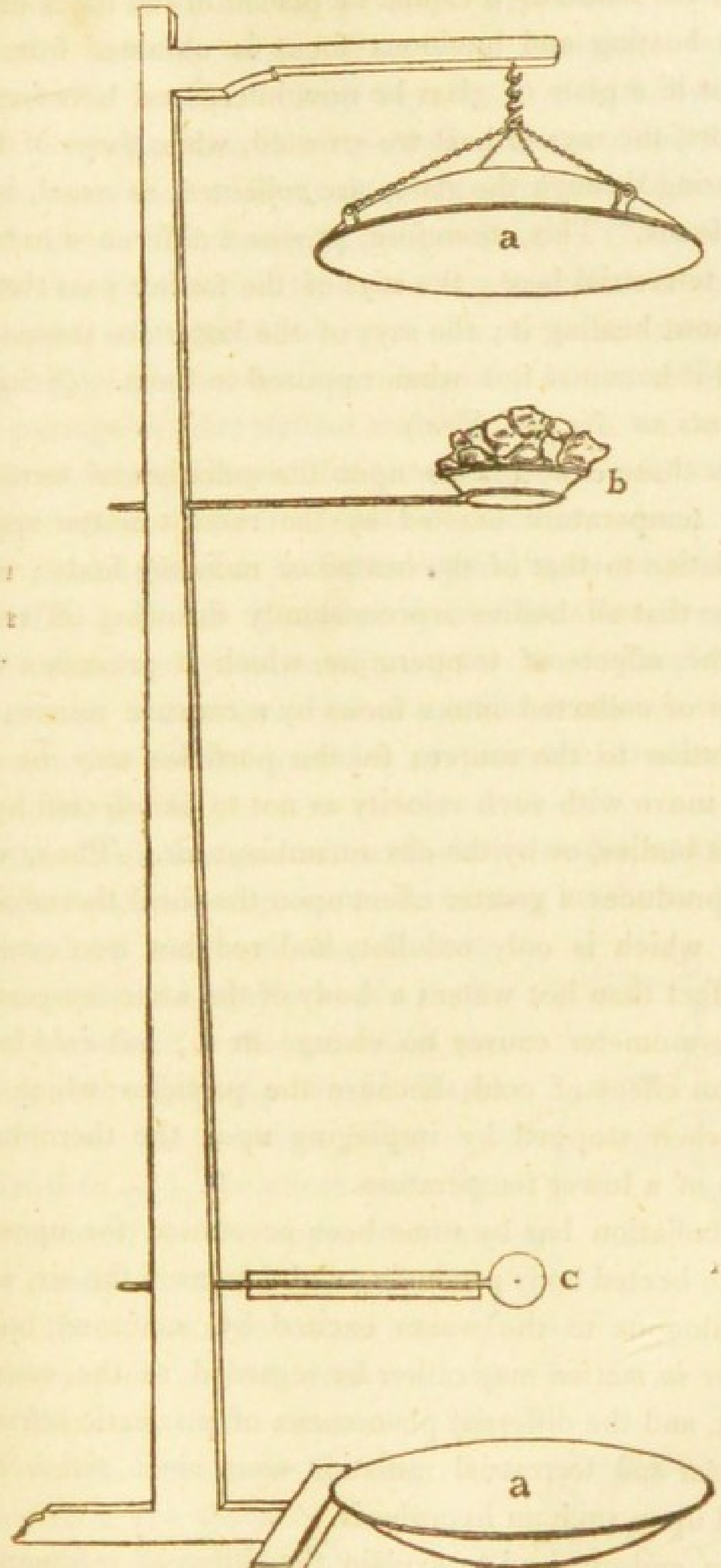


Fig. 21.

Lowry sculp.

Publd. June 1st. 1812. by J. Johnson & Co. St. Pauls Church Yd. London.


a
b
c
a

106. If the flame of a candle be placed in the focus of one mirror, a heating and luminous focus is obtained from the other: but if a plate of glass be now interposed between the two mirrors, the rays of heat are arrested, while those of light, freely passing through the glass, are collected, as usual, in the opposite focus. This, therefore, proves a difference between solar and terrestrial heat; the rays of the former pass through glass without heating it; the rays of the latter are stopped by glass, and it becomes hot when opposed to them. (Scheele's *Experiments on Air and Fire.*)

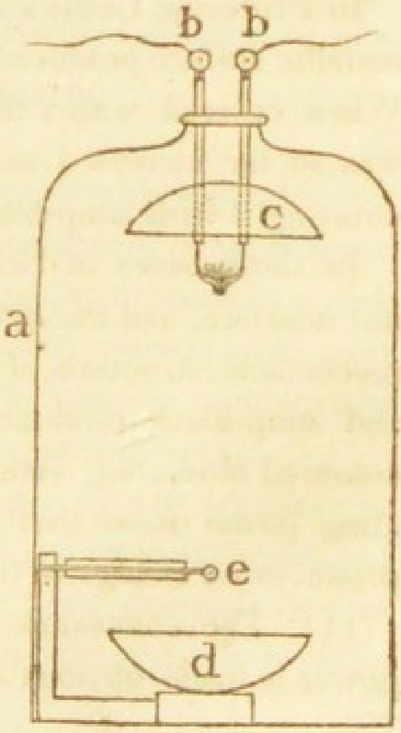
107. In these experiments upon the radiation of terrestrial heat, the temperature excited by the radiant matter appears always relative to that of the heated or radiating body; and if we assume that all bodies are constantly throwing off radiant matter, the effects of temperature which it produces when condensed or collected into a focus by a concave mirror, will bear a relation to the source; for the particles may be conceived to move with such velocity as not to be affected by circumjacent bodies, or by the circumambient air. Thus, white hot iron produces a greater effect upon the focal thermometer than that which is only red hot, and red hot iron causes a greater effect than hot water; a body of the same temperature as the thermometer causes no change in it; but cold bodies produce an effect of cold, because the particles which they radiate, when stopped by impinging upon the thermometer bulb, are of a lower temperature.

108. Radiation has by some been accounted for upon the idea of the heated body producing undulations in the air, something analogous to the waves excited by sonorous bodies; but *matter in motion* may rather be regarded as the cause of the effect, and the different phenomena of prismatic refraction and of solar and terrestrial radiation seem most satisfactorily explained upon such an hypothesis.

Newton endeavoured to explain the different refrangibility of the rays of light, by supposing them composed of particles of different sizes, and adopting this hypothesis, we should say, that the particles of red light were largest; those of violet light smallest. The heating rays (103) would consist of particles yet larger than those producing colour; and the smallest particles, or most attenuated radiant matter would be that which produces certain chemical changes (112). (*Newton's Optics.*) Upon this hypothesis too, it would appear that the particles of terrestrial heat are of so large a size as to be arrested in their progress by glass and other transparent bodies which allow a free passage to solar radiant matter.

Newton has also put the query, whether light and common matter are not convertible into each other. And, if we consider sensible heat in bodies to depend upon vibrations of their particles, a certain intensity of vibrations may send off particles into free space; and particles moving rapidly in right lines, may, in losing their own motion, communicate a vibratory motion to the particles of terrestrial bodies. (*Davy's Elements*, p. 215.)

109. Radiation goes on in all elastic media, and in the Torricellian and air-pump vacuum, as may be shewn by igniting charcoal by means of the Voltaic battery, placed in the focus of a small mirror confined in the exhausted receiver of the air-pump. Sir H. Davy found that the receiver being exhausted to $\frac{1}{120}$, the effect upon the thermometer in the opposite focus was nearly three times as great as when the air was in its natural state of condensation. *a* is the receiver. *b*, *b*, the insulated wires connected with the voltaic apparatus igniting the charcoal in the focus of the upper mirror *c*. In the focus of the lower mirror *d* is the thermometer *e*.



110. It has long been known, in regard to solar rays, that their heating effect depends much upon the colour of the surfaces upon which they impinge, and that black and dark bodies are more heated than those which are white or of light tints, circumstances dependent upon absorption and reflection.

Professor Leslie has shown that the phenomena of terrestrial radiation are connected with the nature of the radiating surface; and that those surfaces which are the best radiators of this heat, are also gifted with the greatest absorbing power. (Leslie *on Heat.*)

Unmetallic and unpolished surfaces are the best radiators, and also the best receivers of radiant heat; while polished metallic substances are the worst radiators, and have the lowest absorbing powers. In the experiments with the metallic mirrors, the whole nearly of the heat is reflected, and the mirror itself does not become warm; but if it be coated with any unpolished and especially unmetallic coating, as with paper, or paint, the radiation is then scarcely perceptible, and the mirror becomes hot from the absorption of the radiant matter.

In Professor Leslie's experiments it was found, that a clean metallic surface produced an effect = 12 upon the thermometer. When covered with a thin coat of glue, its radiating power was so far increased as to produce an effect = 80; and, on covering it with lamp-black, it became = 100.

In these cases of radiation the *colour* of the surface does not interfere, and the different effects must be referred to the mechanical structure of the radiating surface. White paper and lamp-black produce nearly the same effects; and paper, coloured blue, red, yellow, and green, does not differ in radiating power from that which is white, provided the colour produces no change of texture in the paper.

111. The connexion of the receptive with the radiating power is made obvious by coating the bulbs of thermometers

with different substances. Thus, the effect of radiant heat upon a thermometer bulb covered with a thin coating of lamp-black being = 100; when the bulb is covered with silver-leaf the effect is only = 12.

112. Upon the principle of the absorption of the solar rays by blackened surfaces, Mr. Leslie has constructed a *photometer*. It is merely a very delicate and small differential thermometer, enclosed in a thin and pellucid glass tube. One of the bulbs is of black glass, which, when the instrument is suddenly exposed to light, becoming warmer than the clear bulb, indicates the effect by the depression of the fluid. (Leslie *on Heat*, p. 424.)

It is obvious from the above mentioned facts, that all vessels intended to retain heat, should be clean and metallic, for polished metallic surfaces have very low radiating powers; whereas those vessels which are either to receive, or to radiate, should be blackened upon their surfaces. The knowledge of these properties is economically applicable in a variety of cases.

SECTION III. *Of the Influence of Radiant Matter in producing Chemical Changes.*

113. RADIANT matter possesses considerable influence over the chemical energies of bodies. If a mixture of equal volumes of the gases called chlorine and hydrogen be exposed in a dark room, they slowly combine, and produce muriatic acid gas; but, if exposed to the direct rays of the sun, the combination is very rapid, and often accompanied by an explosion.

Chlorine and carbonic oxide have scarcely any tendency to combine, even at high temperatures, when light is excluded, but exposed to the solar rays they enter into chemical union. Chlorine has little action upon water, unless exposed to light, and, in that case, the water, which consists of oxygen and hydrogen, is decomposed. The hydrogen unites with the chlorine to produce muriatic acid, and the oxygen is evolved in a gaseous form.

These, and numerous other similar cases which might be adduced, show that radiant matter influences the chemical energies of bodies, independent of its heating powers. Scheele (*Experiments on Air and Fire*, p. 78, &c.) was the first who entered upon this curious investigation; and many important facts connected with it have been more lately ascertained by Ritter, Wollaston, and Davy. Scheele threw the prismatic spectrum upon a sheet of paper, moistened with a solution of nitrate of silver, a salt quickly decomposed by the agency of light. In the blue and violet rays the silver was soon reduced, producing a blackness upon the paper, but in the red ray scarcely any similar effect was observed. Wollaston and Ritter discovered that these chemical changes were most rapidly effected in the space which bounds the violet ray, and which is out of the visible spectrum.

114. It has thus been ascertained, that the solar beams are refrangible into three distinct kinds of rays,—the *calorific*, or heating rays; the *luminous*, or *colorific* rays, which produce vision and colour; the *decomposing* rays, or those which have a tendency to interfere with the chemical constitution of bodies.

In the prismatic spectrum these three sets of rays are imperfectly separated, and arranged according to their respective refrangibilities. The heating rays are the least refrangible, the colorific rays are possessed of more refrangibility, and the decomposing, or, as some have called them, the deoxidizing rays, are the most refrangible.

115. Sir H. Davy has observed, that certain metallic oxides, when exposed to the violet extremity of the prismatic spectrum, undergo a change similar to that which would have been produced by exposure to a current of hydrogen; and that,

when exposed to the red rays, they acquire a tendency to absorb oxygen. (*Elements of Chemical Philosophy.*) In such general facts, he traces an analogy between the effects of the solar beam, and the agencies of electricity. In the Voltaic circuit, the maximum of heat is at the positive pole, where the power of combining with oxygen is also given to bodies; the agency of rendering bodies inflammable is exerted at the opposite surface; and similar chemical effects are produced by negative electricity, and by the most refrangible rays; and by positive electricity, and the rays which are least refrangible.

116. In nature the influence of the solar rays is very complex, and the growth, colour, flavour, and even the forms of many vegetables, are much dependent upon them. This is seen in many plants which are protected from the sun's rays; celery and endive are thus cultivated with the view of rendering them palatable; and plants which are made to grow in a room imperfectly illuminated, always bend towards the apertures by which the sun's rays enter. The changes too which vegetables effect upon the circumambient atmosphere are influenced by the same cause.

In the animal creation, brilliancy of colour and gaudy plumage belong to the tropical climates; more sombrous tints belong to the polar inhabitants; and dull colours characterize nocturnal animals, and those who chiefly abide below the surface.

Section IV. *Of the Phenomena exhibited by Luminous and Incandescent Bodies, and of the Nature and Properties of Flame.*

117. There are many substances which, when heated to a certain point, become luminous without undergoing combustion, and such bodies are said to be *phosphorescent*. The tem-

peratures which they require for this purpose are various; it generally commences at about 400°, and may be said to terminate at the lowest visible redness. Some varieties of phosphate of lime, of fluor spar, of bituminous carbonate of lime, of marble, and sand, and certain salts, are the most remarkable bodies of this description. (Wedgwood, *Phil. Trans.* vol. 82.)

Their luminous property may be best exhibited by scattering them in coarse powder upon an iron plate heated nearly to redness. Oil, wax, spermaceti, and butter, when nearly boiling, are also luminous.

118. Another class of phosphorescent bodies have been termed *solar phosphori*, from becoming luminous when removed into a dark room after having been exposed to the sunshine. Of this description are Canton's, Baldwin's, and the Bolognian phosphorus. Canton's phosphorus is prepared thus:—Calcine oyster-shells in the open fire for half an hour, then select the whitest and largest pieces and mix them with one third their weight of flowers of sulphur, pack the mixture closely into a covered crucible, and heat it to redness for an hour. When the whole has cooled, select the whitest pieces for use. (*Phil. Trans.* vol. 48.)

Baldwin's phosphorus is prepared by heating nitrate of lime to a dull red heat; and the Bolognian phosphorus, discovered by Vincenzio Cascariolo, a shoemaker, of Bologna, is made by reducing compact sulphate of baryta to a fine powder, which is formed into cakes with mucilage, and these are heated to redness. (Aikin's *Dictionary, Art. Phosphori.)*

Mr. B. Wilson has also made a variety of curious experiments on solar phosphori; and, he has discovered the simplest and most effectual of these bodies, which may be obtained by closely observing the following directions:—Take the most flaming coals off a brisk fire, and throw in some thick oyster-shells; then replace the coals, and calcine them for an hour; remove them carefully, and, when cold, it will be found that, after exposing them for a few minutes to the light, they will glow in the dark with most of the prismatic colours. (Wilson *on Phosphori*, p. 20.)

119. A third set of bodies, belonging to this class, are those which are *spontaneously phosphorescent*. Such are especially, the flesh of salt-water fish just before it putrefies, and decayed wood. The glow-worm, the hundred-legged-worm, and the lanthorn-fly, are also luminous when alive.

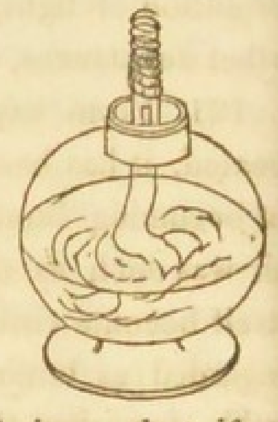
It appears from the experiments of Canton and of Dr. Hulme (*Phil. Trans.* Vols. 59, 90, and 91), that sea-fish become luminous in about twelve hours after death, that it increases till putrefaction is evident, and that it then decreases. Immersion in sea-water does not affect this luminous matter, on the contrary, the brine is itself rendered luminous; but it is extinguished by pure water, and by a variety of substances which act chemically upon the animal matter.

120. Percussion and friction are often attended by the evolution of light, as when flint pebbles, pieces of sugar, and other substances, are struck or rubbed together.

121. From experiments in which air has been intensely heated, it has been concluded that gaseous matter is incapable of becoming luminous; for, though the temperature of the air was such as to render solid bodies white hot, it did not itself become visible. Flame, however, may, in general, be regarded as luminous gaseous matter. Hydrogen gas, probably, furnishes the purest form of flame which can be exhibited, for the flames of bodies which emit much light, derive that power from solid matter which is intensely ignited and diffused through them, and which, in ordinary flames, as of gas, tallow, wax, oil, *&c.*, consists of finely divided charcoal.

The intensity of the heat of flames which are but little luminous, as of hydrogen gas, spirit of wine, *&c.*, may be shewn by introducing into them some fine platinum wire, which is instantly rendered white hot in those parts where the combustion is most perfect. It is even intensely ignited in the current of air above the flame, as may be shewn by holding a piece of platinum-wire over the chimney of an Argand lamp fed with spirit of wine, or by the common expedient of lighting paper by holding it in the current of heated air which rushes out of a common lamp-glass.

The high temperature of flame is further proved by certain cases of combustion without flame. Thus, if a heated wire of platinum be introduced into any inflammable or explosive mixture, it will become ignited, and continue so till the gas is consumed; and inflammation will, in most cases, only take place when the wire becomes white hot. This experiment is easily made by pouring a small quantity of ether into the bottom of a beer-glass, and holding a piece of heated platinum wire a little above its surface; the wire becomes red hot, but does not inflame the vapour of the ether till it acquires an intense white heat.



The same fact is exhibited by putting a small coil of platinum wire round the wick of a spirit lamp, which, when heated, becomes red hot, and continues so, as long as the vapour of the spirit is supplied, the heat never becoming sufficiently intense to produce its inflammation.

Such being the nature of flame, it is obvious, that if we cool it by any means, we must at the same time extinguish it. This may be effected by causing it to pass through fine wire gauze, which is an excellent conductor and radiator of heat, and consequently possessed of great cooling power. If a piece of fine brass or iron wire-gauze be brought down upon the flame of a candle, or what answers better, upon an inflamed jet of coal gas, it will, as it were, cut the flame in half.

That the cooled gaseous matter passes through, may be shewn by again lighting it upon the upper surface.

The power, therefore, of a metallic tissue thus to extinguish flame, will depend upon the heat required to produce the combustion, as compared with that acquired by the tissue; and the flame of the most inflammable substances, and of those that produce most heat in combustion, will pass through a metallic tissue that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion, so that different flames will pass through at different degrees of temperature.

The discovery of these facts, respecting the nature and properties of flame, led Sir H. Davy to apply them to the construction of the miners safety-lamp, which will be explained under the article *Carburetted hydrogen gas*.

122. The phenomena exhibited by phosphorescent and incandescent bodies, and in the process of combustion, have sometimes been explained upon the idea that the light and heat evolved, were previously in combination with the substances, and that they are afterwards merely emitted, in consequence of decomposition, and that the solar phosphori absorb light and again give it out unchanged. But it appears more probable that any particles violently repelled into space may become radiant matter, rather than that it should consist of a *specific* substance: thus, mechanical action, and chemical changes, may each tend to the emission of radiant matter; and incandescence will result when the vibrations which heat occasions among the particles of bodies are of such violence as to cause their repulsion into space.

CHAPTER III.

Of the Simple Supporters of Combustion.

123. THE substances belonging to this class are characterized by possessing very energetic powers of combination, in respect to the simple inflammable bodies, and they are each of them capable of producing acids, whence they may also be termed *acidifying* principles. When their compounds are submitted to electro-chemical decomposition, these elements are attracted by the positive surface; hence their natural or inherent electrical states may be considered as negative.

These acidifying, electro-negative supporters of combustion, are three in number:

1. Oxygen.
2. Chlorine.
3. Iodine.

The following examples will serve to give some idea of the principles of nomenclature generally adopted in chemistry. The above bodies in entering into combination with each other, and with the bodies described in Chapters IV. and V., produce two classes of compounds. Those which are not acid, are usually distinguished by the termination *ide*, as *oxide* of chlorine, *oxide* of nitrogen, *chloride* of sulphur, *iodide* of iron, *&c.*; and where more than one compound of this kind is produced, the terminations *ous* and *ic* are used to designate the relative proportions of the supporters of combustion. Thus nitrogen forms two oxides; that containing the smallest proportion of oxygen is the *nitrous* oxide, that containing the largest the *nitric* oxide. The acid compounds are similarly designated, as *nitrous* and *nitric* acid; *sulphurous* and *sul-*

uric acid. The different combinations of the metals with oxygen, are perhaps best distinguished by prefixing to the word *oxide* the first syllable of the Greek ordinal numerals, originally proposed by Dr. Thomson. Thus the *protoxide* of a metal will denote the compound containing a minimum of oxygen, or the first oxide which the metal is capable of forming; *deutoxide* will denote the second oxide of a metal, &c.; and when a metal is combined with the largest possible quantity of oxygen, the compound, if not acid, may be called *peroxide*. The same rule applies to the *chlorides* and *iodides*.

The acids terminating in *ous* produce compounds in which the termination *ite* is used, while those ending in *ic* form compounds in which the ending *ate* is used. Thus the combination of sulphurous acid and potassa, is a *sulphite* of potassa; that of sulphuric acid and potassa, a *sulphate* of potassa, &c. The compounds of the bodies contained in Chapter IV., with each other, and with those in Chapter V., are commonly designated by the termination *uret*, as *sulphuret* of phosphorus, *phosphuret* of carbon, &c.

The terms *bi sulphuret, bi sulphate, bi phosphuret, bi phosphate*, &c., applied to compounds, imply that they contain twice the quantity of sulphur, sulphuric acid, phosphorus or phosphoric acid, existing in the respective sulphuret, sulphate, phosphuret, and phosphate.

Section I. *Of Oxygen* *.

124. This elementary gaseous body may be obtained by heating to redness, in a glass retort, the salt called *oxymuriate of potash*, 100 grains of which yield about 100 cubical inches; it may be collected over water in the hydro-pneumatic apparatus. It is also given off from black oxide of

* From ὀξὺς and γεννάομαι, the producer of acids.

manganese, red oxide of lead, and nitre, when exposed to a red heat*.

125. Oxygen gas is insipid, colourless, and inodorous; its specific gravity is 15, hydrogen being assumed = 1. 100 cubical inches at mean temperature and pressure weigh 33.75 grains.

It is a powerful supporter of respiration and combustion. A small animal confined in oxygen gas, lives thrice as long as when confined in the same bulk of common air. A lighted taper, or a burning piece of sulphur, or phosphorus, introduced into this gas, is very rapidly consumed, with intense ignition.

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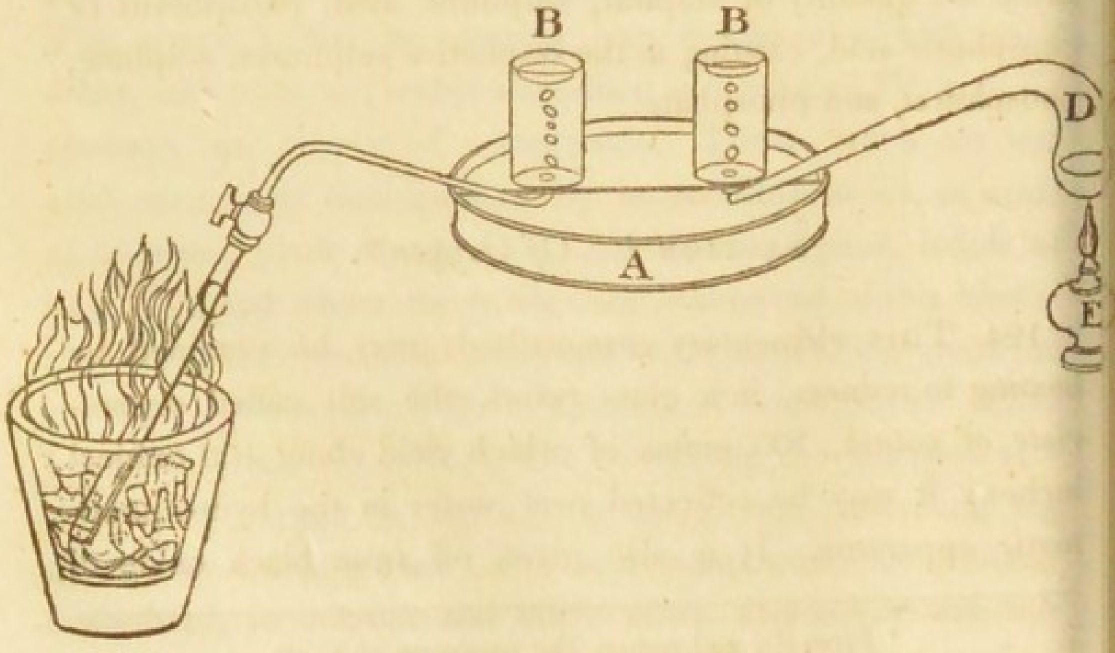
* Common glass, or earthen ware retorts, are used in these, and a variety of other chemical operations; or, where a red heat is required they may be made of wrought iron, either in the same form, or in that of a bottle, tube, or other convenient shape.

The hydro-pneumatic apparatus consists of a japanned iron or copper vessel, of different shape and size, according to the particular purposes for which it is intended, and containing a shelf perforated with holes through which the gas may pass into inverted vessels properly placed for its reception. In this wood-cut, A is the hydro-pneumatic trough; B, B, inverted glasses for the reception of gas; C, a wrought iron tube placed in a pan of charcoal for the evolution of gases requiring a red heat; D, a retort heated by the spirit lamp E.



For experiments, in which larger vessels are employed for collecting

126. The phenomena of combustion were referred by Stahl and his associates, to a peculiar principle which they called *phlogiston;* it was supposed to exist in all combustibles, and combustion was said to depend upon its separation; but this explanation was absurdly at variance with the well-known fact, that bodies during combustion increase in weight.

After the discovery of oxygen gas, it was adopted by Lavoisier as the universal supporter of combustion. The basis of the gas was supposed to unite to the combustible, and the heat and light which it before contained in the gaseous state, were said to be evolved in the form of flame. But in

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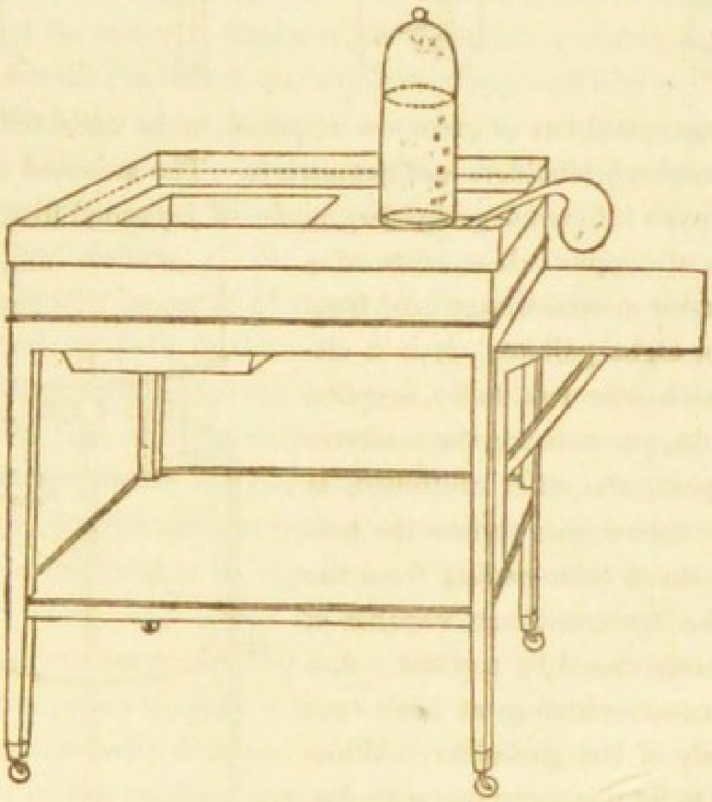
or transferring gases, the annexed form of the apparatus is most convenient.



Vessels of various forms are employed for receiving, retaining, and measuring, gases. Where it is intended to introduce different substances into the gas, they may be of the form represented in figure 1, drawn into a neck with a glass-stopper at top, and open at bottom. Some of these should be graduated into cubic inches, and supplied with a stop-cock, as in figure 2. For measuring small quantities of gases, tubes are this case, several requisites are not fulfilled; the light depends upon the combustible, and not upon the quantity of oxygen consumed; and there are very numerous instances of com-

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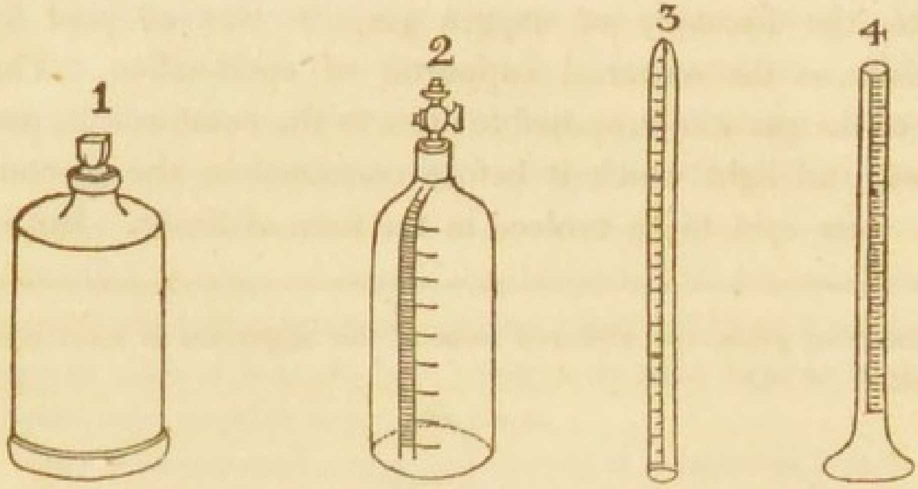
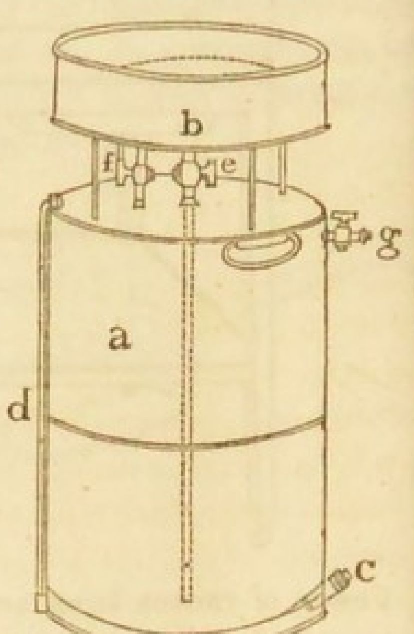
employed, some of which should be divided into 100 equal parts, others into tenths and hundredths of a cubical inch. Figures 3, 4.



Where large quantities of gases are required to be collected and preserved, we employ gasholders and gasometers. The annexed cut represents Mr. Pepys's improved gasholder, made of japanned iron, or what is preferable, of copper. It consists of a body or reservoir *a*, which may hold from two, to six or eight gallons. *b*, is a cistern from which issue two tubes, supplied with stop-cocks, one entering the reservoir at its upper part; the other continued, as shewn by the dotted lines to near the bottom. *c*, is a short tube issuing from the bottom of the reservoir, and capable of being accurately closed by a screw. *d*, is a glass-tube communicating at both ends with the body of the gasholder. When it is intended to fill this apparatus with gas, the tube *c* is closed, and the stop-cocks, *e*, *f*, are opened; water is then poured into the cistern, which running down the long tube, forces the air out through the shorter one. The reservoir being thus filled, the stopcocks are closed, and the aperture *c*, is opened, into which the beak of the retort, or tube, whence the gas issues, is introduced, and bubbling up, displaces the water which



bustion in which oxygen, instead of being solidified, becomes gaseous during the operation; and, lastly, in others, no oxygen whatever is present. Combustion, therefore, cannot be regarded as dependent upon any peculiar principle or form of matter, but must be considered as a general result of intense chemical action. It may be connected with the electrical energies of bodies; for all bodies which powerfully act upon each other, are in the opposite electrical states of positive and negative; and the evolution of heat and light may depend upon the annihilation of these opposite states, which happens whenever they combine.

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runs out at the same opening. When it is seen in the tube *d*, that nearly the whole of the water is displaced, the aperture is closed, and the vessel is now filled with gas, which may either be drawn off into receivers, placed in the cistern *b*, by opening the two stopcocks *e*, *f*, or by opening the stopcock *f*, and opening *g*, it may be propelled into bladders, or transferred in any convenient way by an attached tube.

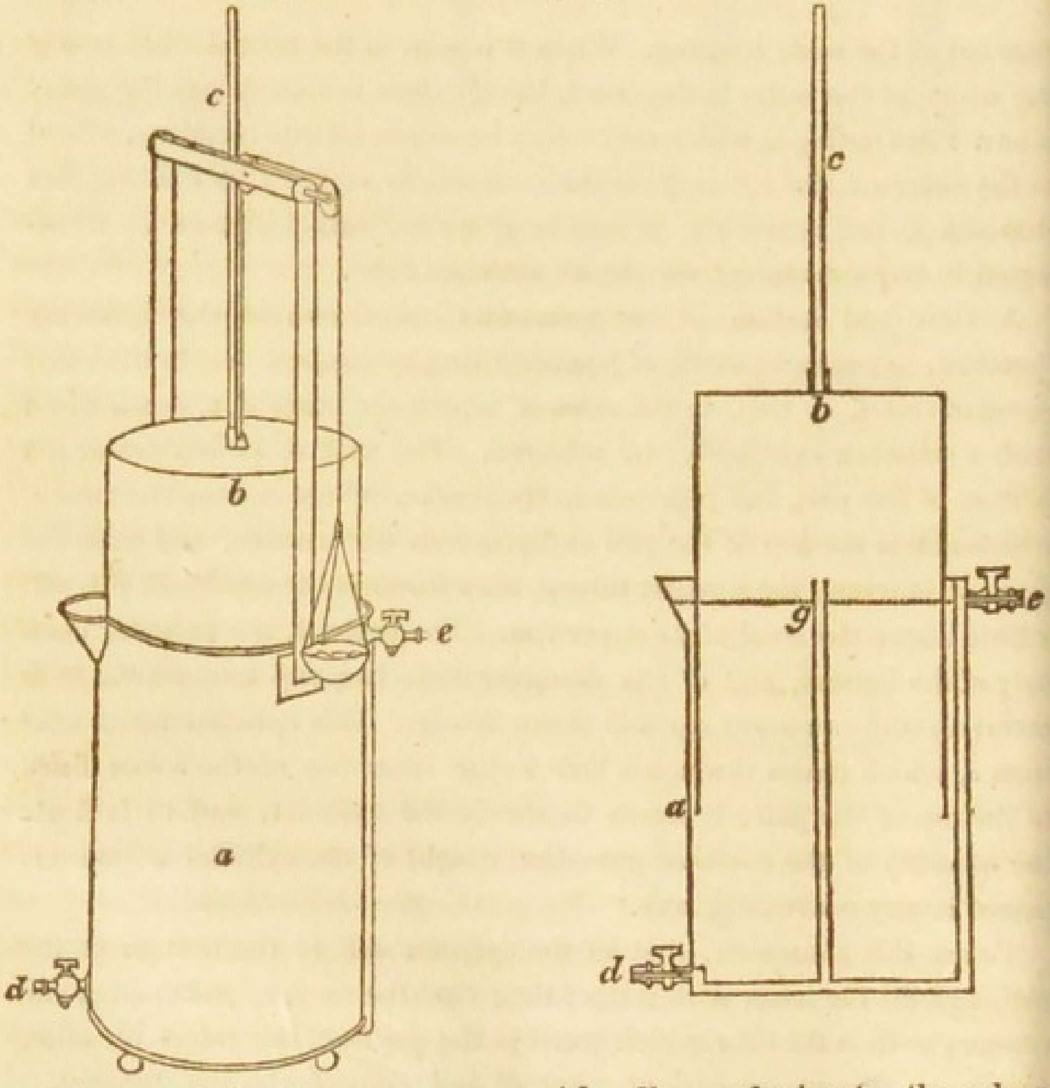
A view and section of the gasometer are shewn in the following sketches:—It may be made of japanned iron or copper. *a a*, is the outer circular vessel, or pail, to the sides of which the tubes *d*, *e*, (each fitted with a stopcock externally) are soldered. The tube *d*, penetrates at the bottom of the pail, and proceeds to the centre, where it joins the tube *e*, which enters the top of the pail and proceeds downwards, and from the place of junction, the upright tube *g*, rises through the middle of the pail a little above the level of its upper rim. The vessel *b*, is a cylinder open only at the bottom, and of less diameter than the pail into which it is inverted, and can move up and down freely. This cylinder has a solid stem *c*, which passes through a hole in the cross bar of the frame fixed to the top of the pail; it serves to steady the cylinder, and to indicate the quantity of the enclosed gas—the weight of the cylinder is counterpoised in any convenient way.

To use this gasometer, first let the cylinder fall to the bottom of the pail, and fill the latter with water; then shut the cock *e*, and open *d*, and connect with it the tube which conveys the gas from the retort or other vessel, or, if more convenient, shut *d*, and convey the gas through *e*.

Section II. *Of Chlorine**.

127. To obtain this gas, a mixture of black oxide of manganese and muriatic acid may be heated over a lamp in a glass retort. It is soon copiously evolved, and may be conveniently collected over warm water; as it is absorbed by cold water, it cannot be long retained over that fluid.

The gas rises and gradually lifts up the cylinder, which must be properly balanced; and when sufficiently filled, the cock, by which it entered, must be closed. The gas may now be drawn off at either of the stop-cocks, by a tube passing into the water-trough, or it may be propelled through a blow-pipe, or otherwise employed.



* A term derived from χλωρος, *greenish yellow,* referring to the colour of this gas.

It may also be procured from a mixture of 8 parts of common salt, 3 of black oxide of manganese, 4 of water, and 5 of sulphuric acid.

Chlorine was discovered by Scheele in 1774; it was called by him *dephlogisticated muriatic acid*. The term *oxymuriatic acid* was afterwards applied to it by the French chemists.

128. Chlorine is a permanently elastic gaseous fluid; it has a pungent and disagreeable smell, and is highly injurious when respired, even largely diluted with atmospheric air. Its colour is greenish yellow.

The specific gravity of chlorine, compared with hydrogen, is as 33,5 to 1; 100 cubic inches weigh 75,375 grains.

At the temperature of 60°, water dissolves two volumes of chlorine. The solution is of a pale yellow colour, has an astringent nauseous taste, and destroys vegetable colours; hence its use in bleaching; though the gas itself, when perfectly free from moisture, has scarcely any action upon them. When a burning taper is immersed in a jar of chlorine, the brilliancy of the flame is much impaired, it becomes red, throws off much charcoal, and is soon extinguished.

Many bodies, such as phosphorus and several of the metals, are spontaneously ignited by chlorine, and burn in it with much brilliancy. In these cases, binary compounds result, some of which, like those of oxygen, are possessed of acid properties. Others are not acid, and such compounds with oxygen being called *oxides*, those which chlorine forms may be termed *chlorides*.

Chlorine was once regarded as composed of oxygen and muriatic acid; a fallacy arising from the presence of water, and which will be rendered more intelligible under the head *Muriatic Acid*. (See Davy's Paper, *Phil. Trans.* 1811.)

Chlorine and oxygen unite in three proportions, forming an oxide and two acids.

129. *Oxide of Chlorine*, or *Euchlorine*, so called by its discoverer, Sir H. Davy (*Phil. Trans.* 1815), from its very deep

colour, may be obtained as follows: Upon 10 or 12 grains of the salt called *oxymuriate of potash*, drop a small quantity of sulphuric acid and stir the mixture with a platinum knife, having so adjusted the relative quantities of salt and acid that they may form together a yellow powder. Put this into a very small retort or bent tube, and by means of a water bath, apply a temperature of 150°. Euchlorine will pass off, and may be collected over quicksilver in small jars, or tubes*. The smell

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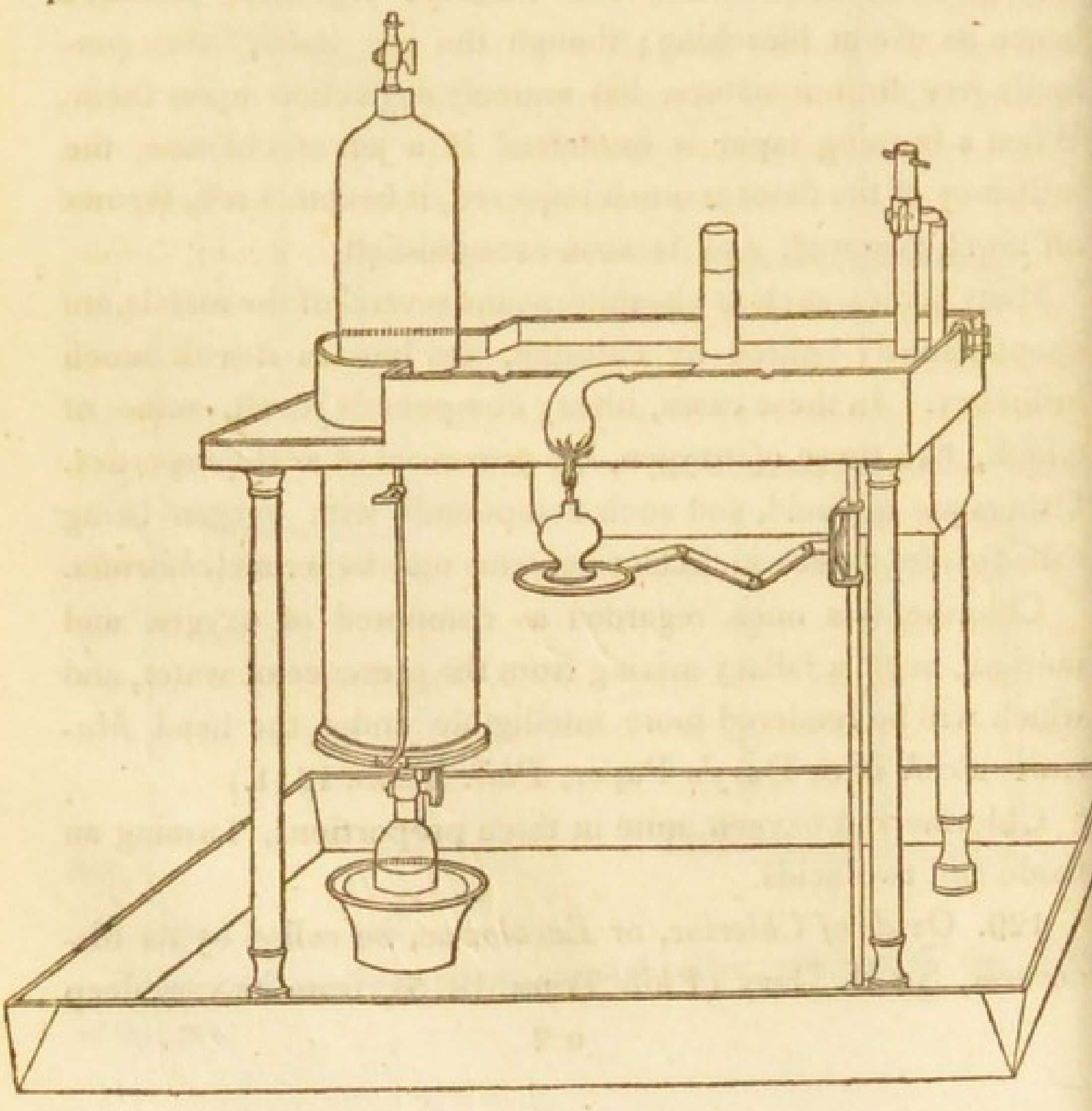
* Those gases which are absorbed by water may, in most instances, be collected over mercury. The best form of the *Mercurio-pneumatic apparatus*, is that contrived by Mr. Newman. (*Journal of Royal Institution*, vol. 1. p. 185.) It is a trough of cast-iron, supported by brass or iron legs, and having a small gasometer at one end. It is placed in a japanned iron-tray to collect the scattered mercury, as shewn in the wood-cut.



of this gas somewhat resembles that of chlorine, but is much less irritating and disagreeable. Its taste is astringent, and not at all acid.

When oxide of chlorine is gently heated, it is decomposed with explosion and expansion; two volumes are enlarged into three, of which two consist of oxygen, and one of chlorine; it is therefore composed of 33,5 parts by weight of chlorine combined with 30 of oxygen*.

130. *Chloric acid.* In the compound which has been thus called by its discoverer M. Gay-Lussac (*Annales de Chimie*, tom. XCI., p. 108), the relative proportions of chlorine to oxygen are to each other as 33,5 to 37,5; but it is a compound which cannot exist, independent of water or some base, and, therefore, may be compared to the *sulphuric* and some other acids, afterwards to be described. It may be prepared by passing a current of chlorine through a mixture of oxide of silver and water. Chloride of silver is produced, which is insoluble, and may be separated by filtration. The excess of chlorine, which the filtered liquor contains, is separable by heat, and the chloric acid dissolved in water remains. It is a sour, colourless liquid, producing peculiar compounds, afterwards to be described. It forms no precipitate in any metallic solution. The compounds may be called *chlorates*. The most remarkable of them have been long known under the name of *Oxymuriates*.

131. *Perchloric* or *oxychloric acid*, is procured by distilling *oxychlorate* of *potassa* with its own weight of sulphuric acid. It consists of 33,5 chlorine + 52,5 oxygen. It does not exist independent of water, or a base.

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* The gas, originally called *Euchlorine* by Sir H. Davy, appears to be a mixture of chlorine with the compound above described, and not a definite compound of two volumes of chlorine and one volume of oxygen.

Section III. *Of Iodine**.

132. Iodine is procured by the following process: Lixiviate powdered *kelp* with cold water. Evaporate the lixivium till a pellicle forms, and set aside to crystallize. Evaporate the mother liquor nearly to dryness, and pour upon the mass half its weight of sulphuric acid. Apply a gentle heat to this mixture in a glass alembic: fumes of a violet colour arise and condense in the form of opaque crystals, having a metallic lustre.

This body was discovered in 1812, by M. Courtois of Paris. Vauquelin (*Annales de Chimie*, tom. xc.), Gay-Lussac (*ib.* xc.), and Davy (*Phil. Trans.* 1814), have successfully investigated its properties.

Iodine has a bluish black colour; its lustre is metallic. It is soft and friable. Its specific gravity = 4,946. It produces a yellow stain upon the skin. Its smell resembles that of diluted chlorine; its taste is acrid. It is extremely volatile, and, at a temperature between 60° and 80°, produces a violet vapour. At 120° or 130° it rises more rapidly. At 220° it fuses, and produces copious violet-coloured fumes, which condense in brilliant plates, and acute octoëdrons. Like chlorine and oxygen, it is electro-negative; and therefore attracted by the positive surface of the Voltaic pile. It renders vegetable colours yellow. It is very sparingly soluble in water, that liquid not holding more than $\frac{1}{7000}$ its weight in solution. The colour of the solution is yellow. It is much more soluble in spirit of wine.

133. *Oxiodic acid* (Davy, *Phil. Trans.* 1815). This compound of oxygen and iodine cannot be obtained directly, for

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* From ἰώδης, *violaceus.*

those bodies exert no mutual action. It is procured by acting upon euchlorine by iodine. A compound is formed, which consists of chloriodic and oxiodic acids. The former is separable by a gentle heat, the latter remains as a white, semitransparent, sour, and inodorous body, very soluble in water. It consists of 117.7 iodine, 37,5 oxygen.

134. *Chloriodic acid* is easily obtained by the direct action of chlorine upon iodine. They unite and form crystals of a deep orange colour, deliquescent, and easily fusible and soluble. The solution is sour. This compound contains 117,7 iodine, 33,5 chlorine. (Davy, *Phil. Trans.* 1814.)

CHAPTER IV.

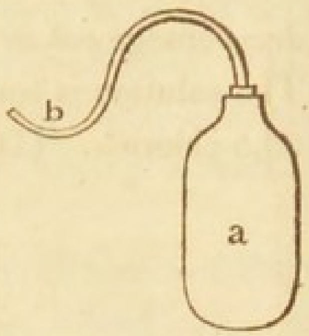
Of Simple Acidifiable and Inflammable Substances.

135. THE bodies belonging to this class are electro-positive, and consequently, when separated from their combinations with the substances described in the last chapter, by Voltaic electricity, they are attracted by the negative surface. With very few exceptions, they combine with the three supporters of combustion, already described, and of these compounds, one or more are acids. They are six in number :—

1. Hydrogen.
2. Nitrogen.
3. Sulphur.
4. Phosphorus.
5. Carbon.
6. Boron.

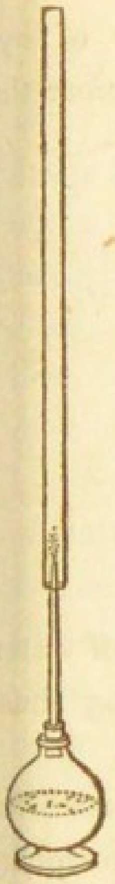
SECTION I. *Hydrogen**.

136. HYDROGEN was first duly examined by Mr. Cavendish, (*Phil. Trans.* vol. LVI). It may be obtained by the action of iron or zinc upon dilute sulphuric acid. Some pieces of iron wire, or of zinc, may be introduced into the flask *a*, and covered with sulphuric acid diluted with six times its bulk of water. The gas escapes by the bent tube *b*, which is inserted by grinding into the neck of the flask, and may be collected in the hydro-pneumatic apparatus.



Hydrogen is an aëriform fluid, not absorbable by water. It has no taste, a slightly disagreeable smell, and may be respired for a short time, though it is instantly fatal to small animals. It is the lightest body known; and we therefore conveniently assume it as unity in speaking of the specific gravity of gases, as well as in referring to the proportions in which bodies combine. 100 cubic inches weigh at mean temperature and pressure 2,25 grains. It is inflammable, and extinguishes flame. When pure, it burns quietly with a lambent blue flame at the surface in contact with air; but, if mixed with thrice its volume of air, it burns rapidly, and with detonation. In making this experiment, a strong phial, capable of holding about 6 ounces of water, may be employed; or the inflammable air pistol, which admits of the mixture being fired by the electric spark. If two volumes of hydrogen and one of oxygen be burned in the same way, the explosion is extremely violent. A current of

* From ὕδωρ, &c., *the base of water.*



hydrogen may be inflamed when issuing from a small aperture, and if a tube of 18 or 20 inches in length be held over the flame, a peculiar musical tone is produced. This effect is not peculiar to hydrogen, but is produced by a variety of other flames*.

The tendency which gaseous fluids have to become completely mixed under all circumstances, and as it were to penetrate each other, is well illustrated where hydrogen is employed. Thus, if two small phials, the one containing oxygen and the other hydrogen, be connected, perpendicularly, by a long glass tube of small bore, it will be found, that although the hydrogen be uppermost, and much lighter than the oxygen, it will, in the course of a few hours, have perfectly mixed with the oxygen, and the gases will be found in equal proportions in both phials. Mr. Dalton has shewn that gases, unlike other fluids, do not remain upon each other without admixture. (*Manchester Memoirs*, Vol. I. New Series.)

Hydrogen, in consequence of its extreme lightness, is employed for filling air-balloons, and is elegantly applied to the purpose of obtaining instantaneous light in Volta's inflammable air lamp.

137. *Hydrogen and Oxygen.*—When two volumes of hydrogen gas are mixed with one volume of oxygen gas, and the mixture inflamed in a proper apparatus by the electric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed.

If pure water be exposed to the action of Voltaic electricity, it is resolved into two volumes of hydrogen, disengaged at the negative pole, and one volume of oxygen, disengaged at the positive pole; so that water is thus proved by synthesis, and by analysis, to consist of two volumes of hydrogen, combined

* Faraday, *Journal of Science and the Arts*, Vol. 5.

with one volume of oxygen. The specific gravity of hydrogen compared with oxygen, is as 1 to 15; therefore the component parts of water by weight are,

1 hydrogen,
7,5 oxygen.

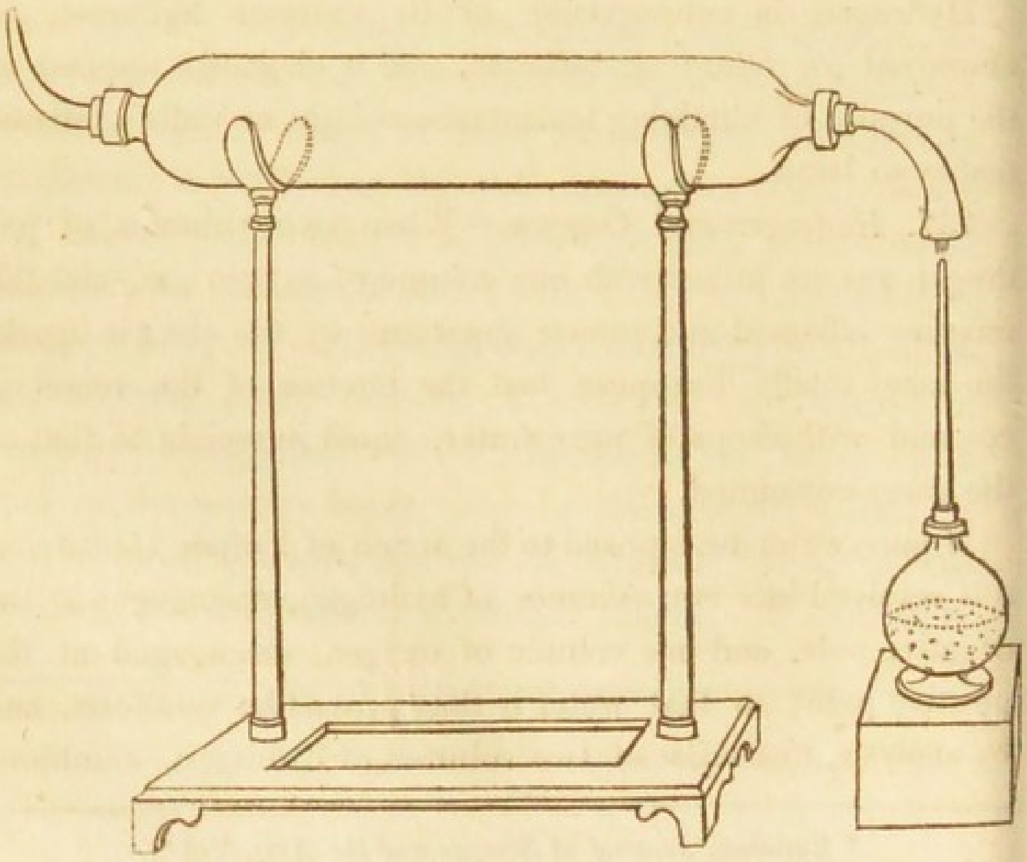
Representative number of water = 8.5

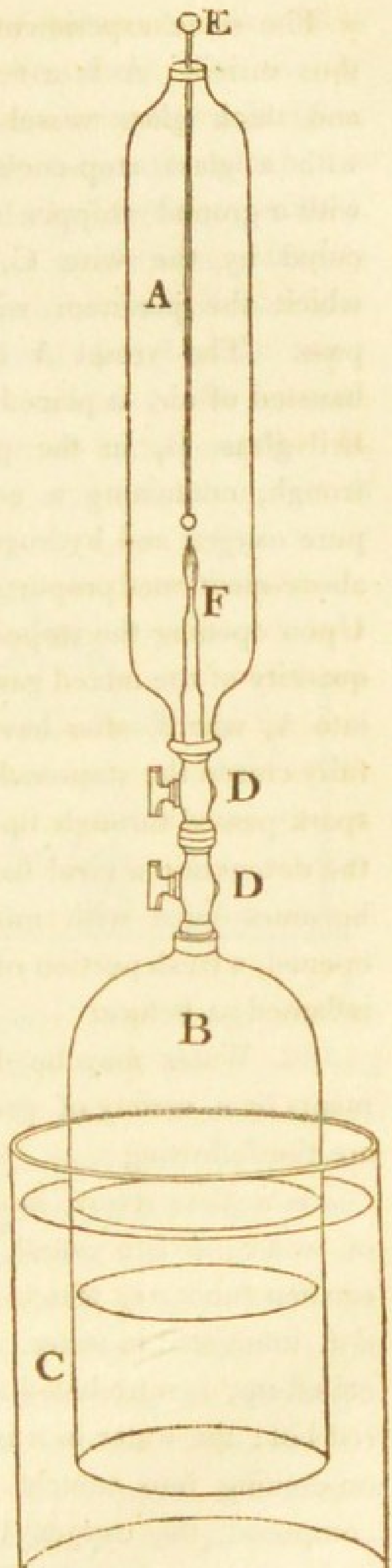
or thus,

Hydr. 1.	Oxyg. 7,5	water 8,5.

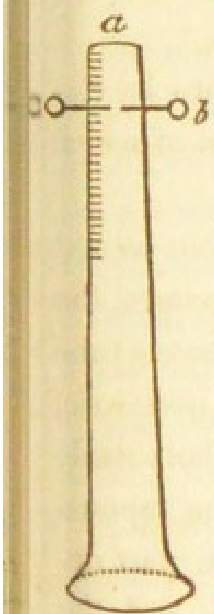
138. The experiments illustrating the composition of water, may be divided into synthetic and analytic. Among these the following may be selected:

Burn a current of hydrogen under the funnel, as represented in the wood-cut; by uniting with the oxygen of the atmosphere it will produce aqueous vapour, which passing into the glass cylinder will condense in drops.

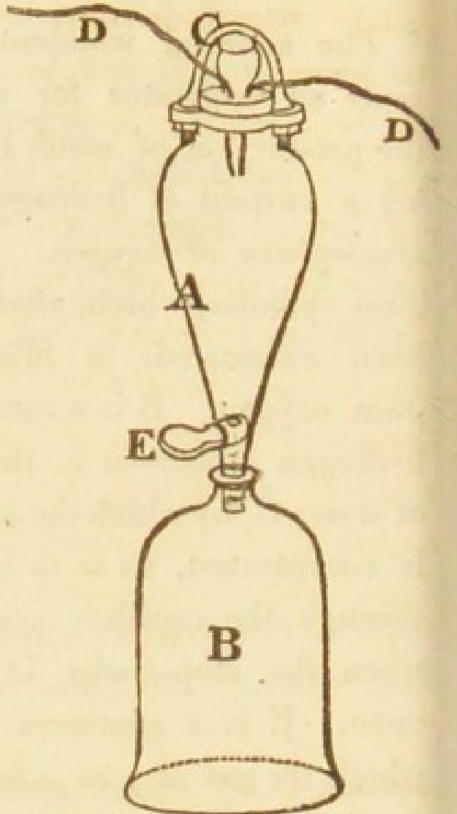




The annexed woodcut represents an apparatus for shewing the production of water by burning a current of hydrogen in an atmosphere of oxygen. A is a glass cylinder, which, after having been exhausted, is filled with pure oxygen. B is a receiver of hydrogen immersed in the vessel of water C, by which the hydrogen is compressed, so as to be urged through the capillary opening F, when the stop-cocks D D are open. E is a platinum wire by which the gas may be inflamed by an electric spark. It burns with the production of intense heat, and water is soon collected in drops upon the interior of the cylinder.



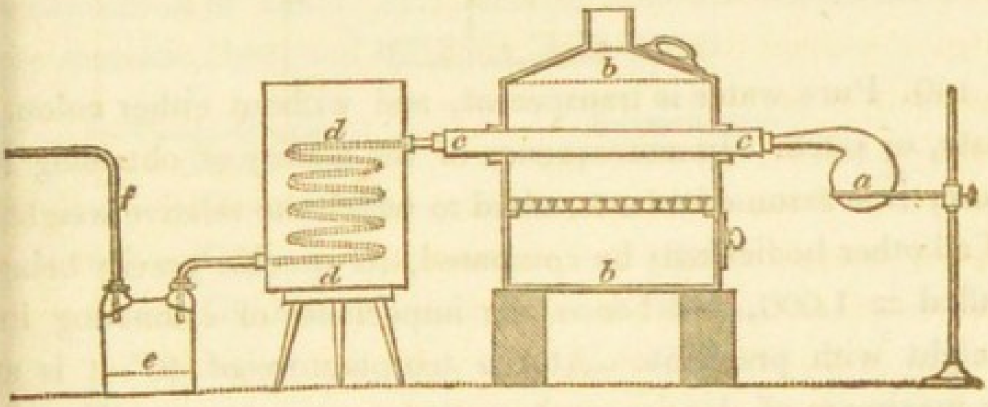
If two measures of pure hydrogen be mixed with one of pure oxygen, and detonated in the graduated glass tube, *a*, standing over water, by an electric spark, passed through the platinum wires *b*, *b*, the gases will entirely disappear. If there be any excess of either of the gases, the portion in excess will remain unconsumed.



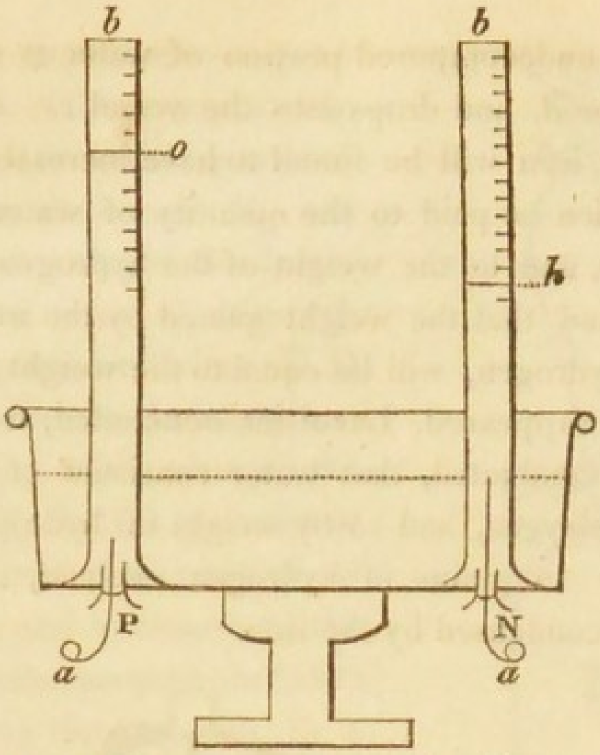
The same experiment may be thus varied. A is a very strong and thick glass vessel provided with a glass stop-cock E, and with a ground stopper firmly secured by the wire C, through which the platinum wires D D pass. The vessel A being exhausted of air, is placed upon the bell glass B, in the pneumatic trough, containing a mixture of pure oxygen and hydrogen in the above-mentioned proportions.(137) Upon opening the stopcock E, a quantity of the mixed gases passes into A, where, after having carefully closed the stop-cock, it may be inflamed by an electric spark passed through the platinum wires. At the instant of the detonation a vivid flame pervades the upper vessel, and it becomes lined with moisture. If the stopcock be again opened, a fresh portion of the mixed gases enters, and may be inflamed as before.

139. Water may be decomposed or resolved into its elements by a variety of processes, the most important of which are the following:

a is a glass retort, into which is introduced a given weight of water; *b b* a small furnace through which passes the earthen tube *c c*, which terminates in the spiral pewter tube *d d*, immersed in water. A given weight of pure iron wire, coiled up, is introduced into the tube *c*, and the whole made red hot; the water in *a* is then made to boil, and the vapour, on coming into contact with the red hot iron, is in part decomposed, the oxygen being retained by the iron, and the hydrogen escaping through the tube *f*, may be collected as usual. Any undecomposed portion of water is condensed in the worm pipe *d*, and drops into the vessel *e*. After this experiment the iron will be found to have increased in weight; and if attention be paid to the quantity of water which has collected in *e*, and to the weight of the hydrogen gas evolved, it will be found that the weight gained by the iron, added to that of the hydrogen, will be equal to the weight of the water which has disappeared. Lavoisier concluded, from an experiment thus conducted, that water consisted of 85 *per cent.* by weight of oxygen, and 15 by weight of hydrogen; that is, that for every 15 grains of hydrogen evolved, 85 grains of oxygen were condensed by the iron.



Decomposition by Voltaic electricity best illustrates the composition of water, since it exhibits both the oxygen and hydrogen in the gaseous form. The wood-cut overleaf represents a section of an apparatus for this purpose. It is a glass vessel containing water, having two wires of platinum, *a a*, passing through its bottom: over these are inverted the tubes *b b*, also filled with water. The wires are rendered positive and negative by connexion with a moderately powerful Voltaic apparatus. Oxygen is evolved at the positive wire, and hydrogen at the negative wire, which gases rise into the tubes, and it is seen that one volume of oxygen, and two volumes of hydrogen, are the constant results. If these gases be mixed and detonated, pure water is again formed.



140. Pure water is transparent, and without either colour, taste, or smell. In consequence of the facility of obtaining it pure, it is assumed as a standard to which the relative weights of all other bodies may be compared, its specific gravity being called = 1.000, and hence the importance of estimating its weight with precision. At the temperature of 40° it is at its maximum of density, and at that temperature an English cubic foot weighs 437102,4946 grains*, or 999,0914161 ounces avoirdupoise, and a cubic inch 252,953 grains.

At the temperature of 32° water congeals into ice, which, if slowly formed, produces needles crossing each other at angles of 60° and 120°. The specific gravity of ice is 0,94.

If water be exposed to heat in open vessels it boils, or is converted into steam, at 212°, the barometer being at 30 inches; but the boiling point of water varies considerably with the pressure (50). The specific gravity of air being considered as = 1; that of steam is 0,6235. At mean pressure, and at the temperature of 212°, the bulk of steam is 1700 times greater than that of water.

* Thomson's *System*, vol. 2. p. 12.

Water, which has been exposed to the atmosphere, always contains a portion of air, as may be proved by boiling it, or by exposing it under the exhausted receiver of the air-pump. To separate the air, the water must be boiled for about two hours. It absorbs oxygen gas in preference to atmospheric air.

141. As hydrogen is the lightest known substance, it is assumed in this work as *unity*, in reference to the representative numbers of other bodies. The principles of numeric representation, or of equivalent or proportional numbers, has already been adverted to (34), and the following will be the representative numbers of the bodies described in the foregoing chapter, the number for oxygen being deduced from the composition of water (137), and of chlorine and iodine from the muriatic (142) and hydriodic acids (144).

Undecompounded Substances.	Representative Number.
Hydrogen	1
Oxygen	7,5
Chlorine	33,5
Iodine	117,7

Compounds.	Component Parts.		Representative Number.
Water	1 proportional of hydrogen	= 1	8,5
	1 ditto oxygen	= 7,5	
Oxide of chlorine	4 proportionals of oxygen	= 30	63,5
	1 ditto chlorine	= 33,5	
Chloric acid	5 proportionals of oxygen	= 37,5	71
	1 ditto chlorine	= 33,5	
Perchloric acid	7 proportionals of oxygen	= 52,5	86
	1 ditto chlorine	= 33,5	
Oxiodic acid	5 proportionals of oxygen	= 37,5	155,2
	1 ditto iodine	= 117,7	
Chloriodic acid	1 proportional of chlorine	= 33,5	151,2
	1 ditto iodine	= 117,7	

142. *Hydrogen and Chlorine.*—When equal volumes of these gases are mixed, and exposed to light, they combine, and produce a sour compound, commonly called *muriatic acid gas;* or, in conformity to more modern nomenclature, *hydrochloric acid gas.*

The best mode of showing the composition of muriatic acid, is to introduce into a small but strong glass vessel a mixture of the two gases, and to inflame them by the electric spark ; no change of volume ensues, and muriatic gas results.

Muriatic acid may be decomposed by the action of several of the metals. Potassium, for instance, absorbs the chlorine, and the hydrogen is evolved ; and muriatic acid gas thus affords half its volume of hydrogen. As the specific gravity of hydrogen to chlorine is as 1 to 33,5 muriatic acid will consist of 1 hydrogen + 33,5 chlorine, and its representative number will be 34,5.

Hydr.	Chlor.		Muriatic Acid.
1	33,5	=	34,5

Muriatic acid may also be readily procured by acting upon common salt by sulphuric acid, the evolved gas must be received over mercury. It was first obtained pure by Dr. Priestly, but its composition was discovered by Scheele, and has since been most ably investigated by Davy.

Muriatic acid gas extinguishes flame. Its specific gravity, compared with hydrogen, is = 17,25. 100 cubic inches = 39,5 grains.

143. Muriatic acid gas is greedily absorbed by water, which takes up 480 times its bulk, and has its specific gravity increased from 1 to 1,210*. Thus dissolved in water, it forms

* For saturating water with gases, which are easily soluble in that fluid, we generally employ *Wolfe's apparatus*, which is shewn in the

the *liquid muriatic acid* or *spirit of salt*, and may easily be procured by distilling a mixture of dilute sulphuric acid and common salt, as directed in the *London Pharmacopœia*. The most economical proportions are 32 parts of salt, and 22 of sulphuric acid, diluted with one-third its weight of water. The retort containing these ingredients may be luted on to a receiver, containing twice the quantity of water used in diluting the sulphuric acid, and the distillation carried on in a sand-bath.

When this liquid acid is pure it is perfectly colourless, but it generally has a yellow hue arising from a little iron. When heated, the gaseous acid is evolved. The following Table

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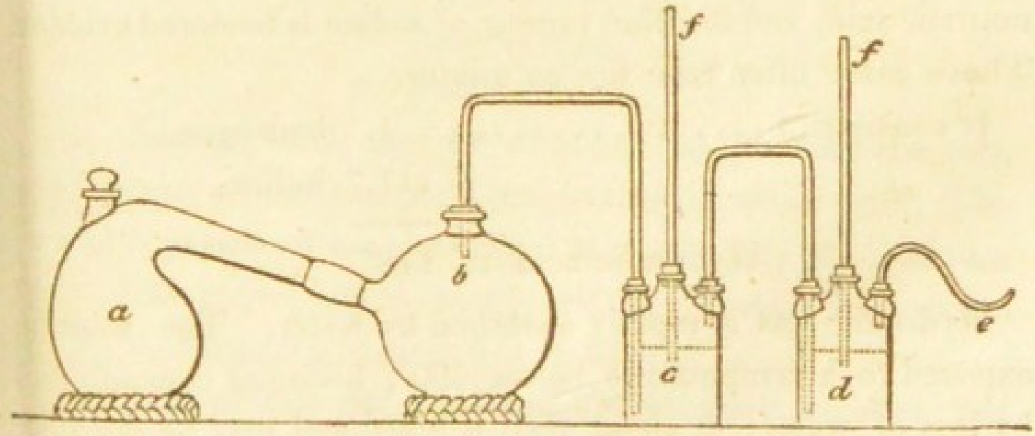
annexed cut. *a* is a tubulated retort in which the materials, producing the gas or vapour, are contained; *b*, a receiver communicating by a bent tube with the three-necked bottle *c*, which is connected also by a tube with *d*. These bottles are about half filled with water, or any other fluid intended to be saturated with the gas; when that in *c* has become saturated, it passes into *d*, and afterwards through the tube *e*, which may be placed under the water, or mercury, in the pneumatic trough. In case absorption should take place in the vessels *a* or *b*, the pressure of the external air might force the water from *d* into *c*, and from *c* into the balloon *b*. This is prevented by the safety tubes *f f*, which, dipping not more than half an inch under the surface of the water, allow a little air to enter so as to compensate for the absorption. The different joints may be secured either by grinding or by well-cut corks, rendered tight by a mixture of drying oil and pipe clay.



shews the quantity of real acid contained in liquid acid of different specific gravities. (Davy's *Elements*, p. 253.)

Table shewing the Quantity of real Acid in Liquid Muriatic Acid of different Specific Gravities. (*Temp.* 45 . *Faht. Barom.* 30.)

Specific Gravity.	100 Grains contain of Muriatic Acid Gas	Specific Gravity.	100 Grains contain of Muriatic Acid Gas
1.21	42.43	1.10	20.20
1.20	40.80	1.09	18.18
1.19	38.38	1.08	16.16
1.18	36.36	1.07	14.14
1.17	34.34	1.06	12.12
1.16	32.32	1.05	10.10
1.15	30.30	1.04	8.08
1.14	28.28	1.03	6.06
1.13	26.26	1.02	4.04
1.12	24.24	1.01	2.02
1.11	22.30		

144. *Hydrogen and Iodine* exert a slow action under ordinary circumstances; but when iodine is presented to nascent hydrogen, they readily unite, and produce a gaseous acid, the *hydriodic acid.* It is prepared by the action of moist iodine upon phosphorus, and must be received over mercury. It is colourless, very sour, and smells like muriatic acid. Its specific gravity to hydrogen is as 59,3 to 1. 100 cubic inches = 133,5 grains. It is instantly decomposed by chlorine, which produces muriatic acid, and the blue vapour of iodine is rendered evident. These gases often take fire on mixture.

It consists of .... 1, hydrogen,
117,7 iodine,

Hydriodic acid = 118

Hydriodic gas is rapidly absorbed by water. The solution exposed to a temperature below 260°, becomes concentrated by loss of water; at about 260° it boils, and may be distilled.

The specific gravity of the strongest liquid acid is 1,7. It becomes dark coloured when kept, in consequence of a partial decomposition.

Section II. *Nitrogen.*

145. This was first recognised as a distinct aëriform fluid by Dr. Rutherford in 1772. (Thesis, *De aere Mephitico.*) It may be obtained by heating phosphorus in a confined portion of dry atmospheric air, which consists of nitrogen and oxygen; the phosphorus absorbs the latter, and the former gas remains. After repeated washing, it may be considered as pure. It may also be obtained by the action of moist sulphuret of iron upon atmospheric air, and by the action of nitric oxide (174).

100 cubic inches weigh 29,25 grains; so that its specific gravity, compared with hydrogen, is as 13 to 1. It is tasteless, inodorous, and insoluble in water. It does not support combustion, and is fatal to animals; hence was called *azote*. It is not inflammable; but when its compounds are submitted to Voltaic decomposition, it is attracted by the negative pole.

146. *Nitrogen and Oxygen.*—These bodies unite in four proportions, and form the compounds called,

1. Nitrous oxide.
2. Nitric oxide.
3. Nitrous acid.
4. Nitric acid.

147. *Nitrous oxide* may be obtained by distilling the salt, called *nitrate of ammonia*, at a temperature of about 420°. The gas which passes off may be collected over water, and is *nitrous oxide.* 100 cubic inches weigh 46,125 grains; its specific gravity, therefore, to hydrogen is as 20,5 to 1.

The taste of this gas is sweet, and its smell peculiar, but agreeable.

Its singular effects, resembling intoxication, when respired, were first ascertained by Sir H. Davy. (*Researches Chemical and Philosophical, chiefly concerning Nitrous Oxide.* London, 1800.) The experiment of breathing this gas, however, cannot be made with impunity, especially by those who are liable to a determination of blood to the head.

It supports combustion, and a taper introduced into a jar of nitrous oxide, has its flame much augmented and surrounded by a purplish halo. Phosphorus and sulphur, when introduced in a state of vivid ignition into this gas, are capable of decomposing it, and burn with the same appearances nearly as in oxygen; but, if when put into the gas, they are merely burning dimly, they then do not decompose it and are extinguished, so that they may be melted in the gas, or even touched with a red hot wire without inflaming.

It is easily absorbed by water, which takes up about its own bulk, and evolves it unchanged when heated.

148. The best analysis of this gas is effected by detonation with hydrogen; one volume of nitrous oxide requires one volume of hydrogen. This mixture, fired by the electric spark, produces water, and one volume of nitrogen remains. Now, as one volume of hydrogen takes half a volume of oxygen to form water, nitrous oxide must consist of two volumes of nitrogen and one volume of oxygen; these three volumes being so condensed in consequence of chemical union, as only to fill the space of two volumes. The specific gravity of nitrogen, compared with oxygen, is as 13 to 15; nitrous oxide, therefore, consists of - - - 13 Nitrogen

7,5 Oxygen

Number for nitrous oxide, ... 20,5

or,	Nitrogen 13	Oxygen 7,5	=	Nitrous oxide 20,5

149. *Nitric oxide* is usually obtained by presenting certain substances to nitric acid, which abstract a portion of its oxygen, leaving the remaining elements in such proportions as to constitute the gas in question; for this purpose some copper filings may be put into a gas bottle with nitric acid, diluted with thrice its bulk of water; an action ensues, red fumes are produced, and there is a copious evolution of the gas, which may be collected and preserved over water. This gas is presently recognised by the red fumes which it produces when brought into the contact of air.

Its specific gravity to hydrogen is as 14 to 1. 100 cubic inches weigh = 31,5 grains. When it has been washed with water it is not acid, as may be proved by the colour of litmus remaining unchanged by it. It extinguishes most burning bodies, but phosphorus readily burns in it, if introduced in intense ignition.

150. It does not detonate when mixed with hydrogen, and subjected to the electric spark; but it may be decomposed by the action of some of the metals at high temperatures, which absorb its oxygen. One volume of nitric oxide is thus resolved into equal volumes of oxygen and nitrogen. If, therefore, we call nitrous oxide a compound of 1 proportional of nitrogen + 1 oxygen, then nitric oxide may be considered as consisting of 1 nitrogen + 2 oxygen, or by weight, 13 nitrogen + 15 oxygen, and its symbol will stand thus:

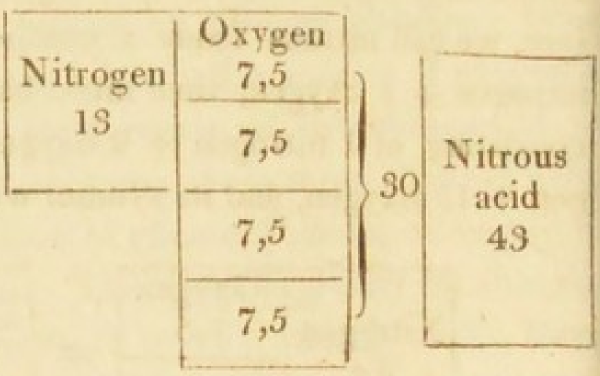
<table>
<tr><td rowspan="2">Nitrogen
13</td><td>Oxygen
7,5</td><td rowspan="2">=</td><td rowspan="2">Nitric oxide
28.</td></tr>
<tr><td>7,5</td></tr>
</table>

Nitric oxide and chlorine, when both are perfectly dry, exert no mutual action, but the presence of water causes an immediate change, it is decomposed, and, furnishing oxygen to the nitric oxide, and hydrogen to the chlorine, nitrous acid and muriatic acid gases are generated. It was the presence of water which misled those, who thought that the red fumes, produced by mixing nitric oxide and chlorine not carefully dried, resulted from the existence of oxygen in chlorine.

151. *Nitrous Acid Gas.*—When nitric oxide is presented to oxygen, the two gases combine, and a new gaseous compound of a deep orange colour results. This compound is not easily examined, because it is absorbed both by quicksilver and water, so that we are obliged to resort to exhausted glass vessels for its production. When we thus mix two volumes of nitric oxide with one volume of oxygen, the gases become condensed to about half their original volumes, and form *nitrous acid gas.*

This gas supports the combustion of the taper, of phosphorus, and of charcoal, but extinguishes sulphur. It is readily absorbed by water, forming a green sour liquid. Its specific gravity to hydrogen is as 28,6 to 1, and 100 cubic inches = 64,48 grains.

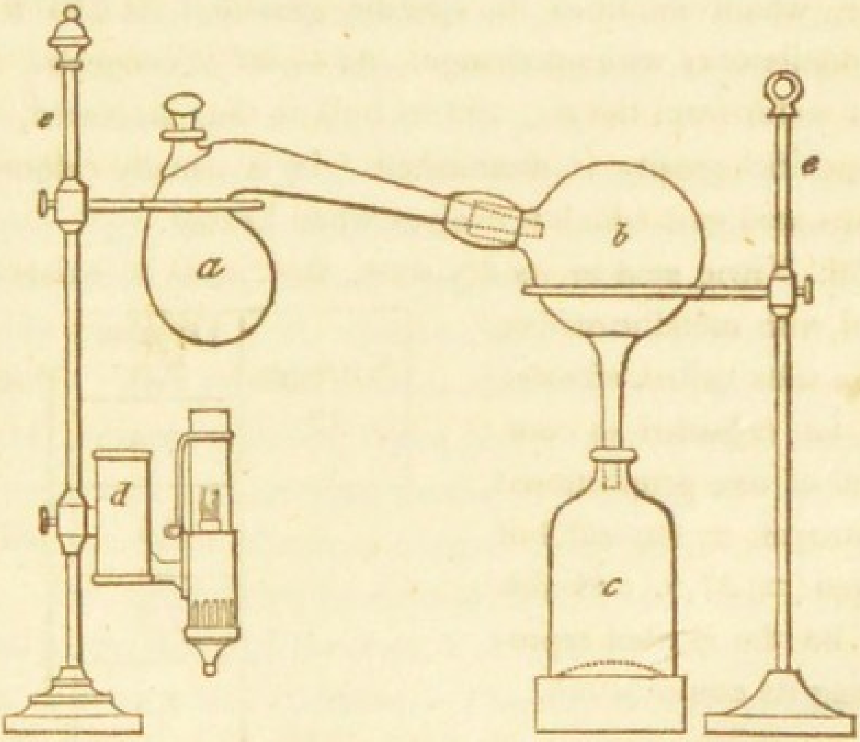
152. It is obvious that this nitrous acid gas must consist of 13 nitrogen + 30 oxygen, and therefore, its number is 43, for nitric oxide is composed of equal volumes of nitrogen and oxygen, and one additional volume of oxygen, or two proportionals by weight are added to form nitrous acid.



153. If the mixture of nitric oxide and oxygen be made over water, in the above proportions, and if the gases be perfectly pure, complete absorption takes place; but if either the

oxygen or nitric oxide contain uncombined nitrogen, it will remain unabsorbed.

154. *Nitric Acid.*—The fourth compound of nitrogen with oxygen is the nitric acid; the nature of which was first demonstrated by Mr. Cavendish in 1785. *(Phil. Trans.)* It is usually obtained from *nitre,* three parts of which are distilled with two of sulphuric acid. This distillation may be conducted upon the small scale in a glass retort, *a,* with a tubulated receiver, *b,* passing into the bottle *c.* The requisite heat is obtained by the lamp *d,* and the whole apparatus supported by the brass stands with sliding rings *e e.* But the manufacturer who prepares nitric acid upon a large scale, generally employs distillatory vessels of stone ware. In the *London Pharmacopœia* equal weights of sulphuric acid and nitre are directed to be employed, but this excess of sulphuric acid is more than requisite.



155. The nitric acid of commerce, as obtained by the above processes, is always impure, and muriatic and sulphuric acids may usually be detected in it. The former may be separated

by *nitrate of silver*, and the latter by *nitrate of baryta*. To obtain *pure nitric acid*, therefore, add to that of commerce a solution of nitrate of silver as long as it produces any white precipitate; and when this has subsided, pour off the clear liquor, and add, in the same way, a solution of nitrate of baryta; then distil the acid, and it will pass over perfectly pure. In the *Pharmacopœia* we are directed to re-distil with a portion of fresh nitre, the intention of which is to retain the sulphuric acid, but this is ineffectual, and the muriatic acid still remains. For pharmaceutical purposes, the ordinary acid is generally sufficiently pure. If, however, pure nitre, and pure sulphuric acid be employed in its production, and the latter not in excess, there is little apprehension of impurity in the resulting acid.

The nitric acid is a colourless liquid, extremely sour and corrosive. Its specific gravity is 1,42; it always contains water, which modifies its specific gravity. At 250° it boils and distils over without change. At — 40° it congeals. It absorbs water from the air, and its bulk is thus increased, while its specific gravity is diminished. It is usually coloured by nitrous acid gas, which it evolves when heated.

156. Nitric acid in its dry state, that is, as it exists combined with metallic oxides, in the salts called *nitrates*, may be regarded as composed of one proportional of nitrogen = 13, and 5 of oxygen = 37,5, and this will be the symbol representing its composition.

Nitrogen 13	Oxygen 7,5	37,5
	7,5	
	7,5	
	7,5	
	7,5	

Consequently, the representative number of *dry* nitric acid is 50,5. But in its liquid state it always contains water, and when, in this state, its specific gravity is 1,5, it may be regarded as a compound of one proportional of dry acid and two of water, and this may be numerically expressed thus:

Acid.		Water.		
50,5	+	17	=	67,5 liquid acid.

157. Nitric acid may be decomposed by passing its vapour through a red hot porcelain tube; oxygen is given off, nitrous acid gas is produced, and a quantity of diluted acid passes over into the receiver, having escaped decomposition, so that it is thus proved to consist of nitrous acid gas, oxygen, and water.

For experiments of this kind the form of apparatus, described for the decomposition of water by iron, may be employed.

The nature of nitric acid was first synthetically demonstrated by Mr. Cavendish, who passed electric sparks through a portion of atmospheric air, or through a mixture of one part of nitrogen and two of oxygen, confined over mercury. After some time the mixture diminished in bulk, and, on admitting a little water, an acid solution was obtained which afforded crystals of nitre when saturated with potash.

158. *Nitromuriatic Acid.*—This term has been applied to the *Aqua Regia* of the alchemists. When nitric and muriatic acids are mixed, they become yellow, and acquire the power of readily dissolving gold, which neither of the acids possessed separately. This mixture evolves chlorine, a partial decomposition of both acids having taken place, and water, chlorine, and nitrous acid gas, are thus produced; that is, the hydrogen of the muriatic acid abstracts oxygen from the nitric to form water. The result must be chlorine and nitrous acid. (Davy, *Journal of Science and the Arts,* Vol. I. p. 67.)

159. *Nitrogen and Chlorine.*—These gases do not unite *directly*, but the compound may be obtained by exposing a solution of *nitrate* or *muriate of ammonia* to the action of chlorine, at a temperature of 60° or 70°. The gas is absorbed, and an oil-like fluid, heavier than water, is produced. It was dis-

covered by M. Dulong, in 1812. (*Annales de Chimie*, Vol. LXXXV.)

Its specific gravity is 1,6; it is not congealed by cold. This substance is dangerously explosive, and is decomposed with violent detonation by many combustibles, especially phosphorus, and fixed oils. At 160° it distils without change, but at 212° explodes and is decomposed. It was submitted to the action of 125 different substances, by Messrs. Porret and Wilson, 28 of which caused it to explode. (Nicholson's *Journal*, Vol. XXXIV.)

Alcohol quietly changes it into a white substance. Mercury absorbs the chlorine, and evolves nitrogen. It yields, by decomposition, 1 volume of nitrogen and 4 of chlorine; and as the specific gravity of nitrogen to chlorine is as 13 to 33,5, so it may be said to consist of 1 proportional of nitrogen + 4 proportionals of chlorine, or $\overset{\text{N.}}{13} + \overset{\text{C.}}{134}$ by weight, and its number will be 147.

Nitrogen	Chlorine	
13	33,5	134
	33,5	
	33,5	
	33,5	

160. *Nitrogen and Iodine.*—A compound of these bodies may be procured by pouring a solution of ammonia upon a very small quantity of iodine. Hydriodic acid is one product, and the other a brown powder, which detonates upon the slightest touch, and is resolved into nitrogen and iodine. When left exposed to air it gradually evaporates.

161. *Nitrogen and Hydrogen—Ammonia, or Volatile Alcali.*—This gaseous compound may be obtained by heating a mixture of *quicklime* and *muriate of ammonia*. Two parts of dry quicklime and one of muriate of ammonia may be introduced

into a small glass retort, and upon the application of a gentle heat the gas passes over. It must be collected over mercury. It is permanently elastic at common temperatures, extremely pungent and acrid, but when diluted by mixture with common air, agreeably stimulant. It converts most vegetable blues to green, and the yellows to red, properties which belong to the bodies called *alcalies*. Ammonia, therefore, has been termed *volatile alcali*.

Its specific gravity to hydrogen is as 8 to 1; 100 cubical inches weighing 18 grains. It extinguishes flame, but forms an inflammable mixture with common air and with oxygen.

162. Water at the temperature of 50° takes up 670 times its volume of ammonia; its bulk is increased, and its specific gravity diminished; that of a saturated solution is 0,875, water being 1,000. The following Table shews the quantity of ammonia in solutions of different specific gravities. (Davy's *Chemical Philosophy*, page 268.)

100 Parts of Specific Gravity.		Of Ammonia.
*8750	Contain	32.5
8875		29.25
9000		26.00
9054*		25.37
9166		22.07
9255		19.54
9326		17.52
9385		15.88
9435		14.53
9476		13.46
9513		12.40
9545		11.56
9573		10.82
9597		10.17
9619		9.60
9692*		9.50

* The three results marked by the asterisk, were gained by experiments, the other numbers by calculation.

The usual state in which ammonia is employed is in solution, both in chemistry and medicine. This solution bears the name of *Liquor Ammoniæ* in the *London Pharmacopœia.* It may be obtained by passing the gas into water in a proper apparatus (97), or by distilling over the water and gas together.

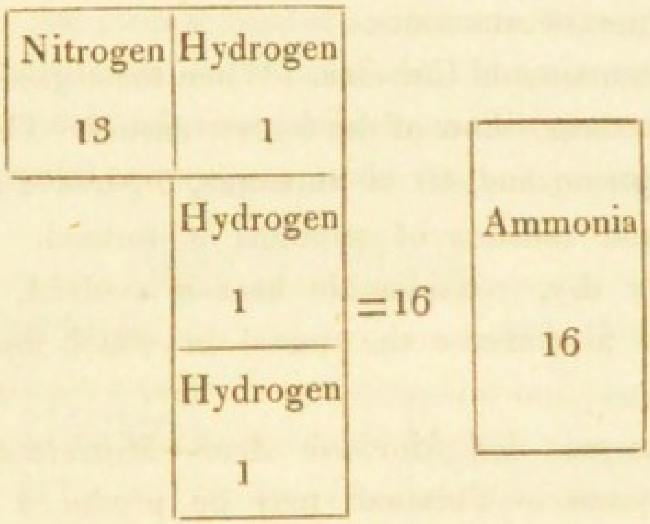
The following process, recommended by Mr. R. Phillips, answers well. On 9 ounces of well-burned lime pour half a pint of water, and when it has remained in a well-closed vessel for about an hour, add 12 ounces of muriate of ammonia in powder and three pints and a half of boiling water; when the mixture has cooled, pour off the clear portion and distil from a retort 20 fluid ounces. The specific gravity of this solution which is sufficiently strong for most purposes is 0,954. (*Remarks on London Pharmacopœia*, p. 34.)

163. Dr. Henry (*Philos. Trans.* 1809,) first observed that a mixture of ammonia and oxygen gas might be fired by an electric spark, and this property furnishes a means of analyzing the alcaline gas. Electricity also decomposes ammoniacal gas. If a succession of electrical sparks be passed through a small portion of the gas confined in a proper tube over quicksilver, it will increase to about twice its original bulk, and lose its easy solubility in water. If the gas thus expanded be mixed with from one-third to one-half its bulk of oxygen, and an electric spark passed through the mixture, an explosion takes place attended by considerable diminution. Note the amount of the diminution, divide it by 3, and multiply the product by 2. The result shews the quantity of hydrogen. Thus, suppose 10 measures of ammonia, expanded by electricity to 18, and that, after adding 8 measures of oxygen gas, we find the whole ($=$ 26 measures) reduced by firing to 6 measures the diminution will be 20. Then $20 \div 3 = 6{,}66$ and $6.66 \times 2 = 13{,}32$ measures of hydrogen gas from 10 of ammonia; and $18 - 13{,}32 = 4{,}68$ for the nitrogen gas contained in the pro-

duct of electrization. Therefore 10 measures of ammonia have been destroyed and expanded into

13.32 measures of hydrogen gas,
4.68 - - - nitrogen gas*.

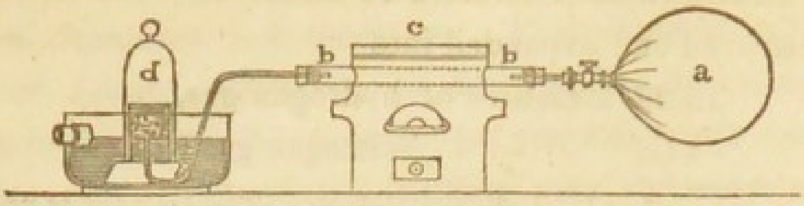
It appears probable that one volume of ammonia is resolved by electric decomposition into two volumes of a mixture of hydrogen and nitrogen, consisting of three volumes of hydrogen and one volume of nitrogen; hence the following symbols will represent the composition and volume of ammonia :



When ammonia and oxygen are detonated, the nitrogen is oxydized as well as the hydrogen; hence, if excess of oxygen be used, the whole of the ammonia disappears, and nitrate of ammonia is formed.

Ammonia may also be decomposed by passing it through a red hot iron tube; it suffers expansion, and is resolved into hydrogen and nitrogen gases, furnishing a singular instance of change of properties in consequence of chemical combination. *a* is a bladder filled with ammonia which may be passed through the iron tube *b*, placed in the furnace *c*; the gas is decomposed, and hydrogen and nitrogen may be collected over the water in *d*.

* Henry's *Elements*, 7th edit. Vol. I. p. 233.



164. Ammonia is produced synthetically during the decomposition of many animal substances; it is also formed during the violent action of nitric acid upon some of the metals, and by moistened iron filings exposed to an atmosphere of nitrogen; in these cases the nascent gases unite so as to form a portion of ammonia.

165. *Ammonia and Chlorine.*—When these gases are mixed, a partial decomposition of the former ensues. On mixing 15 parts of chlorine and 40 of ammonia, 5 parts of nitrogen are liberated, and muriate of ammonia is formed. If the gases be perfectly dry, considerable heat is evolved, and a flame is perceived to traverse the vessel in which the experiment is made.

166. *Ammonia and Muriatic Acid—Muriate of Ammonia—Sal Ammoniac.*—This salt may be produced directly by mixing equal volumes of ammonia and muriatic acid, when an entire condensation ensues.

The specific gravity of ammonia to muriatic acid is as 16. to 34,5; therefore, muriate of ammonia consists of 34,5, muriatic acid + 16 ammonia.

Ammonia	Muriatic Acid.
16	34,5

Muriate of ammonia was formerly imported from Egypt, but is now abundantly prepared on the Continent and in this country. Its preparation will be hereafter described. When obtained by evaporation from its solution in water, it forms octoedral, prismatic, and plumose crystals; but, in commerce, it usually occurs, as procured by sublimation, in white cakes, hard and somewhat elastic, and in this compact state it requires for solution 3,25 parts of water at 60°. When heated it sublimes without decomposition in the form of white vapour.

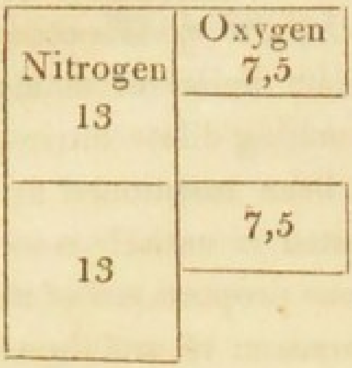
167. *Ammonia and Nitric Acid—Nitrate of Ammonia.*—This salt may be procured by the direct union of ammonia with nitric acid, or more easily by saturating dilute nitric acid with carbonate of ammonia. It has been mentioned as the source of nitrous oxide, and when heated is entirely resolved into that gas and water. It consists of one proportional of nitric acid = 50,5 + one proportional of ammonia = 16, and therefore the representative number of the nitrate of ammonia is 66,5. Or it may be considered as containing 2 proportionals of nitrogen, 3 of hydrogen, and 5 of oxygen, as the following symbols show:

Nitrate of Ammonia.

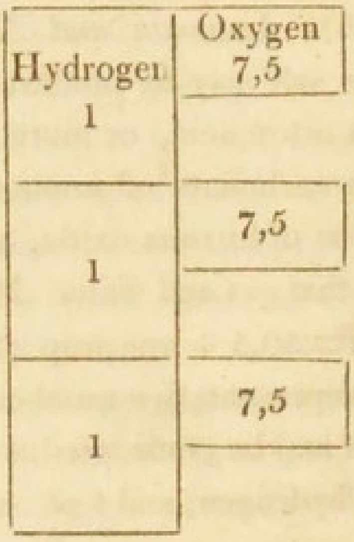
Nitric acid. 50,5		Ammonia. 16	
Nitrogen 13	Oxygen 7,5	Nitrogen 13	Hydrogen 1
	7,5		
	7,5		1
	7,5		
	7,5		1

Nitrous oxide consists of 1 proportional of nitrogen = 13 + 1 of oxygen = 7,5; hence the two proportionals of nitrogen in the salt (1 in the acid and 1 in the ammonia) will require two of oxygen to produce nitrous oxide, and the remaining 3 of oxygen will unite to the 3 of hydrogen, and form water. And accordingly nitrous oxide and water are the only possible results; so that the elements, after the decomposition of the salt, are arranged thus :

Two proportionals of Nitrous oxide.



Three proportionals of water.



Nitrate of ammonia has long been known, and was formerly called *Nitrum flammans*. It differs in form according to the manner in which its solution has been evaporated; if at a temperature below 100°, its crystals are 6 sided prisms terminated by 6 sided pyramids; if boiled down, its crystals are thin and fibrous: it is deliquescent and soluble in twice its weight of water at 60°, and in its own weight at 212°. It contains different proportions of water of crystallization; according to Berzelius, the prismatic variety affords 11,232 per cent. (80 *Annales de Chimie*.) According to Davy, the fibrous variety contains 8,2 per cent., and the compact, obtained by evaporating the solution till it concretes 5,7 per cent of water of crystallization. (Davy's *Researches*, p. 71.)

168. *Atmospheric Air*.—The composition of atmospheric air has been frequently alluded to in the preceding pages, and as the student is now acquainted with its essential component parts, namely, oxygen and nitrogen, it may be right to consider its properties more at length.

The atmosphere is a thin, transparent, invisible, and elastic fluid, which surrounds our planet, and reaches to a considerable height above its surface, probably about 40 miles.

That air is a ponderous body, was first suspected by Galileo, who found that a copper ball, in which the air had been condensed, weighed heavier than when the air was in its ordinary state of tension. The fact was afterwards demonstrated by Torricelli, whose attention was drawn to the subject by the attempt of a well-digger at Florence, to raise water by a sucking-pump, to a height exceeding 33 feet. It was then found that the pressure of the atmosphere, and not Nature's abhorrence of a vacuum, was the cause of the ascent of the water in the pump-pipe, and that a column of about the height mentioned was sufficient to equipoise the atmosphere.

In 1643, Torricelli filled a glass tube, three feet long, and closed at one end, with quicksilver, and inverted it in a basin of the same fluid; he found that the mercury fell about 6 inches, so that the atmosphere appeared capable of counterbalancing a column of mercury 30 inches in height. The empty space, in the upper part of the tube, has hence been called the *Torricellian vacuum*, and is the most perfect that can be formed.

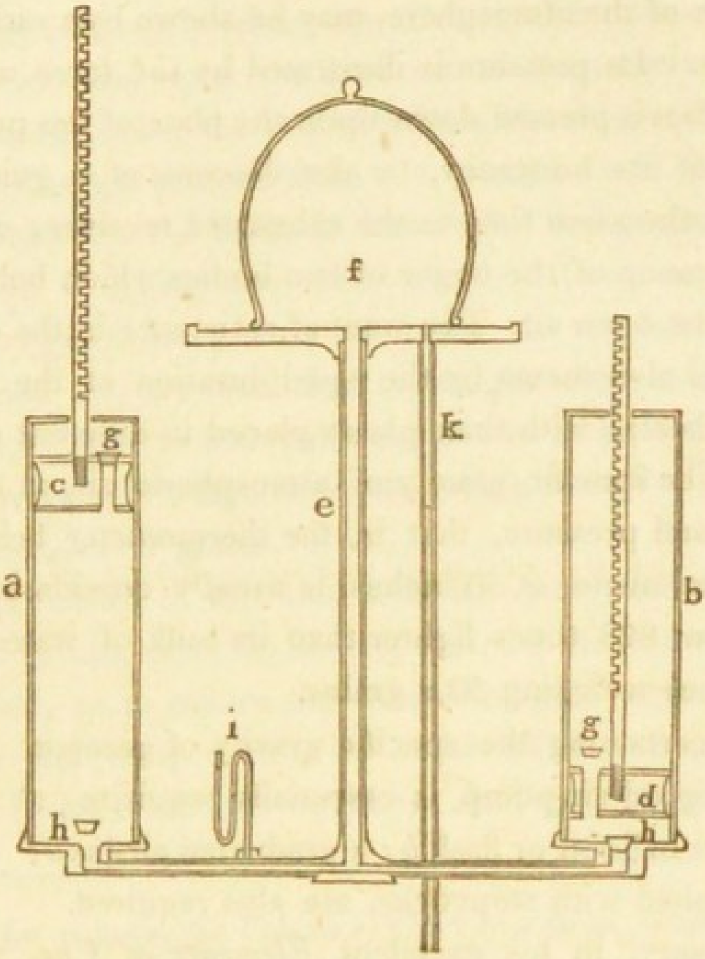
Paschal and Torricelli afterwards observed, that upon ascending a mountain, the quicksilver fell in the tube, because there was less air above to press upon the surface of the metal in the basin, and thus a method of measuring the heights of mountains by the *barometer*, as the instrument is now called, was devised. Sir Henry Englefield has constructed a barometer, expressly for these investigations, the mode of using which is described in the *Journal of Science and the Arts*, Vol. V. p. 229.

The barometer indicates, by its rise and fall, a corresponding change in the density of the atmosphere. At the surface of the earth the mean density or pressure is considered equal to the support of a column of quicksilver 30 inches high.

		Inches.
At 1,000 feet above the surface the column falls to		28,91
2,000	....	27,86
3,000	....	26,85
4,000	....	25,87
5,000	....	24,93
1 Mile	....	24,67
2	....	20,29
3	....	16,68
4	....	13,72
5	....	11,28
10	....	4,24
15	....	1,60
20	....	0,95

169. The general mechanical properties of the air are best illustrated by the *air-pump*, the construction of which much resembles that of the common sucking-pump used for raising water, excepting that all the parts are more accurately and nicely made, the object being to exhaust the air as completely and expeditiously as possible. The annexed sketch will give an idea of the operation of the common air-pump. *a*, *b*, are cylinders, into which the sliding-pistons *c*, *d*, are accurately fitted. *e*, is a tube issuing from the bell glass placed upon a brass plate *f*, and entering the lower part of the cylinders at *h*, *h*, where are valves opening upwards. In each piston is also a valve opening upwards at *g*, *g*. The cylinder *a*, represents the piston in the act of being drawn up. By elevating the piston *c*, an attempt will be made to form a vacuum underneath it; but a portion of the air, in consequence of its elasticity, will pass out of the bell *f*, along the tube *e*, and, elevating the valve *h*, will fill the space below the piston, the valve *g* being kept closed by the weight of the incumbent atmosphere. In the cylinder *b*, the piston is represented in the act of depression, the valve *h*, therefore is forced down upon the orifice, which it

perfectly closes; and the air, confined between it and the piston, now makes its escape by the piston valve *g*, which is accordingly open, so that at every stroke of the pump a portion of air is withdrawn from the receiver *f*.



With this air-pump it is obviously impossible to obtain more than an imperfect vacuum in the receiver *f*, for the valves can only act by the elasticity of the remaining air; and, accordingly, if a barometer be placed under the receiver, the mercury will never attain a level in the tube and basin, but will always indicate a degree of pressure, as is shewn by the small syphon gauge at *i*; and if a tube 3 feet long have its upper end opening into the receiver, and its lower end plunged into a basin of mercury, the mercury will never rise so high as in the common barometer, where the vacuum above it is perfect, but will indicate the pressure of a remnant of air in the receiver. The syphon gauge, and the barometer as applied at *k*, are very useful appendages to the air-pump, as shewing the degree of exhaustion, and its permanence.

The operation of the pump in removing air, and the mechanical properties of the atmosphere, may be shewn by a variety of experiments. Its pressure is illustrated by the force with which the bell glass is pressed down upon the plate of the pump; the absence of its buoyancy, by the descent of a guinea and a feather at the same time in the exhausted receiver; and by the preponderance of the larger of two bodies which balance each other in the open air. The want of resistance in the exhausted receiver is also shewn by the equal duration of the motion of two fly-wheels, with their plates placed in different directions.

170. The specific gravity of atmospheric air, at mean temperature and pressure, that is, the thermometer being at 60°, and the barometer at 30 inches, is usually considered as = 1. It is about 828 times lighter than its bulk of water, 100 cubical inches weighing 30,2 grains.

For ascertaining the specific gravity of gaseous bodies, a good air-pump is essentially requisite; a light glass balloon or flask *b*; a graduated air-jar *a*; each supplied with stopcocks, are also required.

Dr. Henry, in his excellent *Elements of Chemistry**, has given the following directions for proceeding to estimate the specific gravity of gases, which can scarcely be improved upon; it only requires to be observed, that the gases should, in general, be retained and collected over mercury, and carefully dried by exposing them to proper substances for absorbing the moisture which they hold in solution, and which would materially affect the accuracy of the result.

* Henry's *Elements*, vol. i. p. 126.

Supposing the receiver *a* to be filled with any gas, the weight of which is to be ascertained, we screw the cock of the vessel *b* on the plate of an air-pump, and exhaust it as completely as possible. The weight of the exhausted vessel is then very accurately taken, even to a small fraction of a grain; and it is screwed upon the air-cock of the receiver *a*. On opening both cocks, the last of which should be turned very gradually, the gas ascends from the vessel *a;* and the quantity which enters into the flask, is known by the graduated scale on *a*. On weighing the vessel a second time, we ascertain how many grains have been admitted. If we have operated on common air, we shall find its weight to be at the rate of about 30.5 grains to 100 cubical inches. The same quantity of oxygen gas will weigh about 34 grains, and of carbonic acid gas upwards of 47 grains.

In experiments of this kind it is necessary either to operate with the barometer at 30 inches, and the thermometer at 60° Fahrenheit, or to reduce the volume of gas employed to that pressure and temperature, by rules which are given in the note*. Great care is to be taken, also, not to warm any of

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* *Rules for reducing the Volume of Gases to a mean Height of the Barometer, and mean Temperature.*

1. *From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches, as is now most usual.*

This is done by the rule of proportion; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is at 29 inches.

$$30 : 29 :: 100 : 96.66.$$

The 100 inches would, therefore, be reduced to 96.66.

2. *To estimate what would be the volume of a portion of gas, if brought to the temperature of 60° Fahrenheit.*

the vessels by contact with the hands, from which they should be defended by a glove. On opening the communication be-

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Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees, which the gas exceeds, or falls below, 60°. If the temperature of the gas be above 60°, subtract, or if below 60°, add, the product to the absolute quantity of gas: and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480; the quotient 0.208 multiplied by 10 gives 2.08, which added to 100 gives 102.08 the answer required. If the temperature had been 70°, and we had wished to know the volume which the gas would have occupied at 60°, the same number 2.08 must have been subtracted from 100, and 97.92 would have been the answer.

3. In some cases, it is necessary to make a double correction, or *to bring the gas to a mean both of the barometer and thermometer.* We must then first correct the temperature, and afterwards the pressure. Thus to know what space 100 inches of gas at 70° Fahrenheit, and 29 inches barometer, would fill at 60° Fahrenheit and 30 inches barometer, we first reduce the 100 inches, by the second process, to 97.92. Then by the first

$$30 : 29 :: 97.92 : 94.63.$$

Or 100 inches thus corrected, would be only 94.63.

4. *To ascertain what would be the absolute weight of a given volume of gas at a mean temperature, from the known weight of an equal volume at any other temperature:* first, find by the second process what would be its bulk at a mean temperature; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus, if we have 100 cubic inches of gas weighing 50 grains at 50° Fahrenheit, if the temperature were raised to 60° they would expand to 102.08. And

$$102.08 : 50 :: 100 : 49.$$

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

5. *To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure,* say, as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which

tween the receiver and the exhausted vessel, if any water be lodged in the air-cock attached to the former, it will be forcibly driven into the latter, and the experiment will be frustrated. This may be avoided by using great care in filling the receiver with water, before passing into it the gas under examination.

The specific gravity of any gas compared with common air is readily known, when we have once determined its absolute weight. Thus, if 100 cubic inches of air weigh 30.5 grains, and the same quantity of oxygen gas, weighs 34 grains, we say,

$$30.5 : 34 :: 1.000 : 1.1147.$$

The specific gravity of oxygen gas will, therefore, be as 1.1147 to 1.000. We may determine, also, the specific gravity of gases more simply by weighing the flask, first when full of common air, and again when exhausted; and afterwards by admitting into it as much of the gas under examination as it will receive, and weighing it a third time. Now as the loss between the first and second weighing is to the gain of weight on admitting the gas, so is common air to the gas whose specific gravity we are estimating. Supposing, for example, that by

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weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

$$29 : 30 :: 50 : 51.72.$$

Then 100 inches of the same gas, under 30 inches' pressure, would weigh 51.72 grains.

6. In some cases it is necessary to combine the two last calculations. Thus, if 100 inches of gas at 50° Fahrenheit, and under 29 inches' pressure weigh 50 grains, to find what would be the weight of 100 inches at 60° Fahrenheit, and under 30 inches of the barometer, first correct the temperature, which reduces the weight to 49 grains. Then,

$$29 : 30 :: 49 : 50.7.$$

100 inches, therefore, would weigh 50.7 grains.

exhausting the flask it loses 30.5 grains, and that by admitting carbonic acid it gains 47; then

$$30.5 : 47 :: 1.000 : 1.5409.$$

The specific gravity of carbonic acid is therefore 1.5409, air being taken at 1.000. And knowing its specific gravity, we can, without any farther experiment, determine the weight of 100 cubic inches of carbonic acid; for, as the specific gravity of air is to that of carbonic acid, so is 30.5 to the number required; or

$$1.000 : 1.5409 :: 30.5 : 47.$$

100 cubic inches, therefore, of carbonic acid will weigh 47 grains.

171. Atmospheric air has already been stated to consist essentially of oxygen and nitrogen gases; but whether it should be considered a mere mixture or a chemical compound seems a question not easily decided.

There are various ways of learning the proportion which the oxygen bears to the nitrogen; and as the relative fitness of the air for breathing has sometimes been considered as depending upon the quantity of oxygen contained in a given volume, the instruments used in these experiments have been called *eudiometers*.

172. From facts already stated it is obvious, that if atmospheric air, mixed with a certain quantity of hydrogen, be detonated by the electric spark, (138) the absorption will be proportionate to the quantity of oxygen present.

When 100 measures of pure hydrogen are mixed with 100 of pure oxygen, the diminution of bulk after detonation will amount to 150 parts, that is, one volume of oxygen requires for its saturation two of hydrogen. If we introduce into the graduated detonating tube (page 91) 300 measures of common air, and 200 of pure hydrogen, there will remain, after detonation 305 measures; so that 195 measures will have disappeared, of which one-third may be estimated as pure oxygen: so that

300 parts of air have thus lost 65 of oxygen, or about 21 per cent.

The general rule, therefore, for estimating the purity of air by hydrogen gas may be stated as follows:—Add to 3 measures of the air under examination 2 measures of pure hydrogen; detonate; and, when the vessel has cooled, observe the absorption; divide its amount by 3, and the quotient is the quantity of oxygen.

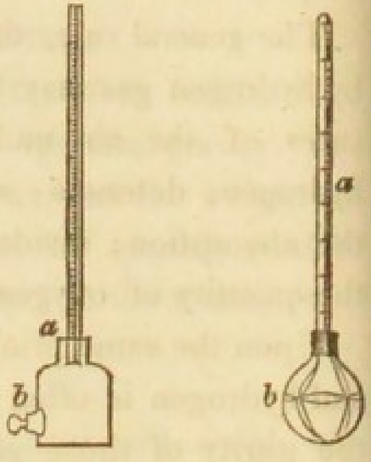
Upon the same principle, detonation of mixtures of oxygen and hydrogen is often resorted to, with a view of ascertaining the purity of those gases. Thus, suppose 100 measures of oxygen, and 300 of hydrogen, to be reduced by detonation to 130, the whole diminution will be = 270, which, divided by 3, gives 90 for the quantity of oxygen; so that it contained 10 per cent. of some gas, not condensible by detonation with hydrogen.

To ascertain the purity of hydrogen, it may be detonated with excess of pure oxygen. Thus, if we add 100 of pure oxygen to 100 of hydrogen, and detonate, there will be a diminution equal to two-thirds, or 150 parts, if the hydrogen be pure. If, however, we suppose 100 of pure oxygen, mixed with 100 of hydrogen, to produce, after detonation, a residue of 80 measures; the diminution will then have been only 120 measures, of which two-thirds, or 80 measures, are hydrogen: so that the inflammable gas will have contained 20 per cent. of some other gaseous body, not condensible by detonation with hydrogen.

This mode of ascertaining the purity of atmospheric air was first resorted to by Volta, and it is susceptible of great accuracy, since pure hydrogen and pure oxygen are easily procured.

173. Scheele, in his eudiometrical experiments, employed sulphuret of potassa, the solution of which rapidly absorbs oxygen, as may be shown by agitating it with some atmo-

spheric air in a graduated glass tube. In this experiment the nitrogen remains unaltered.



The best instruments for these experiments are the eudiometric tubes of Dr. Hope (*Nicholson's Journal*, Vol. IV.) and Dr. Henry (*Elements*, Vol. I. p. 149), as represented in the marginal wood-cut. The former consists of a small bottle, holding about 3 ounces, into which the graduated glass tube *a* is carefully fitted by grinding. It also has a ground stopper at *b*. To use it, the phial is filled with the solution of the alcaline sulphuret, and the tube *a*, containing the air to be examined, fitted into its place. After inverting and agitating the instrument, the stopper *b* may be opened under water, and the absorption is shewn by the rise of the fluid in the tube. For the glass bottle Dr. Henry substituted the elastic gum bottle *b*, in the neck of which a short piece of glass tube is secured, into which the tube *a* is fitted by grinding.

In the *Philosophical Transactions* for 1807, Mr. Pepys has described a modification of this Eudiometer, which may be often advantageously employed in delicate experiments, and by which an absorption of only $\frac{1}{1000}$ part of the gas under examination may be measured.

174. When nitric oxide gas and atmospheric air are mixed, there is a production of nitrous acid, in consequence of the union of oxygen with the oxide (151); and if the mixture be made over water, an absorption proportional to the quantity of nitrous acid formed ensues. Upon this principle nitric oxide may be used in eudiometrical experiments, and, if proper precautions be attended to, it furnishes tolerably accurate results. Dr. Priestly and Mr. Cavendish (*Phil. Trans.* 1783) availed

themselves of this mode, and Mr. Dalton has offered some remarks upon its relative accuracy (*Philosophical Magazine*, Vol. XXVIII). It appears to me that the most certain results are obtained by adding to 100 parts of the atmospheric air, previously introduced into a small beer glass, an equal volume of nitric oxide gas. The mixture may be gently agitated, and in two or three minutes, carefully decanted into a graduated tube, when it will be found that 84 measures have disappeared; of which one-fourth, or 21 measures, are oxygen.

Sir H. Davy suggested the use of a solution of sulphate of iron, impregnated with nitric oxide gas, for the absorption of oxygen; it may be employed in the same way as the alcaline sulphuret. (173).

175. If a stick of phosphorus be confined in a portion of atmospheric air, it will slowly absorb the oxygen present. The rapid combustion of the same substance may also be conveniently resorted to. For this purpose a small piece of phosphorus may be introduced into the bulb of the tube *a*, containing a given measure of the air to be examined, confined over mercury, which, to prevent loss by expansion, should be suffered to occupy about half the tube, or to stand at *b*. The phosphorus may then be inflamed in the tube; and when the combustion is over, and the tube cold, the residuary air may be transferred for measurement. These eudiometrical methods were used by Lavoisier, Berthollet, and Seguin (*Annales de Chimie*, Tom. IX. and XXXIV.) and are both susceptible of accuracy, and a loss of volume = 21 per cent. of the atmospheric air, will invariably be found to have occurred.

176. By experiments thus conducted, it has been found that the composition of the atmosphere is extremely uniform in all

parts of the world, and at all heights above its surface; and that it consists of,

	By measure.	By weight.
Oxygen	21	23
Nitrogen	79	77
	100	100

Though these are the essential component parts of atmospheric air, it contains other substances; which, however, may be regarded as adventitious, and the quantity of which is liable to vary: of these carbonic acid, (219) and aqueous vapour are the most important and constant. The quantity of the former may usually be considered as amounting to less than 1 per cent. The proportion of aqueous vapour is constantly fluctuating, probably a 60th, and a 300th part, are the extremes: according to Mr. Dalton, the average quantity may amount to about $\frac{1}{70}$th of its bulk (*Manchester Memoirs*, Vol. V.).

SECTION III. *Sulphur.*

177. Sulphur, or brimstone, is a brittle substance of a pale yellow colour, insipid and inodorous, but exhaling a peculiar smell when heated. Its specific gravity is 1,990.

Sulphur is principally a mineral product, and occurs crystallized, its primitive form being a very acute octoëdron, with an oblique base.

When sulphur is heated to about 180°, it volatilizes, and its peculiar odour is strong and disagreeable; at 225° it liquefies; between 350° and 400° it becomes viscid, and of a deep brown colour; and at about 600° it quickly sublimes. When slowly cooled after fusion, it forms a fibrous crystalline mass. It suffers no change by exposure to air, and is insoluble in water. It is met with in masses, in rolls, or sticks, and in the form of powder, when it is usually called *flowers of sulphur*.

Massive sulphur is chiefly brought to this country from Sicily: it occurs native, and is found associated with sulphate of lime, sulphate of strothia, and carbonate of lime. Its colour is various shades of yellow, and the transparent crystals are doubly refractive: it is not uncommon among volcanic products.

Roll sulphur is chiefly obtained from sulphuret of copper in this country; which is roasted, and the fumes received into a long chamber of brick-work, where the sulphur is gradually deposited: it is then purified by fusion, and cast into sticks.

178. *Sulphur and Oxygen.*—To oxygen it unites in two proportions, giving rise to the compounds, sulphurous and sulphuric acid. *Sulphurous acid*, or, as it should rather be called, *sulphuric oxide*, is a gaseous body, which may be obtained by several processes. It may be procured directly by burning sulphur in oxygen gas, or indirectly by boiling mercury in sulphuric acid. It must be collected and preserved over mercury; for water takes up rather more than 30 times its bulk of this gas, forming the liquid sulphurous acid, which, when recently prepared, has a sulphurous astringent taste, and destroys many vegetable colours; but by keeping it acquires a sour flavour, and reddens the generality of vegetable blues.

179. If sulphur be burned in oxygen, sulphurous acid is produced without any change in the volume of the gas, so that its composition is easily learned by the increase of weight; and as 100 cubic inches of oxygen (weighing 33,75 grains), dissolve 33,75 grains of sulphur, it is obvious that the sulphurous acid is composed of equal weights of sulphur and oxygen; and if we regard it as consisting of two proportionals of oxygen and one of sulphur, the latter element will be represented by the number 15; and the sulphurous acid, consisting of 1 proportional of sulphur = 15, and 2 of oxygen = 15, will be represented by 30, which is also its relative specific gravity to hydrogen, considering the latter as = 1; 100 cubical inches of sulphurous acid gas weigh 67,5 grains.

This gas has a suffocating nauseous odour, an astringent taste; it extinguishes flame, and kills animals.

180. When sulphurous acid is mixed in equal volume with ammonia, a yellowish salt is produced, which is a *sulphite of ammonia,* and which consists of 60 sulphurous acid + 16 ammonia.

181. *Sulphuric Acid.*—This body was formerly obtained by the distillation of green vitriol, and called *oil of vitriol.* It is now procured in this country by burning a mixture of 8 parts of sulphur and 1 of nitre in close leaden chambers containing water, by which the fumes produced are absorbed, and by evaporation the acid is procured in a more concentrated state. This improved method of preparing sulphuric acid was invented by Dr. Roebuck, about the year 1746. (Parke's *Chemical Essays,* Vol. II.)

Sulphuric acid, as usually met with, is a limpid colourless fluid, having a specific gravity of 1,85, it boils at 620°, and freezes at 15°. It is very acrid and caustic, and when diluted with water, produces a very sour liquid. It rapidly absorbs water from the atmosphere, and upon sudden mixture with water produces much heat.

182. In sulphuric acid 1 proportional of sulphur = 15, is combined with 3 of oxygen = 22,5, and, consequently, *dry* sulphuric acid is correctly represented by 15 + 22,5 = 37,5; but it only exists in this state (like the nitric and chloric acids) when united with bases, and in its ordinary state contains water, and may, therefore, be called *Hydrosulphuric Acid.* It has been found by experiment, that 100 parts of sulphuric acid, specific gravity 1,9, contain 18,2 of water; consequently, it may be looked upon as composed of 1 sulphur + 3 oxygen + 1 water: or of 15 sulphur

22,5 oxygen

8,5 water

46 = number for liquid sulphuric acid.

183. The strength of sulphuric acid is best judged of by its saturating power, and by its specific gravity. Mr. Dalton (*New System of Chemical Philosophy*, Vol. II. p. 404,) has published a Table, exhibiting the specific gravity and boiling point of the acid of various strengths. Dr. Ure also has given several valuable Tables relating to this subject, in his *Experiments to Determine the Law of Progression*, followed in the density of sulphuric acid at different degrees of dilution. (*Journal of Science and the Arts*, Vol. IV. p. 114.) An extremely useful Table of this kind will also be found in Mr. Parkes's *Essays* above quoted (Vol. II. p. 444).

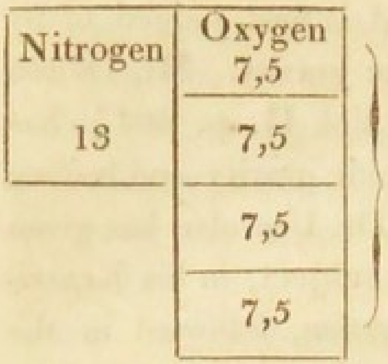
184. The *formation* of sulphuric acid by the combustion of sulphur and nitre is as follows:

The sulphur, by burning in contact with atmospheric air, forms *sulphurous acid*. The nitre gives rise to the production of *nitric oxide*, which, with the oxygen of the air, produces *nitrous acid gas*. When these gases (*i.e.*, sulphurous and nitrous acids) are *perfectly dry*, they do not act upon each other, but moisture being present in small quantity, they form a white solid, which is instantly decomposed when put into water; the nitrous acid reverts to the state of nitric oxide, having transferred one additional proportional of oxygen to the sulphurous acid, and, with water, producing the sulphuric acid; while the nitric oxide, by the action of the air, again affords nitrous acid, which plays the same part as before.

Sulphurous acid consists of

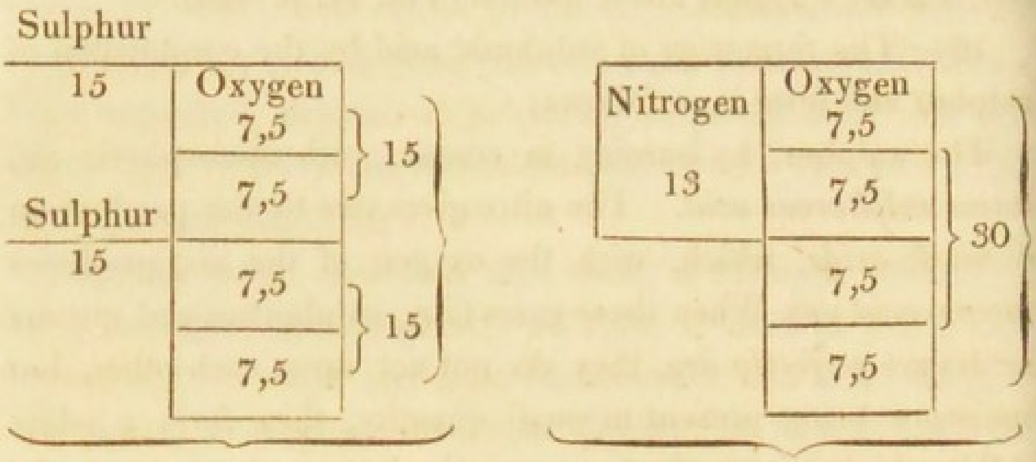
Sulphur		
15	Oxygen 7,5	15;
	7,5	

And nitrous acid contains



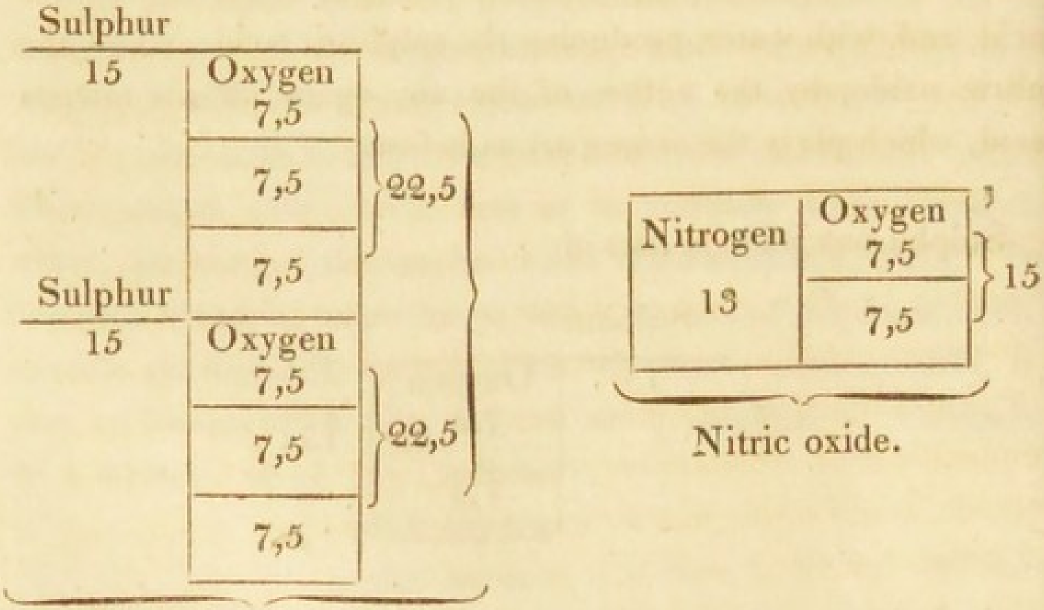
30; hence every *two* portions of sulphurous acid require *one* of nitrous acid, which transfers *two* of oxygen, and passes back into the state of nitrous gas, sulphuric acid being, at the same time, produced.

The gases, therefore, before decomposition, may be thus represented:



Sulphurous acid. Nitrous acid gas.

And after decomposition as follows:



Sulphuric acid. Nitric oxide.

185. The decomposition of sulphuric acid may be effected by passing it through a red hot platinum tube, when it is resolved into sulphurous acid, oxygen, and water.

186. Sulphuric acid is largely consumed in a variety of manufactures. It is used by the makers of nitric, muriatic, citric, and tartaric acids ; by bleachers, dyers, tin-plate makers, brass-founders, and gilders. For these purposes it is generally sufficiently pure as it comes from the wholesale manufacturer ; but, as traces of lead, lime, and potassa, are usually found in it, it often requires to be purified by distillation for the use of the experimental chemist.

187. When sulphuric acid was procured by the distillation of green vitriol, it was frequently observed that a portion concreted into a white mass of radiated crystals. The same substance has also been remarked as occasionally formed in the acid of the English manufacturers. It has been called *glacial* or *fuming sulphuric acid*, and is by Dr. Thomson considered as the pure or anhydrous acid ; it appears, however, probable, that it consists of sulphuric acid, combined with a portion of sulphurous acid. (See *Sulphate of Iron*).

188. *Sulphuric Acid and Ammonia—Sulphate of Ammonia*—may be obtained by passing ammonia into sulphuric acid, but is usually prepared by saturating dilute sulphuric acid with *carbonate of ammonia*. By crystallization it affords six-sided prisms. Its taste is bitter and pungent. This salt is important as a source of the muriate of ammonia, which is obtained by sublimation from a mixture of common salt and sulphate of ammonia ; by this process sulphate of soda is also formed. It dissolves in twice its weight of water at 60°, and consists of 1 proportional of sulphuric acid = 37,5 + 1 proportional of ammonia = 16. Its number, therefore, is 53,5. When heated, ammonia is given off, and a *supersulphate* remains, consisting of 2 proportionals of acid + 1 of alcali.

189. *Sulphur and Chlorine—Chloride of Sulphur.*—This

compound was first described by Dr. Thomson, in 1804. (Nicholson's *Journal,* Vol. VII.) When sulphur is heated in chlorine, it absorbs rather more than twice its weight of that gas. 10 grains of sulphur absorb 30 cubic inches of chlorine, and produce a greenish-yellow liquid, consisting of 15 sulphur + 33,5 chlorine, and represented, therefore, by the number 48,5. It exhales suffocating and irritating fumes when exposed to the air. Its specific gravity = 1,6. It does not affect dry vegetable blues; but when water is present, instantly reddens them, sulphur is deposited, and sulphurous, sulphuric, and muriatic acids are formed in consequence of a decomposition of the water.

190. *Sulphur and iodine* readily unite, and form a black crystallizable compound, first described by M. Gay Lussac. (*Annales de Chimie,* 91.)

191. *Sulphur and Hydrogen—Sulphuretted Hydrogen Gas.*—This gaseous compound of sulphur and hydrogen was discovered by Scheele in 1777. It may be obtained by presenting sulphur to nascent hydrogen, which is the case when sulphuret of iron is acted upon by dilute sulphuric acid. This gas may be collected over water, though, by agitation, that fluid absorbs thrice its bulk. It has a fetid odour. Its specific gravity to hydrogen is as 16 to 1. 100 cubic inches = 36 grains. It is inflammable, and during its slow combustion, sulphur is deposited, and water and sulphurous acid formed. It extinguishes flame; and, when respired, proves fatal. It is very deleterious, even though largely diluted with atmospheric air. It exists in some mineral waters.

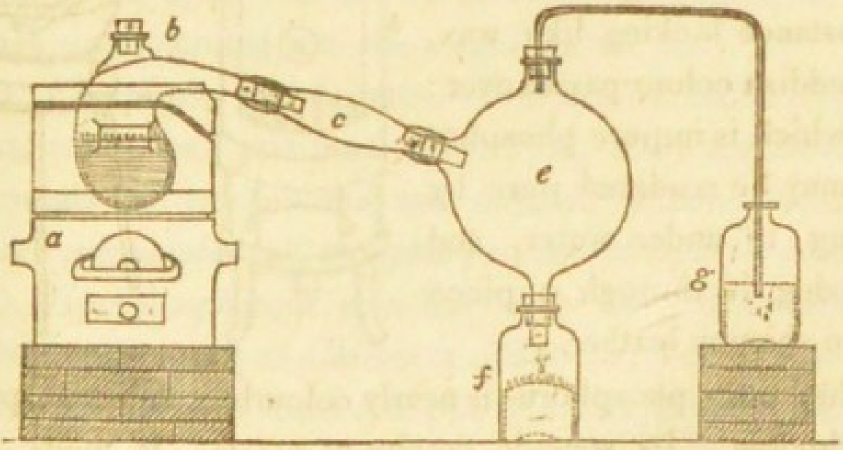
192. When one volume of sulphuretted hydrogen, and $1\frac{1}{2}$ of oxygen are inflamed in a detonating tube, 1 volume of sulphurous acid is produced, and water is formed. Thus the sulphur is transferred to 1 volume of the oxygen, and the hydrogen to the half volume. Sulphuretted hydrogen, therefore, consists of 15 sulphur + 1 hydrogen, and its number is 16. Sulphu-

retted hydrogen may also be decomposed by a succession of electric sparks. Its volume is unchanged, but the sulphur is thrown down.

193. Chlorine and iodine instantly decompose sulphuretted hydrogen; sulphur is deposited, and hydrochloric and hydriodic acids are formed. It is also decomposed by the metal potassium, which absorbs the sulphur and liberates pure hydrogen, when heated in the gas. Nitric acid poured into the gas occasions a deposition of sulphur, and nitrous acid and water are formed.

194. *Sulphuretted hydrogen and ammonia* readily unite in equal volumes, and produce *hydrosulphuret of ammonia*. At first white fumes appear, which become yellow, and a yellow crystallized compound results, consisting of 16 sulphuretted hydrogen, + 8 ammonia. It is of much use as a test for the metals, and may be procured by distilling, at nearly a red heat, a mixture of 6 parts of slacked lime, 2 of muriate of ammonia, and 1 of sulphur.

The following is the disposition of the apparatus for this experiment: *a*, a small furnace; *b*, a tubulated earthen retort containing the above materials; *c*, an adopting tube; *e*, a glass balloon for condensing the vapour; *f*, a receiver; *g*, a bottle of water into which the glass tube issuing from the upper part of the receiver *e*, is made to dip about half an inch.



There is another compound of hydrogen and sulphur, which has been called *supersulphuretted hydrogen*. It is a liquid, formed by adding muriatic acid to a solution of sulphuret of potash, and appears to consist of two portions of sulphur $= 30 +$ one of hydrogen $= 1$.

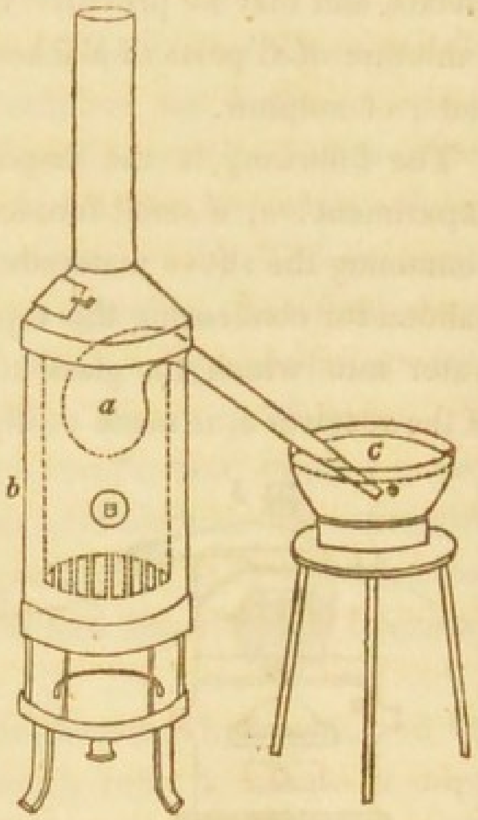
195. *Sulphur and nitrogen* do not form any definite compound, though the nitrogen evolved during the decomposition of certain animal substances, often seems to contain sulphur.

Sulphur, always, in its ordinary state, contains hydrogen, which it gives off during the action of various bodies for which it has a powerful attraction.

SECTION IV. *Phosphorus.*

196. PHOSPHORUS is obtained by distilling phosphoric acid with an equal weight of charcoal at a red heat.

197. This mixture is put into the coated glass, or earthen retort *a*, placed in the small portable furnace *b*, the tube of the retort should be immersed into the basin of water *c*. A great quantity of gas escapes, and when the retort has obtained a bright red heat, a substance looking like wax, of a reddish colour passes over: this, which is impure phosphorus, may be rendered pure by melting it under water, and squeezing it through a piece of fine shamoy leather.



When pure, phosphorus is nearly colourless, semitransparent, and flexible. Its specific gravity $= 1{,}770$. It melts, when air is excluded, at 105°. If suddenly cooled after having been heated to 140°, it becomes black; but, if slowly cooled, remains colourless. At 500°, it boils, and rapidly evaporates. When exposed to air, it exhales luminous fumes, having a peculiar alliaceous odour; it is tasteless.

At a temperature of about 100°, it takes fire, and burns with intense brilliancy, throwing off copious white fumes. If, instead of burning phosphorus with free access of air, it be heated in a confined portion of very rare air, it enters into less perfect combustion, and three compounds of phosphorus with oxygen are the result, each characterized by distinct properties. The first is a red solid, less fusible than phosphorus; the second is a white substance, more volatile than phosphorus; the third a white and fixed body.

198. The red solid consists of a mixture of phosphorus and oxide of phosphorus. *Oxide of phosphorus* is the white substance with which phosphorus becomes encrusted when kept for some time in water. It is very inflammable, and less fusible and volatile than phosphorus. It is this substance which is generally used in the phosphoric match boxes. To prepare it for this purpose, a piece of phosphorus may be put into a small phial, and melted and stirred about so as to coat its interior, with a hot iron wire. A portion of the phosphorus is thus oxidized by its imperfect combustion, and a small quantity, taken out upon the end of a brimstone match, instantly inflames upon coming into the contact of the air.

199. *Phosphorus and Oxygen.*—Besides the oxide of phosphorus, which has just been alluded to, there are three *acid* compounds of phosphorus and oxygen, which have been termed *hypophosphorous*, *phosphorous*, and *phosphoric* acids.

200. *Hypophosphorous acid* has lately been discovered by M. Dulong (*Annales de Chimie et Physique*, Vol. II. p. 141). It is prepared as follows: Upon one part of *phosphuret of baryta*, pour four parts of water, and when the evolution of phosphuretted hydrogen gas has ceased, pour the whole upon a filter. To the filtered liquid add sulphuric acid as long as

any precipitate forms, separate the precipitate, which is a compound of sulphuric acid and baryta, and the clear liquor now contains the hypophosphorous acid in solution.

When concentrated by evaporation, a sour viscid liquid is obtained, incapable of crystallization, and eagerly attractive of oxygen.

201. *Phosphorous acid* was first examined in its pure state, by Sir H. Davy. It is best obtained by mixing *chloride of phosphorus* (207) with water, filtering and evaporating the solution, when a white crystallized solid is obtained, of a sour taste and very soluble. This body consists of phosphorous acid combined with water, and has, therefore, been called the *hydro-phosphorous acid.*

202. *Phosphoric acid* may be formed by burning phosphorus in excess of oxygen. There is intense heat and light produced, and white deliquescent flocculi .ine the interior of the receiver. Phosphoric acid may also be obtained by acting upon phosphorus by nitric acid. For the purpose of procuring phosphorus, this acid is most economically obtained by the decomposition of bone earth, which consists chiefly of phosphate of lime. The following is the mode of proceeding :

On 20 pounds of calcined bone, finely powdered, pour 20 quarts of water, and 8 pounds of sulphuric acid, diluted with an equal weight of water. Let these materials be stirred together, and simmered for about 6 hours. Let the whole be then put into a conical bag of linen, to separate the clear liquor, and wash the residuum till the water ceases to taste acid. Evaporate the strained liquor, and when reduced to about half its bulk, let it cool. A white sediment will form which must be allowed to subside ; the clear solution must be decanted, and boiled to dryness into a glass vessel. A white mass will remain, which is the dry phosphoric acid. This may be fused in a crucible, and poured out in a clean copper dish. A transparent glass is obtained, containing phosphate and a little sulphate of lime

Phosphoric acid is a deliquescent substance: when fused it has been called *glacial phosphoric acid.* It is inodorous, very sour, volatile at a red heat, but unchanged by it. As commonly prepared, it is an unctuous fluid. Specific gravity = 2.

203. The composition of these acids of phosphorus has been variously given by different chemists. Sir H. Davy's recent experiments upon this subject, (*Phil. Trans.* 1818,) appear to furnish the least exceptionable results, and he has stated them thus:

Hypophosphorous acid,	Phosphorus	45,	Oxygen	15
Phosphorous acid	....	45	......	30
Phosphoric acid	....	45	......	60

If these numbers be reduced to the equivalents which I have employed, the number representing phosphorus, would be 11,25. The hypophosphorous acid would then consist of two proportionals of phosphorus = 22,5, and one proportional of oxygen =7,5. The phosphorous acid of one of oxygen and one of phosphorus, and the phosphoric of one and two.

From some experiments which I have made upon the quantity of oxygen absorbed by phosphorus during its conversion into phosphoric acid, by burning it in great excess of oxygen, I was induced to believe that, at mean temperature and pressure, each grain of phosphorus condensed rather less than 4,5 cubic inches of oxygen, which would give a result differing from that of Sir H. Davy. On the whole, however, I am induced to believe the results of his experiments less liable to fallacy than my own; and adopting the number 11 as representative of phosphorus, the phosphorous acid will consist of one proportional of phosphorus = 11, and one of oxygen = 7,5, and will be represented by the number 18,5: and the phosphoric acid containing one proportional of phosphorus and two of oxygen, 11 + 15, will be represented by 26.

204. When phosphorus is exposed to a moist atmosphere, it undergoes an apparent deliquescence producing a sour liquid,

composed of phosphorous and phosphoric acids and water. M. Dulong has called this *phosphatic acid.*

205. *Phosphite of ammonia* may be obtained in delicate tabular crystals, decomposable by heat.

206. *Phosphate of ammonia* is a common ingredient in the urine of carnivorous animals. It may be obtained pure by saturating phosphoric acid with ammonia, and forms octoëdral crystals soluble in two parts of water at 60°.

It consists of..............	26 acid
	16 ammonia
	42

207. *Phosphorus and Chlorine.*—These elements unite in two proportions, forming two definite compounds, the *chloride* and *bichloride* of phosphorus.

When phosphorus is submitted to the action of chlorine, it burns with a pale yellow flame, and produces a white volatile compound, which attaches itself to the interior of the vessel. This substance was long mistaken for phosphoric acid, but its volatility is alone sufficient distinction; it rises in vapour at 200°. It is fusible and crystallizable: and when brought into the contact of water, a mutual decomposition is effected, and phosphoric and muriatic acids result. When passed through a red-hot porcelain tube with oxygen, phosphoric acid is produced and chlorine evolved.

With ammonia it forms a singular compound, which, though consisting of three volatile bodies, remains unchanged at a white heat, and is insoluble in water.

When phosphorus is burned in chlorine, one grain absorbs 8 cubic inches; so that the compound formed must be regarded as the *bichloride,* and consists of 11 of phosphorus + 67 of chlorine, and its number is 78.

208. *Chloride of Phosphorus,* consisting of 11 phosphorus + 33,5 chlorine, is procured by distilling a mixture of phosphorus and *corrosive sublimate,* which is a bichloride of mer-

cury. In this experiment *calomel*, or chloride of mercury, is formed, and the phosphorus combines with one proportional of chlorine.

The chloride of phosphorus, when first obtained, is a liquid of a reddish colour; but it soon deposits a portion of phosphorus, and becomes limpid and colourless. Its specific gravity = 1,45. Exposed to the air it exhales acid fumes: it does not change the colour of dry vegetable blues. Chlorine converts it into bichloride. Ammonia separates phosphorus, and produces the singular triple compound before adverted to.

Chloride of phosphorus acts upon water with great energy, and produces muriatic and *phosphorous* acids, while the bichloride produces muriatic and *phosphoric* acids: for, as in the bichloride there are two proportionals of chlorine, so, in acting upon water, two of oxygen must be evolved, which uniting to one of phosphorus generate phosphoric acid. The chloride of phosphorus, on the contrary, containing only one proportional of chlorine, produces muriatic acid and phosphorous acid, when it decomposes water.

Before decomposition.

$$\left.\begin{array}{l}\text{1 Chlorine} = 33{,}5\\ \text{1 Phospho.} = 11\end{array}\right\}\overset{\text{Chloride of Phosp.}}{44{,}5}\quad\Bigg|\quad\left.\begin{array}{l}\text{1 Hydrog.} = 1\\ \text{1 Oxygen} = 7{,}5\end{array}\right\}\overset{\text{Water.}}{8{,}5}$$

After decomposition.

$$\left.\begin{array}{l}\text{1 Chlorine} = 33{,}5\\ \text{1 Hydrog.} = 1\end{array}\right\}\overset{\text{Muriatic Acid.}}{34{,}5}\quad\Bigg|\quad\left.\begin{array}{l}\text{1 Phospho.} = 11\\ \text{1 Oxygen} = 7{,}5\end{array}\right\}\overset{\text{Phosp. Acid.}}{18{,}5}$$

But the phosphorous acid thus produced, always contains water, which it throws off when heated in ammonia, forming, with that alcali, a dry phosphite. This experiment shews that the *hydrophosphorous acid* consists of 2 proportionals of phosphorous acid = 37 + 1 water = 8,5.

209. *Phosphorus and Iodine.*—When these substances are

brought together in an exhausted vessel, they act violently, and form a reddish compound; the *iodide of phosphorus* decomposes water with great energy, and produces phosphorous and hydriodic acids. It consists of 11 phosphorus + 117,7 iodine.

Periodide of phosphorus is a black compound, formed by heating one part of iodine with rather more than 20 of phosphorus. It consists, according to Dr. Thomson, of 1 proportional of phosphorus + 2 of iodine. It does not decompose water.

210. *Phosphorus and Hydrogen.*—When phosphorus is presented to nascent hydrogen, two gaseous compounds result. The one inflames spontaneously upon the contact of the atmosphere. This may be procured by heating phosphorus in a solution of caustic potash; or better, by acting upon *phosphuret of lime* by dilute muriatic acid. The gas may be collected over water. It is colourless, has a nauseous odour like onions, a very bitter taste, and inflames when mixed with air, a property which it loses by being kept over water. For our knowledge of the properties and composition of this gas, we are chiefly indebted to Dr. Thomson, who has shown that the hydrogen suffers no change of bulk in uniting to the phosphorus; so that the difference of weight between this gas and pure hydrogen, indicates the weight of phosphorus: 100 cubic inches of phosphuretted hydrogen = 27 grains; hence the gas may be regarded as containing one proportional of phosphorus and one of hydrogen, or $11 + 1 = 12$.

When phosphuretted hydrogen is mixed with oxygen, it requires a volume and a half of the latter gas for its perfect combustion; and as the hydrogen would require half its volume of oxygen for the production of water, the remaining volume must unite to the phosphorus to produce phosphoric acid.

211. The next compound of phosphorus and hydrogen has been called, by Sir H. Davy, *hydrophosphoric gas.* It is procured by heating the solid hydrophosphorous acid. The gas must be collected over mercury. Its specific gravity to hydro-

gen is as 13 to 1. It is not spontaneously inflammable, but explodes when heated with oxygen. It inflames spontaneously in chlorine. Its smell is less disagreeable than the former. It consists of 2 of hydrogen and 1 of phosphorus $\overset{H}{2}+\overset{P}{11}=13$; but the two volumes of hydrogen are condensed into one, consequently, when the gas is decomposed, as for instan ce, by subliming sulphur in it, two volumes of sulphuretted hydrogen are formed. 100 cubical inches weigh 29,25 grains.

When hydrophosphorous acid is decomposed for the production of this gas, phosphoric acid is always generated. Hydrophosphorous acid has been stated to contain two proportionals of phosphorous acid + one of water. Hence the elements

$$\left.\begin{array}{ll}22 & \text{phosphorus}\\ 15 & \text{oxygen}\end{array}\right\}=\text{phosphorous acid,}$$

$$\left.\begin{array}{ll}7{,}5 & \text{do.}\\ 1 & \text{hydrogen}\end{array}\right\}=\text{water,}$$

or 45,5 parts of hydrophosphorous acid contain

22 phosphorus
22,5 oxygen
1 hydrogen.

The three proportionals of oxygen=22,5 will require one proportional and a half of phosphorus = 16,5, to form phosphoric acid; and the remaining half proportional of phosphorus will unite to the one of hydrogen to form hydrophosphoric gas.

To avoid fractions the phenomena may be stated thus:

Four proportionals of hydrophosphoric acid contain

$$\begin{array}{llcr}
4 \text{ phosphorus} & & = & 44\\
4 \text{ oxygen} & & = & 30\\
\left.\begin{array}{l}2 \text{ do.}\\ 2 \text{ hydrogen}\end{array}\right\} & \begin{array}{l}\text{in the}\\ \text{water}\end{array} & \begin{array}{c}=\\ =\end{array} & \begin{array}{r}15\\ 2\end{array}
\end{array}$$

The whole of the oxygen, amounting to 6 proportionals (*i. e.* $7{,}5 \times 6 = 45$), unites to three proportionals of phosphorus ($11 \times 3 = 33$), to form phosphoric acid. The two of hydrogen = 2, combine with the remaining proportional of phosphorus = 11 to form hydrophosphoric gas.

212. *Phosphorus and Nitrogen* produce no definite compound, though in some cases of animal decomposition the evolved nitrogen appears to hold phosphorus in solution.

213. *Phosphorus and Sulphur* may be readily united by fusion in an exhausted vessel. When one proportional of phosphorus is united to one of sulphur (11 + 15), the compound bears a high temperature without decomposition. It is a crystallisable solid at temperatures below 50°. (Faraday. *Journal of Science*, Vol. IV. p. 361.)

SECTION V. *Carbon.*

214. THE purest form of this elementary substance is the diamond, a mineral body first discovered in Asia, in the provinces of Golconda and Visapour, in Bengal, and in the island of Borneo. About the year 1720 diamonds were first found in the district of Serra Dofrio, in Brazil. They always occur in detached crystals in alluvial soil. The primitive form of the diamond is the regular octoëdron, each triangular facet of which is sometimes replaced by six secondary triangles, bounded by curved lines; so that the crystal becomes spheroidal, and presents 48 facets. Diamonds, with 12 and 24 facets, are not uncommon. (Jameson's *Mineralogy*, 2d edit. Vol. I. p. 1). The diamond has been found nearly of all colours: those which are colourless are most esteemed; then those of a decided red, blue, or green tint. Black diamonds are extremely rare. Those which are slightly brown, or tinged only with other colours, are least valuable. The fracture of the diamond is foliated, its laminæ being parallel to the sides of a regular octoëdron. It is brittle and very hard; its specific gravity = 3,5.

The art of cutting and polishing diamonds, though probably of remote antiquity in Asia, was first introduced into Europe, in 1456, by Louis Berghen, of Bruges, who accidentally discovered that by rubbing two diamonds together, a new facet was produced. The particular process of forming the rough gems into *brilliants* and *rose diamonds* has been described at length by Jeffries (*Treatise on Diamonds and Pearls*, 3d edit. London, 1800). By either of these processes, but especially by the former, so much is cut away, that the weight of the polished gem does not exceed half that of the rough stone; so that the value of a cut diamond is esteemed equal to that of a similar rough diamond of twice the weight, exclusive of the cost of workmanship. The weight, and therefore the value of diamonds, is estimated in *carats*, 150 of which are about equal to one ounce troy, or 480 grains. They are divided into halves, quarters or carat grains, eighth, sixteenth, and thirty-second parts.

The difference of value between one diamond and another, is, generally speaking, as the squares of their respective weights: thus, the value of three diamonds, of one, two, and three carats weight respectively, is as one, four, and nine. The average price of rough diamonds is estimated by Jeffries, at £2. per carat, and, consequently, when wrought, the cost of the first carat, exclusive of workmanship, will be £8., which is the value of a rough diamond of two carats.

	£
A wrought diamond of three carats is worth..	72
4 carats	128
5 ditto	200
10 ditto	800
20 ditto	3,200
30 ditto	7,200
40 ditto	12,800
50 ditto	20,000
60 ditto	28,800
100 ditto	80,000

This mode of valuation, however, only applies to small diamonds, in consequence of the difficulty of finding purchasers for the larger ones.

The largest known diamond is probably that mentioned by Tavernier, in the possession of the Great Mogul. Its size is about that of half an hen's egg: it is cut in the rose form, and when rough, is said to have weighed 900 carats. It was found in Golconda about the year 1550.

Among the crown jewels of Russia is a magnificent diamond, weighing 195 carats. It is the size of a small pigeon's egg, and was formerly the eye of a Brahminical idol, whence it was purloined by a French soldier; it passed through several hands, and was ultimately purchased by the empress Catherine for the sum of £90,000. in ready money, and an annuity of £4,000.

Perhaps the most perfect and beautiful diamond hitherto found, is a brilliant brought from India by an English gentleman of the name of Pitt, who sold it to the Regent Duke of Orleans, by whom it was placed among the crown jewels of France. It weighs rather more than 136 carats, and was purchased for £100,000.

215. Another form of carbon is *charcoal*, the purest variety of which is *lamp-black*.

Charcoal may be prepared by heating pieces of wood, covered with sand, to redness, and keeping them in that state for about an hour. They are converted into a black brittle substance, which appears to be the same from whatever kind of wood it has been procured.

Common charcoal employed as fuel is usually made of oak, chesnut, elm, beech, or ash wood, the white and resinous woods being seldom used. Young wood affords a better charcoal than large timber, which is also too valuable to be thus employed. It is formed into a conical pile, which being covered with earth or clay, is suffered to burn with a limited access of atmospheric air, by which its complete combustion, or reduction to ashes, is prevented.

Another, and a more perfect mode of preparing charcoal, consists in submitting it to a red heat in a kind of distillatory apparatus, consisting of cast iron cylinders, from which issue one or more tubes for the escape of gaseous matters. The makers of gunpowder particularly prefer this process. (a plate of this apparatus is given by Mr. Parkes, in his *Chemical Essays.*)

Lamp-black is prepared principally by turpentine manufacturers from refuse and residuary resin, which is burned in a furnace, so constructed, that the dense smoak arising from it may pass into chambers hung with sacking, where the soot is deposited, and from time to time swept off, and sold without any further preparation. (Aikin's *Dictionary. Art. Charcoal.*) When lamp-black has been heated red hot in a close vessel, it may be considered as very pure carbon.

216. The quantity of charcoal obtained from different kinds of wood is liable to much variation. From 100 parts of the following woods, Messrs. Allen and Pepys obtained the annexed quantities of charcoal. (*Phil. Trans.* 1807).

Beech	15,00
Mahogany	15,75
Lignum Vitæ	17,25
Oak	17,40
Fir	18,17
Box	20,25

217. Charcoal is a black insoluble inodorous insipid brittle substance; an excellent conductor of electricity, but a bad conductor of heat; unchanged by the combined action of air and moisture at common temperatures; infusible; and easily combustible in oxygen gas. It is capable of destroying the smell and taste of a variety of vegetable and animal substances. (*Lowitz, in Crell's Annals,* Vol. II. p. 165). The use of charring

piles; of throwing charcoal into putrid water; of wrapping it in cloths that have acquired a bad smell; of adding it to port wine, with a view of making it tawny; depends upon the above properties.

Newly-made charcoal has the property of absorbing certain quantities of the different gases. Upon this subject the experiments of M. Theodore de Saussure are the most recent. (Thomson's *Annals*, Vol. VI.) The charcoal was heated red hot, then suffered to cool under mercury, and introduced into the gas. The following are the volumes of different gases absorbed by a volume of charcoal = 1.

	Volumes.
Ammonia	90
Muriatic acid	85
Sulphurous acid	65
Sulphuretted hydrogen	55
Nitrous oxide	40
Carbonic acid	35
Bicarburetted hydrogen	35
Carbonic oxide	9,42
Oxygen	9,25
Nitrogen	7,5
Carburetted hydrogen	5,
Hydrogen	1,75

The absorption was always at its maximum at the end of 24 hours.

The results of these experiments are widely different from those of Count Morozzo, (*Journal de Physique*, 1783) and of M. Rouppe, (*Annales de Chimie*, Vol. XXXII.) It would also appear, that this property depends upon the mechanical texture of the charcoal, and consequently will vary in the different woods; for by exposing the charcoal of different woods to air, Allen and Pepys found that they increased very differently in weight.

By a week's exposure, Charcoal from

Lignum Vitæ gained	9,6 per cent.
Fir	13,0 ditto.
Box....................	14,0 ditto.
Beech	16,3 ditto.
Oak....................	16,5 ditto.
Mahogany	18.0 ditto.

The matter absorbed in these cases consisted principally of aqueous vapour, which is very greedily imbibed by newly-made charcoal.

Carbon and Oxygen.—There are two compounds of carbon and oxygen; the carbonic oxide and the carbonic acid.

Carbonic Oxide is usually obtained by subjecting carbonic acid to the action of substances which abstract a portion of its oxygen. Upon this principle, carbonic oxide gas is produced by heating a mixture of chalk and charcoal, or of equal weights of chalk and iron or zinc filings. The gas should be well washed, and may be preserved over water.

218. Its specific gravity to hydrogen is as 13,2 to 1; 100 cubical inches weighing 29,7 grains. It is fatal to animals, extinguishes flame, and burns with a pale blue lambent light, when mixed with, or exposed to, atmospheric air.

When a stream of carbonic oxide is burnt under a dry bell-glass of air or oxygen, no moisture whatever is deposited.

When two volumes of carbonic oxide, and one of oxygen, are acted on by the electric spark, a detonation ensues, and two volumes of carbonic acid are produced. Whence it appears, that carbonic acid contains just twice as much oxygen as carbonic oxide.

Carbonic oxide may be considered as a compound of one volume of oxygen and one volume of gaseous carbon, or of one proportional of carbon and one of oxygen, the latter being so expanded as to occupy two volumes.

219. The representative number of carbon, as obtained by

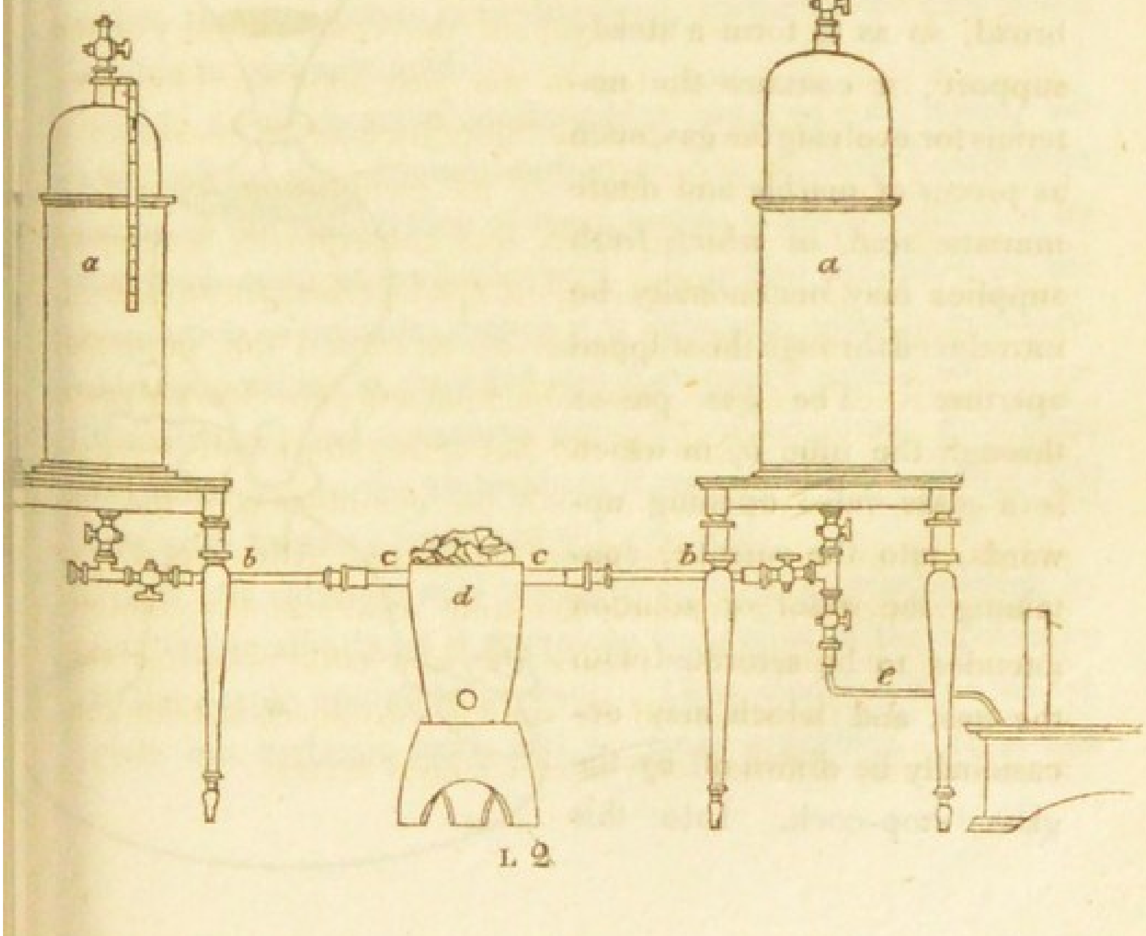
considering this gas as a compound of one proportional, and one of oxygen, is 5,7; and 5,7 carbon + 7,5 oxygen = 13,2 carbonic oxide.

220. *Carbonic acid* may be obtained by burning carbon, either pure charcoal or the diamond, in oxygen gas: the oxygen suffers no change of bulk, so that the composition of carbonic acid is easily learned by comparing its weight with that of an equal volume of pure oxygen. 100 cubic inches of oxygen weigh 33,75 grains: 100 cubic inches of carbonic acid weigh 46,57 grains; hence 100 cubical inches of carbonic acid must consist of 33,75 grains of oxygen, + 12,82 grains of carbon, and 12,82 : 33,75 : : 5,7 : 15. Hence 1 proportional of charcoal = 5,7 + 2 proportionals of oxygen, = 15 will constitute carbonic acid, represented by the number 20,7., or by the following symbol:

Carbon	Oxygen	Carbonic Acid.
5,7	7,5	= 20,7
	7,5	

221. It is not evident to whom the combustibility of the diamond first occurred; but in the year 1694 the Florentine academicians proved its destructibility by heat by means of a burning lens. The *products* of its combustion were first examined by Lavoisier in 1772, and subsequently with more precision by Guyton Morveau, in 1785. (*Annales de Chimie*, XXXI.) In 1797, Mr. Tennant demonstrated the important fact, that when equal weights of diamond and pure charcoal were submitted to the action of red hot nitre, the results were in both cases the same; and in 1807 the combustion of the diamond in pure oxygen was found by Messrs. Allen and Pepys to be attended with precisely the same results as the combustion of pure charcoal. Hence the inevitable inference that charcoal and the diamond are similar substances in their chemical nature, differing only in mechanical texture.

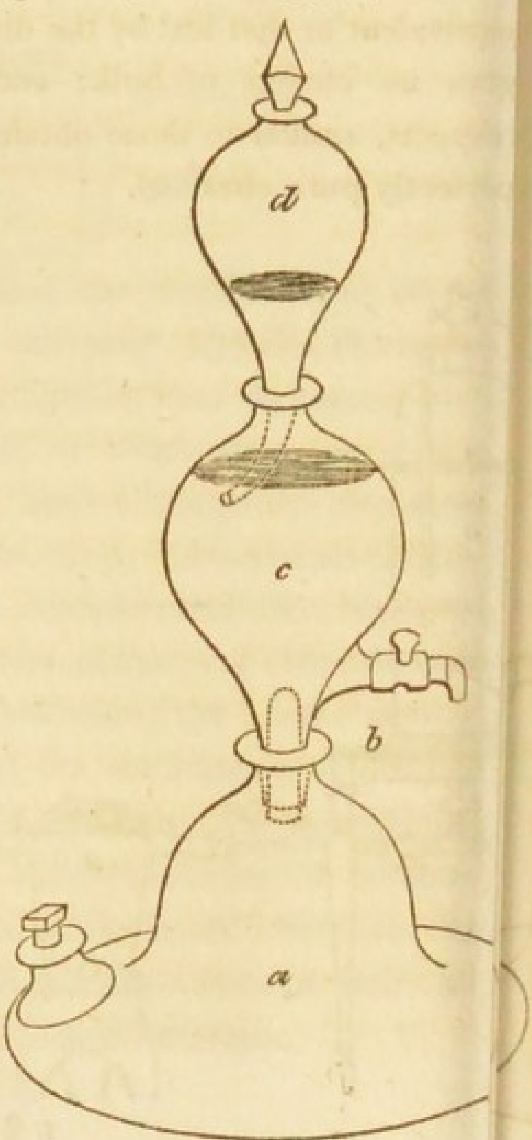
The following method of illustrating the products of the combustion of the diamond was employed by the last mentioned chemists: *a a* are mercurial gazometers, one of which is filled with pure oxygen gas. The brass tubes *b b*, properly supplied with stop-cocks, issue from the gazometers, and are connected with the platinum tube *c c*, which passes through the small furnace *d*. *e* is a glass tube passing into the mercurio-pneumatic apparatus, by which the gas may be drawn out of the gasometers into convenient receivers. A given weight of diamond is introduced into the centre of the platinum tube, which is then heated to bright redness, and the gas passed over it, backwards and forwards, by alternately compressing the gasometers. Carbonic acid is soon formed, and it will be found, that the increase of weight sustained by the oxygen is equivalent to that lost by the diamond; that the oxygen undergoes no change of bulk; and that the results are, in all respects, similar to those obtained by a similar combustion of perfectly pure charcoal.



222. Carbonic acid is a most abundant natural product; the best mode of procuring it for experiment consists in acting upon pounded marble *(carbonate of lime)* by dilute muriatic acid.

It may be collected over water, but must be preserved in vessels with glass stoppers, since water, at common temperature and pressure, takes up its own volume: under a pressure of two atmospheres it dissolves twice its volume, and so on. It becomes brisk and tart, and reddens delicate vegetable blues. By freezing, boiling, or exposure to the vacuum of the air-pump, the gas is given off.

The effervescent quality of many mineral waters is referable to the presence of this gas, and they are often imitated by condensing carbonic acid into water, either by a condensing pump, of which a description is given by Mr. Pepys, (*Journal of Science and Arts*, Vol. IV. p. 305) or by a Nooth's apparatus, as represented in the annexed wood-cut. It consists of three vessels, the lowest, *a*, flat and broad, so as to form a steady support; it contains the materials for evolving the gas, such as pieces of marble and dilute muriatic acid, of which fresh supplies may occasionally be introduced through the stopped aperture. The gas passes through the tube *b*, in which is a glass valve opening upwards, into the vessel *c*, containing the water or solution intended to be saturated with the gas, and which may occasionally be drawn off by the glass stop-cock. Into this



dips the tube of the uppermost vessel *d*, which occasions some pressure on the gas in *c*, and also produces a circulation and agitation of the water. At the top of *d* is a heavy conical stopper, which acts as an occasional valve, and keeps up a degree of pressure in the vessels.

223. Carbonic acid is unrespirable, and it extinguishes flame. Its weight may be shown by placing a lighted taper at the bottom of a tall glass jar, and then pouring the gas out of a bottle into it, in the manner of a liquid; it descends and extinguishes the flame, and will remain a long time in the lower part of the vessel. Hence in wells, and in some caverns, carbonic acid frequently occupies the lower parts, while the upper parts are free from it. The miners call it *choak damp*.

224. The presence of carbonic acid is instantly detected by *lime water*, which it renders turbid, and causes a deposit of a white matter, which is *carbonate of lime*. The addition of water saturated with carbonic acid to lime water, also occasions a milkiness from the same cause. If excess, either of the gas, or of its aqueous solution, be added to the lime water, the precipitate is re-dissolved, carbonate of lime being soluble in carbonic acid.

225. As all common combustibles, such as coal, wood, oil, wax, tallow, *&c.*, contain carbon as one of their component parts, so the combustion of these bodies is always attended by the production of carbonic acid. It is also produced by the respiration of animals; hence it is detected, often in considerable proportion, in crowded and illuminated rooms, which are ill ventilated, and occasions difficulty of breathing, giddiness, and faintness. In the atmosphere it may also be detected, (176) varying in quantity from 1 to 0,1 per cent.

226. As carbonic acid is usually retained in combination by very feeble affinity, so it is evolved from most of the *carbonates* by the simple operation of heat. Thus chalk, when heated, gives out carbonic acid, and becomes *quicklime*. It is also

evolved from its combinations by most of the other acids; and if nitric, muriatic, or sulphuric acid, be poured upon the carbonates, the presence of carbonic acid is indicated by *effervescence*.

227. In section 220, the nature of carbonic acid has been synthetically demonstrated. It may be analysed by the action of the metal *potassium*, which is capable of abstracting its oxygen, and with the aid of heat, burns in it with great splendour: charcoal is deposited, and an *oxide of potassium* is formed. In this and in some other cases, oxygen is seen alternately producing acid and alcali. If carbonic acid, obtained by burning the diamond in oxygen, be thus decomposed by potassium, the carbon makes its appearance in the form of charcoal, equal in weight to the diamond consumed.

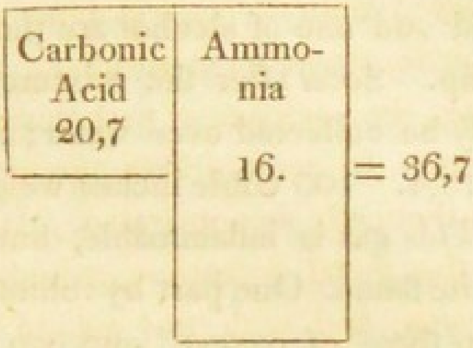
228. *Chlorine* and carbon do not combine; but chlorine unites with *carbonic oxide*, and produces a triple compound, called by Dr. Davy, *phosgene gas*, as it is most easily produced by exposing a mixture of equal volumes of chlorine and carbonic oxide to the action of light. A condensation = 0,5 takes place. The compound has a peculiar pungent odour. It is soluble in water, and is resolved into carbonic and muriatic acid gases. The weight of phosgene to hydrogen is as 46,7 to 1. 100 cubical inches weigh 107,075 grains. It condenses four times its volume of ammoniacal gas, producing a peculiar compound of a white colour. (*Philos. Trans.* 1807.) The term *chlorocarbonic acid* has been applied to this compound.

Iodine exerts no action either upon carbon or carbonic oxide.

229. *Carbonic acid and ammonia.—Carbonate of ammonia.*—These gases readily combine, and produce one of the most useful and best known of the ammoniacal compounds.

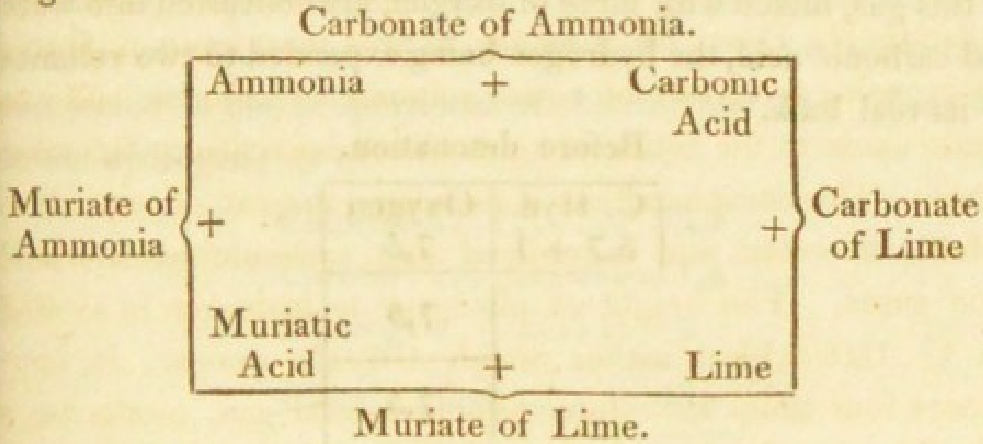
When one volume of carbonic acid and two volumes of ammonia are mixed in a glass vessel, over mercury, a complete condensation ensues, and a *subcarbonate of ammonia* is produced.

It consists of 16 ammonia + 20,7 carbonic acid, and is represented by 36,7.



If water be present, it so far overcomes the elasticity of the gas, as to enable the salt formed to take up another volume of carbonic acid, and thus a *bicarbonate* is formed.

Subcarbonate of ammonia crystallizes in octoëdrons, though it is generally met with in cakes broken out of the subliming vessel, being obtained by sublimation from a mixture of muriate of ammonia and carbonate of lime, as shewn in this diagram.



Its odour is pungent; its taste hot and saline. A pint of water at 60° dissolves rather less than 4 ounces. This solution is directed in the *Pharmacopœia*, under the name of *Liquor Ammoniæ Subcarbonatis*. By exposure to air it loses ammonia, and becomes a bicarbonate.

230. *Carbon and Hydrogen.*—These bodies combine in two proportions, and form gaseous compounds, consisting of 1 carbon + 1 hydrogen, and 1 carbon + 2 hydrogen.

There are several processes by which they may be obtained. The first compound is obtained by the decomposition of alcohol by sulphuric acid. For this purpose four parts of the acid and one of alcohol are put into a retort, and heated by a lamp. Soon after the mixture boils the gas is evolved. It may be collected over water; its specific gravity to hydrogen is 13,4. 100 cubic inches weigh 30,15 grains.

This gas is inflammable, burning with a bright yellowish white flame. One part by volume, requires, for perfect combustion three of oxygen, and two of carbonic acid are produced. When sulphur is heated in one volume of this gas, charcoal separates, and two volumes of sulphuretted hydrogen result. As hydrogen suffers no change of volume by combining with sulphur, it follows that carburetted hydrogen contains two volumes of hydrogen condensed into one, hence the quantity of oxygen required for its consumption.

The following symbols shew that one volume or proportional of this gas, mixed with three of oxygen, are converted into water and carbonic acid, the hydrogen being expanded to two volumes, or its real bulk.

Before detonation.

C. Hyd.	Oxygen
5,7 + 1	7,5
	7,5
	7,5

After detonation.

			Carbon.		
Hydrogen 1	Oxygen 7,5	Water	5,7	Oxygen 7,5	Carbonic acid.
				7,5	

This gas, therefore, is constituted of 1 proportional of carbon = 5,7 + 1 proportional of hydrogen = 1, and its number is 6,7.

231. When this gas is mixed with chlorine in the proportion of 1 to 2 by volume, the mixture on inflammation produces muriatic acid, and charcoal is abundantly deposited; but if

the two gases be mixed in an exhausted vessel, or over water, they act slowly upon each other, and a peculiar fluid is formed, which appears like a heavy oil; hence this variety of carburetted hydrogen has been termed *olefiant gas.*

Chloric ether is the term applied to this fluid by Dr. Thomson, who, in 1810, ascertained that its component parts were chlorine and carburetted hydrogen. It has more lately been examined by M. M. Robiquet and Colin. (*Annales de Chimie et Phys.* Vol. I and II.) Chloric ether may be formed by allowing a current of each gas to meet in a proper receiver; there should be excess of olefiant gas, for if the chlorine be in excess, the ether absorbs it. It is transparent and colourless; its taste, sweet and somewhat acrid; its specific gravity = 1,2. It boils at 152°. It burns with a green flame evolving muriatic acid and largely depositing charcoal. As it is produced by equal volumes of chlorine and carburetted hydrogen, it is probably a compound of one proportional of chlorine and two of carburetted hydrogen; or of

Chlorine	33,5
Carbon	11,4
Hydrogen	2
Chloric ether	46,9

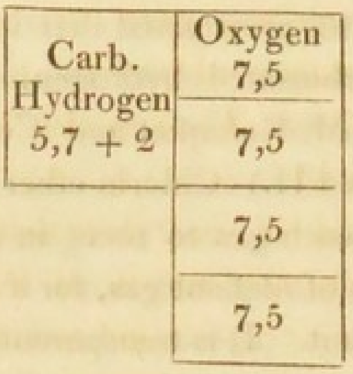
232. The other variety of carburetted hydrogen is often generated in stagnant ponds. It may be procured by passing the vapour of water over red hot charcoal, or by distilling moist charcoal in an iron retort at a red heat, and washing the gas thus afforded in lime-water, by which the carbonic acid is separated.

100 cubic inches of this gas weigh only 17,325 grains, so that its specific gravity to hydrogen is 7,7.

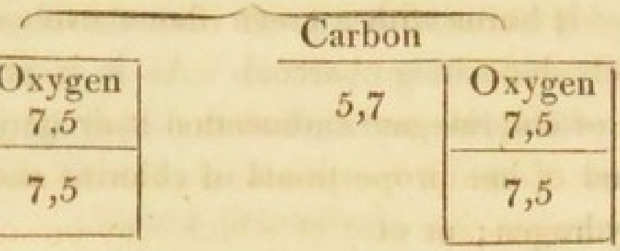
It burns with a pale blue flame. It requires for perfect combustion twice its volume of oxygen; water is generated, and one volume of carbonic acid results, so that it contains only half the quantity of carbon existing in the former compound, or it may be considered as composed of carbon 5,7 + 2 hydrogen.

The following symbols shew the proportions and arrangement of the elements, before and after detonation; the hydrogen here, as in the former case, being condensed to half its volume by union with the carbon.

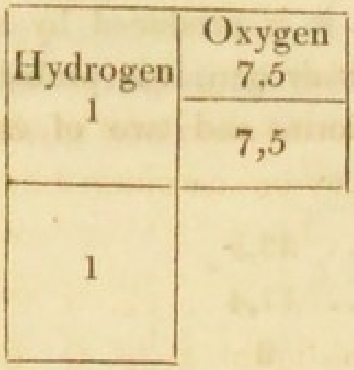
Before detonation.



After detonation.



5,7 Carbon, + 15 oxygen
= 20,7 Carb. acid.



2 hydrogen + 15 oxygen
= 17 water.

233. The varieties of carburetted hydrogen, which have just been described, are abundantly produced during the destructive distillation of common pit-coal; and the gas thus obtained is employed for the purposes of illumination as an economical substitute for tallow, oil, *&c.* This process is carried on upon a very extensive scale in London, in several public and many private establishments. The coal is placed in oblong cast iron cylinders, or *retorts,* which are ranged in furnaces, to keep them at a red heat, and all the volatile products are conveyed by a common tube into a *condensing vessel,* kept cold by immersion in water; and in which the water, tar, ammoniacal, and other condensible vapours, are retained; the gaseous pro-

ducts consist principally of a mixture of carburetted and bi-carburetted hydrogen, sulphuretted hydrogen, and carbonic oxide, and acid: these are passed through a mixture of quick-lime and water, in vessels called *purifiers*, by which the sulphuretted hydrogen and carbonic gases are absorbed, and the carburetted hydrogen gases, transmitted sufficiently pure for use into *gasometers*, whence the pipes issue for the supply of streets, houses, *&c.* The coke remaining in the retorts is of a very good quality*.

The best kind of coal for distillation is that which contains most bitumen and least sulphur. The chaldron should yield about 12,000 cubical feet of purified gas, of which each Argands burner, equal to six wax candles, may be considered as consuming from four to five cubical feet per hour.

The economy of gas illumination may be judged of by examining the value of the products of distillation of a chaldron of coals, the average cost of which may be considered as £3. It should afford—

1¼	chaldron of coke, at 30*s*..	1	17	6
24	gallons of tar and ammoniacal liquor, at 3*d*.	0	6	0
12,000	cubic feet of gas, at 15*s*. per 1,000 C. F...	9	0	0
		£11	3	6

These products are taken at their lowest value, but they afford ample grounds for showing the advantage of gas illumi-

* Mr. Parker, of Liverpool, (*Philos. Magaz.* Vol. LII. p. 292) has proposed to pass the gas as it comes from the coal retorts through red hot iron tubes, by which the contaminating gases and vapours are further decomposed, and the quantity of useful gas much increased. This is no doubt a valuable suggestion; it was attempted at Apothecaries' Hall when the gas apparatus was erected there, but abandoned in consequence of the difficulty of keeping the iron tubes in repair. If it succeeded, it would greatly diminish the quantity of tar, which is the only useless product.

nation; not merely for public purposes, but also in private establishments. It appears that where more than fifty lights are required, a coal gas apparatus will be found profitable.

234. Messrs J. and P. Taylor have lately constructed an apparatus for the conversion of oil into gas. It consists of a furnace with a contorted iron tube passing through it, into which, when red hot, the oil is suffered to drop: it is decomposed, and converted almost entirely into charcoal, which is deposited in the tube, and into bi-carburetted hydrogen, of which from two to three cubic feet may be regarded as equivalent to five or six of coal gas, for the production of light.

The commonest whale oil, or even pilchard dregs, quite unfit for burning in the usual way afford abundance of excellent gas, requiring no other purification than passing through a refrigerator, to free it of a quantity of empyreumatic vapour.

235. The fitness of the gas obtained from coal for the purposes of illumination, is, *ceteris paribus*, dependent upon the quantity of bi-carburetted hydrogen, or olefiant gas, which it contains; and as olefiant is heavier than carburetted hydrogen, so the fitness of the purified mixed gas for illumination will be directly as its specific gravity; or, the relative proportion of olefiant gas may be imperfectly judged of by mixing the purified coal gas with its volume of chlorine over water, by which the olefiant will be more quickly absorbed than the light hydrocarburet, and its quantity shewn by the amount of the absorption which takes place*.

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* It has been generally supposed, that chlorine furnishes a means of separating bi-carburetted from carburetted hydrogen; but in some experiments which I have seen made by Mr. Faraday, it appears that this is by no means the case, and that the action of chlorine upon carburetted hydrogen is analogous to its action upon bi-carburetted hydrogen, though not quite so rapid: the above mode of analysis therefore is imperfect, though a *rapid* absorption may be considered as indicating bi-carburetted hydrogen gas.

Experiments thus conducted, show that purified *coal gas* seldom contains more than 10 per cent. of bi-carburetted hydrogen, while *oil gas* is almost completely composed of it; hence its superiority for burning, and the relatively small quantity consumed.

An account of the apparatus for the production of coal gas, and of its construction and expense, will be found in Mr. Accum's *Treatise on Gas Lights*. Dr. Henry (*Philos. Trans.* 1808.) has given some important experiments upon the production of gas from coal, by which it appears that its composition is very various at different stages of the distillation. The following statement, deduced from experiments made in the Royal Institution, shews that the mode of distillation affects the quantity and quality of the products:—4lb. of coal were introduced into the *cold* retort, which was gradually raised to a red heat. 22 cubic feet of gas were obtained, consisting of

5	Olefiant gas.
70	Carburetted hydrogen.
18	Carbonic oxide and hydrogen.
6	Carbonic acid.
1	Sulphuretted hydrogen.
100	

The same quantity of coal, introduced into the *red hot* retort, gave 26 cubic feet of gas, composed of

8	Olefiant gas.
72	Carburetted hydrogen.
13	Carbonic oxide and hydrogen.
4	Carbonic acid.
3	Sulphuretted hydrogen.
100*	

236. The second variety of carburetted hydrogen, (232) or

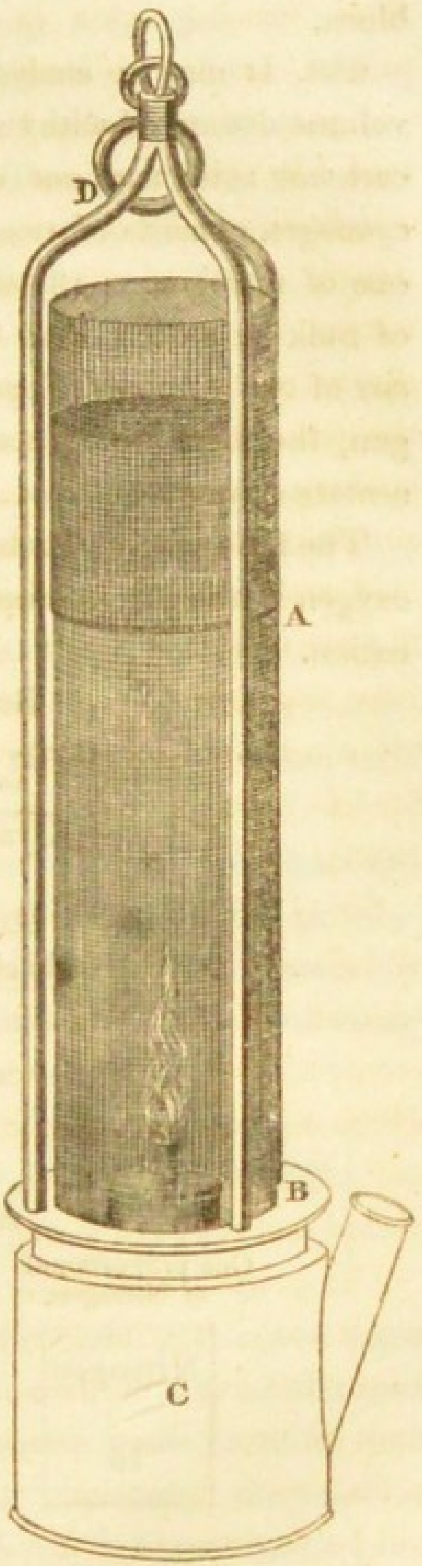
* *Journal of Science and the Arts,* Vol. I. p. 75.

light hydro-carburet, is contained abundantly in coal strata, from fissures in which it is sometimes evolved in large quantities, forming what in the language of the north country miners is called a *blower*. When this gas has accumulated in any part of the gallery or chamber of a mine, so as to be mixed in certain proportions with common air, the presence of a lighted candle, or lamp, causes it to explode, and to destroy, injure, or burn, whatever is exposed to its violence. The miners are either immediately killed by the explosion, and thrown with the horses and machinery through the shaft into the air, the mine becoming as it were an enormous piece of artillery from which they are projected; or they are gradually suffocated, and undergo a more painful death from the carbonic acid and nitrogen remaining in the mine after the explosion of the *fire damp;* or what, though it appears the mildest, is perhaps the most severe fate, they are burned or maimed, and often rendered incapable of labour and of healthy enjoyment for life. (Davy, *on the Safety Lamp for Coal Miners*, London, 1818).

Sir H. Davy, in the treatise just quoted, has given a sketch of different, but ineffectual contrivances of others, for the prevention of these dreadful, and hitherto frequently occurring, accidents; and has described the train of investigation by which he was led to the discovery of a remedy at once simple and efficient, and which has already been submitted to repeated and successful trials.

The properties of flame, and the principle of safety adopted in this lamp, have already been adverted to (121.) It is obvious from what has there been said, that if the flame of a common lamp be every where properly surrounded with wire gauze, and in that state immersed into an explosive gaseous mixture, it will be inadequate to its inflammation, and that part only will be burned which is *within* the cage, communication to the inflammable air *without* being prevented by the cooling power of the metallic tissue: so that by such a lamp the explosive mixture will be consumed, but cannot be exploded.

The annexed is a representation of the Safety Lamp, as recommended for general use by Sir H. Davy. A, is a cylinder of wire gauze, with a double top, securely and carefully fastened, by doubling over, to the brass rim B, which screws on to the lamp C. The whole is protected, and rendered convenient for carrying, by the frame and ring D. If the cylinder be of twilled wire gauze, the wire should be at least of the thickness of one-fortieth of an inch, and of iron or copper, and 30 in the warp, and 16 or 18 in the weft. If of plain wire gauze, the wire should not be less than one-sixtieth of an inch in thickness, and from 28 to 30 both warp and woof. (Davy *on the Safety Lamp*, p. 114, *et seq.*)



237. *Carbon and Nitrogen—Carburet of Nitrogen—Cyanogen.*— This gaseous compound was discovered in 1815 by Gay-Lussac. (*Annales de Chimie*, xcv.) It may be obtained by heating dry and pure *prussiate of mercury*. The gas evolved must be collected over

It has a penetrating and very peculiar smell; it burns with a purple flame. Its specific gravity to hydrogen is 24,4; 100

cubic inches weighing 54,9 grains. Water dissolves 4,5 volumes, and alcohol 23 volumes of this gas. It reddens vegetable blues.

238. It may be analysed by detonation with oxygen. One volume detonated with two of oxygen, produces two volumes of carbonic acid, and one of nitrogen. Whence it appears that cyanogen consists of two proportionals of carbon = 11,4, and one of nitrogen = 13, the nitrogen having suffered no change of bulk by uniting with the carbon; or it may be said to consist of two volumes of gaseous carbon + one volume of nitrogen, the three being condensed into one volume. Its representative number is 24,4.

The following symbols exhibit the mixture of cyanogen with oxygen in the above proportions, and the result of their detonation.

Before detonation.

One proportional of Cyanogen
and four of Oxygen.

Cyanogen	Oxygen 7,5
C. N. 11,4 + 13	7,5
	7,5
	7,5

After detonation.

One proportional
of Nitrogen.

Nitrogen
13

Two proportionals of
Carbonic acid.

5,7	Oxygen 7,5
	7,5
5,7	7,5
	7,5

239. *Cyanogen and Chlorine* combine and produce the *Chlorocyanic acid.* M. Gay Lussac procured this compound by passing a current of chlorine through a solution of hydrocyanic acid (240) in water till the liquid discoloured a solution of indigo in sulphuric acid. He then deprived it of excess of chlorine by agitation with mercury. To separate chlorocyanic acid from this liquid, he took a glass cylinder, filled it two-thirds with mercury, and then to the brim with the above liquid, and inverted it in a basin of mercury. This basin and cylinder were put under the receiver of an air-pump, and the air drawn out, till the mercury and liquid were displaced; the cylinder filled with the vapour of chlorocyanic acid; on admitting the air, the vapour condensed into a liquid, and the mercury rose in the cylinder. (Thomson, Vol. II. p. 276).

Chlorocyanic acid thus obtained is a colourless liquid, having a peculiar and irritating odour. It reddens litmus; is not inflammable; and does not form detonating mixtures either with oxygen or hydrogen.

It appears from the researches of Gay Lussac, that this acid consists of one proportional of cyanogen + one proportional of chlorine, or 24,4 + 33,5 = 57,9. The gases by combination suffer no change of volume; hence the following symbols represent its composition and volume.

Cyanogen	Chlorine
24,4	33,5

Chlorocyanic Acid
57,9

240. *Cyanogen combines with hydrogen*, and produces a triple compound, the *Hydrocyanic* or *Prussic acid.* It may be obtained by moistening prussiate of mercury with muriatic acid, and distilling at a low temperature, having surrounded the receiver with ice. A liquid is thus obtained which has a strong pungent odour, very like that of bitter almonds: its taste is acrid, and it is highly poisonous. It volatilizes so rapidly as to freeze

itself. It reddens litmus. The specific gravity of its vapour, compared with hydrogen, is 12,7, so that 100 cubic inches = 28,575 grains; detonated with oxygen it gives as results one volume of carbonic acid gas, half a volume of hydrogen, and half a volume of nitrogen; so that it consists of one volume of cyanogen + one volume of hydrogen, and its representative number is 25,4.

241. It appears from the experiments of Mr. Porrett, (*Philos. Trans.* 1814) and from those of M. Gay Lussac, (*Annales de Chimie*, XCV.) that cyanogen is capable of forming a compound with sulphuretted hydrogen. It may be obtained by mixing one volume of cyanogen with one and a half of sulphuretted hydrogen; they slowly combine and form a yellow crystallized compound.

According to Dr. Thomson, Mr. Porrett obtained an analogous body by a much more circuitous process; he has termed it sulphuretted chyazic acid; and Dr. Thomson, who regards it as consisting of cyanogen and sulphur only, calls it *Sulpho-cyanic acid*. (*System*, Vol. II. p. 290.)

Sulphocyanic acid is soluble in water: its smell resembles vinegar. Repeated distillation decomposes it. It appears from Gay Lussac's experiments to consist of two proportionals of cyanogen, three of sulphur, and three of hydrogen: Dr. Thomson considers it as containing two of cyanogen and three of sulphur; this would give as its ultimate constituent,

4	proportionals of carbon	22,8
2	of nitrogen	26,0
3	of sulphur	45,0
		93,8*

* The substance described by Mr. Porrett is evidently perfectly distinct from that of Gay-Lussac, which is not sour, and which appears to contain the above components.

242. *Carbon and Sulphur—Sulphuret of Carbon.*—This is a liquid obtained by passing sulphur over red hot charcoal. When pure, it is transparent and colourless. Its specific gravity is 1,272. It boils at 106°, and does not freeze at — 60°. It is very volatile, and has a pungent taste and peculiar fetid odour. It is inflammable, and, when burned with oxygen, produces sulphurous and carbonic acids. It consists of one proportional of charcoal and two of sulphur; $5,7 + 30 = 35,7$*. It was discovered by Lampadius, who called it *alcohol of sulphur*. (Crell's *Annals*, 1796, II.)

Section VI. *Boron.*

243. This substance is obtained by heating in a copper tube two parts of the metal called potassium with one of boracic acid, previously fused and powdered. In this experiment the boracic acid, which consists of boron and oxygen, is decomposed by the potassium. The fused matter is washed out of the tube with water, and the whole put upon a filter. The boron remains in the form of a brown insipid insoluble powder, unaltered by exposure to air at common temperatures, but when heated to 600° it burns with much brilliancy, especially in oxygen gas, and produces *boracic acid*.

244. Boracic acid is usually obtained by dissolving the salt called *borax* in hot water, and subsequently adding half its weight of sulphuric acid; as the solution cools, white scaly crystals appear, which are nearly tasteless, and which consist of boracic acid, combined with water, which it loses by exposure to a strong red heat, and fuses into a glass. It is

* Berzelius and Marcet. *Phil. Trans.* 1813.

very difficultly soluble in water; the solution reddens vegetable blues. Its solution in spirit of wine burns with a green flame. Its nature was first shewn by Davy in 1807.

245. The experiments upon the composition of boracic acid are much at variance. Berzelius's determination probably approaches nearest to truth: he regards it as containing 1 boron + 3 oxygen *. If, therefore, we consider it as consisting of one proportional of boron and two of oxygen, the number representing boron will be 5, and boracic acid will consist of

5 boron.
15 oxygen.
——
20 boracic acid.

246. Boron burns in chlorine, but the chloride has not been examined, nor have its other compounds been investigated.

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* Thomson's *System*, Vol. I. p. 249. 5th edit.

CHAPTER V.

Of the Metals, and their Combinations.

247. THE metals constitute a numerous and important class of simple substances; many of them were diligently examined by the older chemists, who have left us valuable information concerning them; many are of more recent discovery; and the existence of several others has been demonstrated within the last twenty years.

The metals are forty-two in number.

1	Gold	22	Columbium
2	Silver	23	Palladium
3	Copper	24	Rhodium
4	Iron	25	Iridium
5	Mercury	26	Osmium
6	Tin	27	Cerium
7	Lead	28	Potassium
8	Zinc	29	Sodium
9	Bismuth	30	Lithium
10	Antimony	31	Barium
11	Arsenic	32	Calcium
12	Cobalt	33	Strontium
13	Platinum	34	Magnesium
14	Nickel	35	Silicium
15	Manganese	36	Alumium
16	Tungsten	37	Yttrium
17	Tellurium	38	Glucium
18	Molybdenum	39	Zirconium
19	Uranium	40	Thorinum
20	Titanium	41	Selenium
21	Chromium	42	Cadmium

Of these metals the first seven were known in very remote ages. The ancients designated them by the names of the planets, to which they were supposed to have some mysterious relation; and each was denoted by a particular symbol, representing both the metal and the planet.

Gold was the Sun, and was thus represented..		☉
Silver	Moon	☽
Mercury....	Mercury	☿
Copper	Venus	♀
Iron	Mars	♂
Tin	Jupiter	♃
Lead	Saturn.......................	♄

Zinc was not known to the ancients, though they were probably acquainted with its ores, and with their property of forming brass when fused with copper. (Pliny, Lib. XXXIV. cap. 2 and 10.) The word *Zinc* first occurs in the writings of Paracelsus, who died in 1541. Bismuth is mentioned in the *Bermannus* of Agricola, written about 1530. Antimony was first obtained in its pure state by Basil Valentine towards the end of the 15th century. The process is described in his *Currus Triumphalis Antimonii*. Arsenic and Cobalt were discovered by Brandt in 1733; *(Acta. Upsal.* 1733 and 1742) their ores were known at a much earlier period. Platinum was first recognised as a peculiar body in 1741, by Mr. Charles Wood, Assay Master in Jamaica; (*Philos. Trans.* Vol. XLIV.) In 1751, the distinctive characters of Nickel were shewn by Cronstedt, *(Stockholm Transactions)* and Manganese was obtained by Gahn in 1774. (Bergman's *Opuscula*, Vol. II.) Tungsten was discovered by M. M. Delhuyart in 1781. *(Mémoires Toulouse).* Tellurium and Molybdenum by Muller and Hielm, in 1782. Uranium by Klaproth in 1789. Titanium by Mr. Gregor, in 1789. Chromium by Vauquelin, in 1797. (*Annales de Chimie,* Vol. XXV.) In 1802, Mr. Hatchett discovered Columbium. *(Phil. Trans.)* Palladium and Rhodium were discovered by Dr. Wollaston; and Iridium and Osmium by Mr. Tennant, all in 1803. *(Philos. Trans.)* Cerium was announced in 1804 by M. M. Hisinger and Berzelius (Gehlen's *Journal,* II.) Potassium and Sodium were discovered in 1807 by Sir H. Davy, whose experiments also led to the discovery of the metallic nature of the ten following bodies. Thorinum and Selenium were announced by Berzelius in 1815 and in 1817; and Mr. Stromeyer, of Gottingen, discovered Cadmium in 1818.

248. The metals, as a class, are characterized by a peculiar lustre and perfect opacity: they are excellent conductors of heat, (45) and of electricity (62).

249. There is the greatest difference in the specific gravity of the different metals, the heaviest and lightest solids being included in the list.

The principal metals, arranged according to their specific gravities, stand as follow:—

1	Platinum	21,00
2	Gold	19,30
3	Tungsten	17,50
4	Mercury	13,50
5	Palladium	11,50
6	Lead	11,35
7	Silver	10,50
8	Bismuth	9,80
9	Uranium	9,00
10	Copper	8,90
11	Arsenic	8,35
12	Nickel	8,25
13	Cobalt	8,00
14	Iron	7,78
15	Molybdenum	7,40
16	Tin	7,30

17	Zinc	7,00
18	Manganese	6,85
19	Antimony	6,70
20	Tellurium	6,10
21	Sodium	0,972
22	Potassium	0,865

250. The specific gravity of solids and liquids is always expressed in numbers referring to water as = 1.

To ascertain the specific gravity of solids we employ a delicate balance, so contrived as to admit of substances being attached to one of the scales by means of a horse-hair or a fine thread of silk. The absolute weight of the body thus suspended is then very carefully ascertained: it is next immersed in distilled water, of the temperature of 60°.; and the beam being again brought to an equilibrium, we learn the weight lost by its immersion; or, in other words, we ascertain the weight of its bulk of pure water. We now divide the sum of its absolute weight by that of the weight which it lost in water, and the quotient is its *specific weight*, or gravity, compared with water of the temperature of 60°.

Suppose a substance, weighing 360 grains, to lose 60 by immersion in water, the specific gravity of that substance will be = 6; for $360 \div 60 = 6$.

251. For ascertaining the specific gravity of liquids, we generally employ a thin phial, holding 1,000 grains of distilled water, at the temperature of 60°. If filled with any other liquid, and weighed, we learn its specific gravity; thus we should find that it would contain 13,500 grains of mercury; 1,850 grains of sulphuric acid; 1,420 grains of nitric acid, *&c.*, which numbers of course represent the specific gravities of those liquids.

252. Among the metals, some are *malleable*, others *brittle*.

Malleability, or the capacity of being extended by the hammer, belongs to the following metals, in the order following:—

Gold
Silver
Copper
Tin
Cadmium
Platinum
Lead
Zinc
Iron
Nickel
Palladium

Potassium, sodium, and frozen mercury, are also malleable.

253. The malleable metals are also *ductile*; that is, they admit of being drawn out into wires. They are arranged according to ductility as follows:—

Gold
Silver
Platinum
Iron
Copper
Zinc
Tin
Lead
Nickel
Palladium

254. Different metallic wires are possessed of different degrees of *tenacity*, by which is meant the power of supporting a weight without breaking. According to the experiments of Guyton Morveau, the following are the weights capable of being sustained by wires $\frac{787}{1000}$ ths of a line in diameter. (*Annales de Chimie*, LXXI.)

	lbs. avoird. decimal parts.
A wire of Iron supports	549,250
Copper	302,278
Platina	274,320
Silver	187,137
Gold	150,753
Zinc	109,540
Tin	34,630
Lead	27,621

255. The following metals are brittle.

Antimony
Arsenic
Bismuth
Cerium
Chrome
Cobalt
Columbium
Manganese
Molybdenum
Tellurium
Tungsten
Titanium
Uranium

256. None of the metals are very *hard*, and many so soft as to yield to the nail. In the following table some of the metals are arranged in the order of their hardness.

Tungsten
Palladium
Manganese
Iron
Nickel
Platinum
Copper
Silver

Bismuth
Gold
Zinc
Antimony
Cobalt
Tin
Arsenic
Lead

Elasticity and sonorousness belong to the hardest metals only.

Such are the essential physical characters of the metals; they also resemble each other in many of their chemical properties, as the following general observations shew.

257. *Action of Heat.*—The metals are all susceptible of fusion by heat, but the temperatures at which they liquefy are extremely various. Mercury is fluid at all common temperatures, and requires to be cooled to — 39° before it congeals. Potassium melts at 150°, and sodium at 200°; arsenic at 360°; tin at 450°; lead at 600°; zinc at 700°; and antimony at 800°. Silver, gold, and copper require a bright cherry-red heat; iron, nickel, and cobalt, a white heat; manganese and palladium, an intense white heat; molybdenum, uranium, tungsten, and chrome, are only very imperfectly agglutinated at the highest temperatures of our furnaces; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat produced by an inflamed current of oxygen and hydrogen, or that of Voltaic electricity (81.)

At higher temperatures than that required for their fusion many of the metals are volatile, and may be distilled in close vessels. Mercury, arsenic, potassium, tellurium, and zinc, are volatile at a dull red heat. Gold and silver are converted into vapour when exposed to the intense heat of the focus of a burning lens, and several of the other metals boil and evaporate under similar circumstances. It is probable that this would happen to all of them, if raised to sufficiently high temperatures.

258. *Action of Oxygen.*—When the metals are exposed at ordinary temperatures to the action of oxygen, or of common air, which produces analogous, though less powerful effects, they are very differently affected. If the gas be perfectly dry, very few of them suffer any change, unless heated in it; they then lose their metallic characters, and form a very important series of compounds, the *metallic oxides*.

A few of the metals resist the action of heat and air so completely, that they may be kept in fusion in an open crucible for many hours without undergoing change. This is the case with gold and silver, and a few others; hence they were called *perfect* or *noble* metals: they may, however, be oxidized by the Voltaic flame, or by passing a strong electric shock through them, when drawn into very fine wire.

Other metals readily absorb oxygen when exposed to a temperature approaching a red heat; as iron, mercury, nickel, *&c.*; others absorb it when in fusion, as lead, tin, antimony, *&c.*; others at lower, or even at common temperatures; as arsenic, manganese, sodium, potassium, *&c.*

That the metals have very different attractive powers in regard to oxygen is also shewn by the circumstance of one metal being frequently oxidized at the expense of another; thus the oxide of mercury, heated with metallic iron, produces metallic mercury and oxide of iron; potassium heated with oxide of manganese, becomes oxidized, and metallic manganese is obtained.

Some of the oxides are decomposed by mere exposure to heat, as those of gold, mercury, *&c.*; others require the joint action of heat, and some body having a high attraction for oxygen, such as charcoal. Thus when oxide of lead is heated with charcoal, carbonic acid gas is evolved, and metallic lead obtained.

Each metal has a certain definite quantity of oxygen with which it combines, and where the same metal unites in more than one proportion with oxygen; in the second, third, and other compounds, it is a multiple of that in the first, consistent with the laws of definite proportions. (30.) Thus 100 parts of mercury combine with 4 of oxygen to produce the *protoxide*, and with 8 to produce the *peroxide*. Copper also forms two oxides; in the one 12,5 of oxygen are united to 100 of metal, and in the other 25.

Among the combinations of metals with oxygen, some are insoluble in water, or nearly so, and have neither taste nor smell; others are soluble and sour, constituting the *metallic acids*; others are soluble and alcaline, forming the *fixed alcalis* and *alcaline earths*. They are of all colours, and frequently the same metal united to different proportions of oxygen produces compounds differing in colour: thus we have the *black* and *red* oxide of mercury, the *white* and the *black* oxide of manganese, *&c.*

259. *Action of Chlorine.*—All the metals appear susceptible of combining with chlorine, and of producing a class of compounds which may be termed *metallic chlorides*.

There are few of the metals which resist the action of chlorine at common temperatures, and when heated they all combine with it; some slowly, others rapidly and with intense ignition. Copper leaf, powdered antimony, arsenic, *&c.*, burn when thrown into the gas: mercury and iron inflame when gently heated in it; silver, gold, and platinum quietly absorb it.

The attraction of chlorine for metals is greater than that of oxygen; consequently, when a metallic oxide is heated in chlorine, oxygen is evolved and a chloride formed. The insoluble chlorides are also formed by adding solution of chlorine or the soluble chlorides, or of muriatic acid, to the soluble metallic salts.

The physical and chemical properties of the chlorides are extremely various. Some are soluble, others insoluble, in water. Several of them decompose water, giving rise to the formation of muriatic acid, and an oxide; or in some cases to a muriate. The same metal often forms more than one compound with chlorine, and where its proportion in the second is twice that in the first, we usually term them *chlorides*, and *bichlorides*. Thus calomel is a chloride of mercury, and corrosive sublimate, a bichloride, or perchloride of mercury.

Many of the metals decompose muriatic acid, in which case hydrogen is evolved and a metallic chloride produced; and when metallic oxides are heated in muriatic acid, they generally give rise to the formation of a chloride and water.

260. *Action of Iodine.*—Iodine aided by heat, acts upon many of the metals, and produces *metallic iodides*. Some of these are soluble in water without decomposition; others decompose water and produce *hydriodates*; others are insoluble. The insoluble iodides may generally be formed by adding a solution of iodine or of hydriodic acid to the soluble metallic salts.

261. *Action of Hydrogen.*—Hydrogen forms permanent compounds with two of the metals only, namely, arsenic and tellurium. It appears to combine with each in two proportions, forming two solid compounds, the hydrurets of arsenic and tellurium; and two gaseous compounds—arseniuretted and telluretted hydrogen. At high temperatures it dissolves potassium forming potassiuretted hydrogen gas.

There are many of the metallic oxides, and a few of the chlorides, which are decomposed by hydrogen: the oxides are reduced with the formation of water, and the chlorides with the production of muriatic acid.

262. *Action of Water.*—Those metals which are speedily acted upon by common air and oxygen, are also generally susceptible of decomposing water; some of them rapidly, others slowly. There are some metals which are not acted upon by

air deprived of moisture, nor by water deprived of air; but moist air, or water containing air, effect their oxidizement, this appears to be the case with iron. Water combines with some of the metallic oxides, and produces hydrated oxides, or *metallic hydrates*. In these the relative proportion of water is definite. Some are easily decomposed by heat; others retain water even when heated to redness.

263. *Action of Nitric Acid.*—As no metal is soluble in an acid except in the state of oxide, and as the greater number of metals are capable of decomposing nitric acid, and of resolving it into some of the other nitric compounds, nitric acid is a very generally acting solvent of these bodies. It dissolves all the metallic oxides and produces a numerous class of *nitrates*, which if prepared with heat and with excess of acid, generally contain the metal at its maximum of oxydizement. The nitrates are all decomposed by a red heat; they give off oxygen and nitrogen, either separate, or combined, and the metallic oxide remains. They are also decomposed when heated with sulphur, phosphorus, or charcoal, and sulphurous, phosphoric, and carbonic acids are formed; the phosphoric, being a fixed acid, remains united to the metallic oxide, while the sulphurous and carbonic acids are usually expelled. The nitrates are decomposed by sulphuric acid, nitric acid is evolved, and *sulphates* are formed.

264. *Action of Ammonia.*—At high temperatures a few of the metals are capable of decomposing Ammonia. Liquid ammonia dissolves several of the metallic oxides, and with some of them forms crystallizable compounds. The compounds of ammonia with the oxides of gold, silver, and platinum, detonate when heated, and the oxide and the ammonia are both decomposed.

265. *Action of Sulphur.* All the metals appear capable of forming *sulphurets*. These are in some cases formed by heating the metal with sulphur; in others by decomposing the

sulphates; and in others by the action of sulphuretted hydrogen. The sulphurets are in general brittle and without lustre. Some are soluble, others insoluble in water. Where the same metal forms two sulphurets, the sulphur, in those containing the largest proportion, is an exact simple multiple of the sulphur in those containing the smallest proportion. When the metallic sulphurets are heated some undergo no change, as those of sodium and potassium; others sublime unaltered, as sulphuret of mercury; others lose a portion of their sulphur, and, if air be admitted, sulphurous acid escapes, and the metal passes into the state of oxide, as sulphuret of lead; others again are entirely decomposed, the metal being completely reduced; this happens on heating sulphuret of platinum or of gold. It is doubtful whether any definite compounds of sulphur with the metallic oxides exist.

266. *Sulphurous Acid* combines with a few of the metallic oxides producing *sulphites;* but in the greater number of instances oxygen is transferred to the acid, and sulphates result.

The *sulphites* are soluble in water, and have a sulphurous taste and smell. Exposed to moist air, they absorb oxygen and pass into the state of sulphates. They are decomposed by sulphuric acid, which expels sulphurous acid, and the salts are converted into sulphates. When perfectly pure they are not affected by solution of baryta.

267. *Sulphuric Acid,* in its concentrated state, is acted upon by a few of the metals only; but when diluted, many of them are oxidized at the expense of the water, hydrogen is evolved, and the metallic oxide combines with the acid producing a *sulphate.* In these cases the hydrogen evolved is the indicator of the quantity of oxygen transferred to the metal; every volume of hydrogen is the equivalent of half a volume of oxygen, and accordingly the production of 100 cubic inches of hydrogen, indicates the transfer of 50 of oxygen, or by weight of about 17 grains. As different metals unite to different weights of

oxygen, they will obviously evolve different quantities of hydrogen. Thus, if one metal to become soluble in sulphuric acid, require to be united with 15, and another with 30 per cent. of oxygen, the latter will evolve twice the volume of hydrogen, compared with the former.

As the evolution of hydrogen, during the solution of a metal in dilute sulphuric acid, is referable to its oxydizement, no hydrogen will be evolved during the action of the acid upon an oxide, but it will be merely dissolved.

The sulphates are an important class of salts. The greater number of them are soluble in water, and the solutions are rendered turbid by the solutions of baryta. They are all decomposed at a red heat by charcoal, and most of them are thus converted into sulphurets; carbonic acid, and carbonic oxide, being at the same time evolved.

268. *Action of Sulphuretted Hydrogen.*—It seems doubtful whether any of the metals combine with sulphuretted hydrogen. It unites with several of their oxides, and forms *hydrosulphuretted oxides*. Many of these compounds are insoluble, and may be formed by adding a solution of sulphuretted hydrogen, or of hydrosulphuret of ammonia, (194) to solutions of the respective metallic salts. Sometimes, however, a decomposition is effected in these cases, both of the sulphuretted hydrogen and of the oxide, and a metallic sulphuret is formed, the hydrogen combining with the oxygen of the oxide to form water, and the sulphur uniting to the metal. In a few cases the metallic oxide is reduced. The following table shews the effect of hydrosulphuret of ammonia upon neutral solutions of several of the metals as far as colour of the precipitate is concerned.

Gold...... a black powder gradually becoming metallic.
Silver .... deep brown gradually becoming black.
Platinum .. black.
Palladium.. dark brown.

Rhodium ......no precipitate.
Mercury ......brownish black.
Lead..........brown
Nickel ....black
Arsenic........white or yellow.
Antimony...... orange.
Uranium ......black.
Cobalt ....ditto.
Titanium ......green.
Bismuth ......brown.
Copper ....grayish brown.
Tin ....deep orange.
Zinc ....yellowish white.
Manganese ....white.
Cadmium ......bright yellow.

269. *Action of Phosphorus.*—Phosphorus combines with the greater number of the metals, forming a series of *metallic phosphurets.* There are two methods of forming them; either by heating a mixture of phosphorus and the metal, or projecting phosphorus upon the metal previously heated to redness; or by heating a mixture of the metal or its oxide, with phosphoric acid and charcoal. These phosphurets have a metallic lustre; if they contain a difficultly fusible metal, they are more fusible than the metal they contain; if an easily fusible metal, less so. They are mostly crystallizable, and totally or partially decomposable at a high temperature. The greater number of the phosphurets have only been examined by Pelletier. *(Annales de Chimie,* Tom. I. et XIII. and *Mémoires et Observations de Chimie.)*

270. The *metallic phosphates* may be formed either by dissolving the oxides in phosphoric acid, or by adding a solution of phosphoric acid, or of an alcaline phosphate, to solutions of those metals which form insoluble or difficultly soluble phosphates. The greater number of the phosphates are decomposed

by ignition with charcoal; and those containing volatile oxides are volatilized at high temperatures.

271. When phosphorus is introduced into the solutions of those metals which have but a feeble attraction for oxygen, it reduces them to the metallic state. Thus gold, silver, and platinum are thrown down by immersing a stick of phosphorus into their respective solutions.

272. *Action of Carbon.*—Carbon unites to very few of the metals, and of the metallic carburets, one only is of importance, namely, carburet of iron, or *steel*.

273. *Carbonic acid* unites with the greater number of the metallic oxides and forms *Carbonates*, of which the distinctive characters have already been noticed (226); many of them are of difficult solubility, and may be formed by adding an alcaline carbonate to the metallic solution.

274. *The action of Boron* upon the metals has not been investigated, though it appears from the experiments of Descotils, (*Recherches Physico-chymiques de* M. M. Gay-Lussac et Thenard) to be capable of uniting to platinum and iron. These compounds may be called *borurets*. The metallic *borates* are numerous, but mostly unimportant.

275. *Action of the metals upon each other.*—The metals may for the most part be combined with each other, forming a very important class of compounds, the *metallic alloys*. Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the two metals in a covered crucible; but if there be a considerable difference in the specific gravity of the metals, the heavier will often subside, and the lower part of the bar or ingot, will differ in composition from the upper; this may be prevented by agitating the alloy till it solidifies. Mr. Hatchett found that when an alloy of gold and copper was cast into bars, the moulds being placed perpendicularly, the upper part of the bar contained more copper than the lower.

Where one of the metals is very volatile, it should generally be added to the other after its fusion; and if both metals be volatile, they may be sometimes united by distilling them together.

It has been a question whether alloys are to be considered as compounds or as mere mixtures; but their properties leave little doubt of their being real compounds, and in some cases they are found to unite in definite proportions only; and it is probable that all the alloys contain a definite compound of the two metals.

276. The principal characters of the alloys are the following:—

1. We observe a change in the ductility, malleability, hardness, and colour. Malleability and ductility are usually impaired, and often in a remarkable degree: thus gold and lead, and gold and tin, form a brittle alloy. The alloy of copper and gold is harder than either of its component parts; and a minute quantity of arsenic added to copper, renders it white.

2. The specific gravity of an alloy is rarely the mean of its component parts, in some cases an increase, in others a diminution of density having taken place, as shewn by the following Table from Thenard. (*Traité de Chimie*, Vol. I. p. 394.)

Alloys possessed of greater specific gravity than the mean of their components.	Alloys having a specific gravity inferior to the mean of their components.
Gold and Zinc	Gold and Silver
Tin	Iron
Bismuth	Lead
Antimony	Copper
Cobalt	Iridium
Silver and Zinc	Nickel
Lead	Silver and Copper

Alloys possessed of greater specific gravity than the mean of their components.	Alloys having a specific gravity inferior to the mean of their components.
Silver and Tin	Copper and Lead
Bismuth	Iron and Bismuth
Antimony	Antimony
Copper and Zinc	Lead
Tin	Tin and Lead
Palladium	Palladium
Bismuth	Antimony
Antimony	Nickel and Arsenic
Lead and Bismuth	Zinc and Antimony
Antimony	
Platinum and Molybdenum	
Palladium and Bismuth	

3. The fusibility of an alloy is generally greater than that of its components. Thus platinum, which is infusible in our common furnaces, forms, when combined with arsenic, a very fusible alloy; and an alloy of certain proportions of lead, tin, and bismuth is fusible at 212°, a temperature several degrees below the melting point of its most fusible constituent.

4. Alloys are generally more oxidable than their constituents taken singly; a property which is, perhaps, partly referable to the formation of an electrical combination. Where an alloy consists of two metals, the one easily and the other difficultly oxidable, it may be decomposed by exposing it to the action of heat and air, the former metal being converted into an oxide; its last portions, however, are often not easily separated, being protected by combination with the least oxidable metal. An alloy of three parts of lead and one of tin is infinitely more oxidable than either of its components, and easily burns at a dull red heat.

5. The action of acids on alloys may generally be anticipated

by a knowledge of their effects upon their constituent metals; but if a soluble metal be alloyed with an insoluble one, the former is often protected by the latter from the action of an acid. Thus, silver alloyed with a large quantity of gold, resists the action of nitric acid in consequence of the insolubility of the latter metal in that acid; and, in order to render it soluble, it is requisite that it should be made to form about a fourth part of the alloy, in which case the nitric acid extracts it, and leaves the gold in an insoluble film or powder.

277. Various classifications of the metals have been adopted by chemical authors; some dependent upon their physical, others upon their chemical properties. The former can scarcely be considered as adapted to chemical inquiry, and the latter involve numerous difficulties in consequence of the gradual transition of metals of one class into those of another. I shall consider the metals in the order in which they are set down in the following Table, and which is nearly that of their respective attractions for oxygen.

1 Potassium	16 Bismuth
2 Sodium	17 Cobalt
3 Lithium	18 Uranium
4 Calcium	19 Titanium
5 Barium	20 Cerium
6 Strontium	21 Tellurium
7 Magnesium	22 Selenium
8 Manganese	23 Arsenic
9 Iron	24 Molybdenum
10 Zinc	25 Chromium
11 Tin	26 Tungsten
12 Cadmium	27 Columbium
13 Copper	28 Nickel
14 Lead	29 Mercury
15 Antimony	30 Osmium

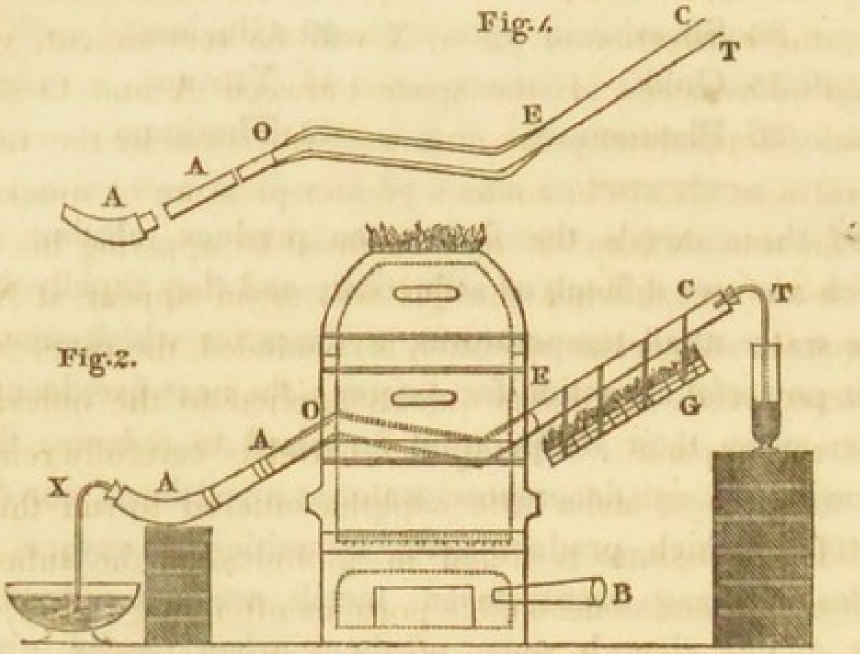
31 Iridium	37 Silicium
32 Rhodium	38 Alumium
33 Palladium	39 Zirconium
34 Silver	40 Glucium
35 Gold	41 Yttrium
36 Platinum	42 Thorinum.

Of these metals the first seven produce alcaline oxides which are very difficult of reduction; and they rapidly decompose water at all temperatures, a character which announces their powerful attraction for oxygen; the next five decompose water when their temperature is raised to redness: the ten following do not decompose water at a red heat; nor do the next five, which produce acids by uniting to oxygen. The oxides of these twenty-seven metals are not reducible by heat alone, though some of them, when heated, give out a portion of oxygen. The nine metals which next follow, osmium excepted, have a comparatively feeble attraction for oxygen; and when their oxides are heated, they are reduced to the metallic state. The last six metals are placed in the list from analogy; they are only known in the state of oxides, which have not hitherto been reduced.

SECTION 1. *Potassium.*

278. THIS metal was discovered in 1807 by Sir Humphry. Davy. (*Philos. Trans.* 1808). He obtained it by submitting caustic, potassa, or potash, to the action of Voltaic electricity: the metal was slowly evolved at the negative pole. By this process, however, it could only be procured in very minute quantities; and various other methods have been devised, of which the best is that described by Gay Lussac and Thenard. (*Recherches Physico-chymiques.*) It is as follows:—

279. A sound and perfectly clean gun-barrel is bent, as shewn in the annexed sketch. It is then covered with an in-



infusible lute between the letters O and E (fig. 1), and the interior of the luted part is filled with clean iron turnings. Pieces of fused potash are then loosely placed in the barrel between E and C. A A is a copper tube and small receiver, which are adapted to the extremity O, and to each other, by grinding. This apparatus is next transferred to the furnace, arranged as shewn in fig. 2. X and T representing two glass tubes dipping into mercury. The furnace is supplied with air by a good double bellows entering at B, and a small wire basket G, is suspended below the space E C. The part of the barrel in the furnace is now cautiously raised to a white heat, and the escape of air by the tube X shews that all is tight. Some burning charcoal is then put at the end E, of the cage G, which causes a portion of potash to liquefy and fall into the low part of the barrel upon the iron. Hydrogen gas instantly escapes by the tube X, and attention must now be had to keep the copper tubes AA, cool, by laying wet cloths upon them. When the evolution of gas ceases, fresh charcoal is placed under the potash, and so on till the whole has passed down; if too much potash be suffered to fall at once, the extrication of gas at X will be very violent, which should be avoided. If the space between A and O should become stopped by potassium, gas will issue by the tube T (which must always be under a greater pressure of quicksilver than the tube X), and it may be fused by applying hot charcoal to the tube, when the gas will again appear at X and cease at T. When the operation is concluded, the tubes X and T are removed, and corks quickly applied to the holes; and when the apparatus is cool, the barrel is carefully removed from the furnace, and a little naphtha suffered to run through it. The potassium is found in globules in the tube and receiver AA, and considerable portions often lodge at O. The success of this operation is certain, if the heat has been sufficient; but the barrel, if not very carefully covered with lute, is apt to melt, and much, if not the whole, of the product is lost.

280. Potassium is a white metal of great lustre. It instantly tarnishes by exposure to air. It is ductile, and of the consistency of soft wax. Its specific gravity is 0,85. At 150° it enters into perfect fusion; and at a bright red heat rises in vapour. At 32° it is a hard and brittle solid. If heated in air it burns with a brilliant white flame. It is an excellent conductor of electricity and of heat.

281. *Potassium and Oxygen.*—When potassium is thrown into water it instantly takes fire; hydrogen gas is evolved, and *oxide of potassium*, or *potassa*, is found dissolved in the water. The quantity of hydrogen evolved in this experiment becomes the indicator of the proportion of oxygen which has been transferred to the metal; 100 parts of potassium are thus found to absorb 20 of oxygen; and if this be considered a protoxide, then 20 : 100 : : 7,5 : 37,5,—so that 37,5 will be the number

representing potassium, and 37,5 P. + 7,5 O. = 45 will represent dry oxide of potassium.

282. Potassa, in the state it is usually met with in laboratories, contains a considerable portion of water, from which it may be freed by the action of iron at high temperatures, and there always remains in the barrel, after the above experiment, a large portion of *dry potassa*. It is a hard grey substance, which, by water, is slowly converted into the *hydrated oxide*, or caustic potash, which may be obtained by evaporation. This substance, after exposure to a red heat, is white and very soluble in water; it may be considered as a compound of 1 proportional of protoxide of potassium = 45 + 1 proportional of water = 8,5, and its number = 53,5.

283. *Peroxide of Potassium.*—If the metal be heated in considerable excess of oxygen, it burns with intense heat and light, and an orange-coloured substance is obtained, which consists of 37,5 potassium + 22,5 oxygen = 60. This peroxide of potassium, when put into water, effervesces, oxygen is given off, and a solution of the hydrated protoxide is obtained.

284. The *hydrated protoxide* or *caustic potash*, is procured in our laboratories by decomposing its subcarbonate by lime. The best process consists in boiling in a clean iron vessel, subcarbonate of potassa, (obtained by calcining tartar) with its weight of pure quick lime, in water. The ley is strained through clean linen, concentrated by evaporation, again strained, and set by in a well-stopped bottle till it admits of being decanted clear from the sediment. The clear solution is to be evaporated to dryness. It is often cast into sticks for the use of surgeons, who employ it as a caustic, and in this state it generally contains some peroxide, and therefore evolves oxygen when dissolved in water. It is the *potassa fusa* of the *London Pharmacopœia*. It may be further purified by the action of alcohol, which dissolves the pure hydrate, and leaves earthy and other impurities,—the alcohol is then driven off by heat.

Hydrate of Potassa thus purified is white, very acrid and corrosive, and at a red heat evaporates in the form of white acrid smoke. It quickly absorbs moisture from the air, and at 60° one part of water dissolves two. It may be crystallized in octoëdrons. It is highly alcaline, and being exclusively procured from vegetables was formerly called *vegetable alcali*.

285. *Chlorine and Potassium* act very energetically on each other, and produce the white compound which has been called *muriate of potash*, but which is a true *chloride of potassium*, consisting of 37,5 P. + 33,5 Ch. When potassium is heated in gaseous muriatic acid, this compound is formed, and hydrogen is evolved. It dissolves without decomposition in three parts of water at 60_0. It crystallizes in cubes; its taste is saline and bitter. In old pharmacy it was called *febrifuge* and *digestive salt of Sylvius*; also, *regenerated sea-salt*.

286. *Chlorate of Potassa* is formed by passing chlorine through a solution of potassa. Chloride of potassium is one of the results, the other is a salt in brilliant rhomboidal tables (formerly called Oxymuriate of Potash), the chlorate. Its taste is cooling and austere. When triturated it appears phosphorescent. When exposed to heat it gives out oxygen, and chloride of potassium remains. It is soluble in 18 parts of cold and 2,5 of boiling water. It acts very energetically upon many inflammables, and triturated with sulphur, phosphorus, and charcoal, produces inflammation and explosion. A mixture of three parts of this chlorate with one of sulphur, detonates loudly when struck upon an anvil with a hammer, and even sometimes explodes spontaneously; hence it should not be kept ready mixed. Chlorate of potassa was proposed by Berthollet as a substitute for nitre in gunpowder. The attempt was made at Essone in 1788; but, as might have been expected, no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration, than it exploded with violence,

and proved fatal to several people. With phosphorus the detonation is dangerously violent. These phenomena depend upon the decomposition of the chloric acid. When sulphuric acid is poured upon mixtures of this salt and combustibles, instant ignition ensues in consequence of the evolution of euchlorine, and when sulphuric or nitric acids are poured upon similar mixtures under water by means of a long funnel, inflammation also ensues.

Chlorate of Potassa consists of one proportional of chloric acid and one of potassa, or 71 C. A. + 45 P. Its ultimate components therefore are

6 proportionals of oxygen ...... 5 in the acid and 1 in the alcali..	= 45
1 proportional of chlorine	= 33,5
1 ———— of potassium	= 37,5
	116

287. *Oxychlorate of Potassa* may be formed by moistening one part of chlorate of potassa with three of sulphuric acid, and subsequently heating the mass till it becomes white: in this state it consists of bi-sulphate and oxychlorate of potassa, which may be separated by solution and crystallization, the former being much more soluble in cold water than the latter salt.

Oxychlorate of potassa does not change vegetable colours, nor is it altered by exposure to air. It requires rather more than 50 parts of water at 60° for its solution. It is insoluble in alcohol. It crystallizes in elongated octoëdrons. When mixed with its own weight of sulphuric acid, and distilled at 280°, solution of oxychloric acid passes over. It may be decomposed by exposure to a temperature of 412°. Oxygen is given off, and chloride of potassium remains in the retort. This salt is thus found to consist of one proportional of oxychloric acid = 86 + one proportional potassa = 45, and its representative number is therefore = 131.

288. *Iodide of Potassium.*—Iodine and potassium act upon each other very energetically, and a crystalline compound is obtained, white, and fusible. The hydriodic acid and potassa produce a similar compound.

289. When iodine is put into solution of potassa, the results are iodate of potassa and iodide of potassium.

290. *Potassium and Hydrogen.*—When potassium is heated in hydrogen, it absorbs a portion of the gas, and produces a grey and highly inflammable hydruret. When hydrogen and potassium are passed together through a white hot tube, the gas dissolves the metal, and produces a spontaneously inflammable *potassiuretted hydrogen gas.* Both these compounds are usually formed, during the operation for obtaining potassium by the gun-barrel.

291. *Nitrate of Potassa—Nitre—Saltpetre.*—This salt is an abundant natural product, and is principally brought to this country from the East Indies, where it is procured by lixiviation from certain soils. In Germany and France it is artificially produced in what are termed nitre beds*. It crystallizes in six-sided prisms, usually terminated by dihedral summits; it dissolves in 7 parts of water at 60°, and in its own weight at 212°. Its taste is cooling and peculiar. It consists of one proportional of acid = 50,5 + one proportional of potassa = 45. Or of

6 proportionals of oxygen ...... 5 in the acid and 1 in the alcali ..	45
1 proportional of nitrogen	13
1 ——— of potassium	37,5
	95,5

* Thenard (*Traité de Chimie Elémentaire*, Tom. II. p. 511.) has described the French process at length. It consists in lixiviating old plaster rubbish, which, when rich in nitre, affords about five per cent. Refuse animal and vegetable matter which has putrefied in contact with calcareous soils produces nitrate of lime, which affords nitre by mixture with subcarbonate of potassa.

292. When exposed to a white heat, it is decomposed into oxygen, nitrogen, and potassa. It fuses at a heat below redness, and congeals on cooling, into cakes called *sal prunelle*. It is rapidly decomposed by charcoal at a red heat; and, if excess of charcoal be used, the results are carbonic oxide, and acid, and nitrogen, and subcarbonate of potassa, formerly called *nitrum fixum*. When phosphorus is thrown upon nitre, and inflamed, a vivid combustion ensues, and a phosphate of potassa is formed.

293. A mixture of three parts of nitre, two of dry subcarbonate of potassa, and one of sulphur, forms *fulminating powder*. If a little of this compound be heated upon a metallic plate, it blackens, fuses, and explodes with much violence, in consequence of the rapid action of the sulphur upon the nitre.

294. Gunpowder consists of a very intimate mixture of nitre, sulphur, and charcoal. The proportions vary. The following are those usually employed:

	Common Gunpowder.	Shooting powder.	Shooting powder.	Miners' powder.
Saltpetre....	75.0	78	76	65
Charcoal....	12.5	12	15	15
Sulphur	12.5	10	9	20

The latter contains the smallest quantity of saltpetre as it requires less *quickness* or *strength*. The ingredients are *perfectly* mixed, moistened, beaten into a cake which is afterwards broken up, granulated, and for the finest powder polished by attrition. The violence of the explosion of gunpowder depends upon the sudden production of gaseous matter, resulting from the action of the combustibles upon the nitre. Carbonic oxide, carbonic acid, nitrogen, and sulphurous acid, are the principal gaseous results, and the solid residue consists of subcarbonate, sulphate and sulphuret of potassa, and charcoal*.

* Cruickshanks, *Nicholson's Journal*, IV.

295. *Potassium unites to Sulphur* with the evolution of much heat and light, and produces a grey compound, which, when acted upon by water, produces sulphuretted hydrogen. It consists of 37,5 P. + 15 S. = 52,5.

296. *Potassa and Sulphur,* when fused together, form a red *sulphuret of potassa. (Liver of sulphur.)* Its taste is bitter and acrid. It is deliquescent and very soluble in water, forming a yellow solution of *hydrosulphuret of potassa.* The action of the sulphuret of potassa on water is complicated, and has been variously explained. By some this is considered as a compound of *potassium* and sulphur; in which case, when acted upon by water, hydrogen is imparted to the sulphur, and oxygen to the potassium; and a sulphuret of potassa with excess of sulphur (or sulphuretted sulphuret of potassa) is formed. If we consider the sulphuret as consisting of *potassa* and sulphur, then the oxygen, as well as the hydrogen, of the water, must be transferred to the sulphur, and sulphuric and sulphurous acid, and sulphuretted hydrogen, would be formed; and generally when the solutions of the *livers of sulphur* are examined, sulphate and sulphite of the alcali, are found. On the whole, however, it appears most probable, that when sulphur and the alcalies are fused together at a high temperature, the latter undergo decomposition, and that sulphurets of their metallic bases are actually formed.

297. *Sulphite of Potassa* is formed by passing sulphurous acid into a solution of potassa, and evaporating out of the contact of air. Rhomboidal plates are obtained, white, of a sulphurous taste, and very soluble. By exposure to air, they pass into sulphate of potassa.

298. *Sulphate of Potassa* is the result of several chemical operations carried on upon a large scale in the processes of the arts. It may be formed directly by saturating sulphuric acid by potassa. It is the *sal de duobus* of the old chemists: the *potassæ sulphas* of the *London Pharmacopœia.* Its taste is

bitter. It crystallizes in short six sided prisms, terminated by six-sided pyramids. The body of the prism is often wanting, and the triangular-faced dodecaëdron results. This salt dissolves in 16 parts of cold, and 5 of boiling water. It consists of

1 proportional of acid	=	37,5
1 ——— alcali	=	45
		82.5

299. *Supersulphate or Bisulphate of Potassa,* is formed by adding sulphuric acid to a hot solution of sulphate of potassa. The first crystals which form are in delicate needles of an acid taste, soluble in 2 parts of water at 60°, and consist of

2 proportionals of acid	=	75
1 ——— potassa	=	45
		120

300. *Phosphuret of Potassium* is a brown compound, which rapidly decomposes water, producing phosphuretted hydrogen gas, and hydrophosphuret of potassa.

301. *Phosphite of Potassa* is a soluble deliquescent uncrystallizable salt.

302. *Phosphate of Potassa* is a soluble difficultly crystallizable salt. It may be obtained by careful evaporation, in four-sided prisms, and octoëdrons. It contains

1 proportional of potassa	=	45
1 ——— phosphoric acid	=	26
		71

303. *Superphosphate or Biphosphate of Potassa* is formed by dissolving the neutral phosphate in phosphoric acid and evaporating till crystals are obtained.

304. *Potassa and Carbonic Acid.*—These bodies combine in two proportions, forming the *subcarbonate* and the *bicarbonate* of potassa, compounds which have been long used and

known under various names—such as *fixed nitre, salt of tartar, salt of wormwood, vegetable alcali, &c.* Their composition was first ascertained by Black. Bergman, in 1774, described their most essential properties. (*Opuscula*, Vol. I. p. 13.)

305. *Subcarbonate of Potassa* is a salt of great importance in many arts and manufactures, and is known in commerce in different states of purity, under the names of *wood-ash, pot-ash*, and *pearl-ash.*

It may be obtained directly by passing carbonic acid into a solution of potassa, evaporating to dryness, and exposing the dry mass to a red heat; or indirectly by burning *tartar*, whence the name *salt of tartar* has been applied to it.

This salt is fusible without decomposition, at a red heat: it is very soluble in water, and deliquesces by exposure to air, forming a dense solution, once called *oil of tartar per deliquium.* Its taste is alcaline, and it renders vegetable blues green. It consists of

1 proportional acid	= 20,7
1 ———— potassa	= 45
	65,7

The potash of commerce is obtained by burning wood, and contains a variety of impurities which render it of variable value. In general, its purity may be judged of by its easy solubility in water, two parts of which should entirely dissolve one part of the salt; the residue, if any, consists of impurities. The quantity of nitric acid of a given density, requisite to saturate a given weight, may also be resorted to as a criterion of its purity. According to Vauquelin (*Ann. de Chim.* Vol. XL.) the principal varieties of this substance used in commerce, contain the following ingredients:

	Potash.	Sulphate of potash.	Muriate of potash.	Insoluble residue.	Carbonic acid and water.	Total.
Potash of Russia ..	772	65	5	56	254	1152
———America ..	857	154	20	2	119	1152
American Pearl-ash	754	80	4	6	308	1152
Potash of Treves. . .	720	165	44	24	199	1152
———Dantzic. . .	603	152	14	79	304	1152
———Vosges....	444	148	510	34	304	1440

A saturated solution of sub-carbonate of potassa in water contains about 48 per cent. of the salt, and has a specific gravity of 1,5.

306. *Bicarbonate of Potassa* is formed by passing a current of carbonic acid into a solution of the subcarbonate. By evaporation crystals are obtained in the form of four-sided prisms, with dihedral summits. Their taste is only slightly alcaline, and they require for solution four parts of water, at 60°. Exposed to a red heat, carbonic acid is evolved, and subcarbonate of potassa remains. This bicarbonate consists of

2 proportionals of	carbonic acid	=	41,4
1 ———————	potassa,	=	45
			86,4

In its crystalline form it contains water equal to one proportional; and, therefore, consists of 86,4 carbonate

86,4	carbonate
8,5	water
94.9	

The subcarbonate and carbonate of potassa, are both decomposed by lime, which deprives them of carbonic acid; hence the use of that earth in the process for obtaining pure *potassa.*

307. The salts of potassium are soluble in water, and afford no precipitates with pure or carbonated alcalis. They produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by ferroprussiate of potassa *. Added to sulphate of alumina, they enable it to crystallize, so as to form alum.

Section II. *Sodium.*

308. Sodium is obtained from soda by an operation analogous to that for procuring potassium from potassa. It is soft, malleable, and easily sectile. Its sp. gr. is 0,9. In colour it resembles lead, it fuses at 180°, and is volatile at a white heat. It burns when heated in contact with air, and requires the same cautions to preserve it as potassium.

309. *Sodium and Oxygen.*—When sodium is thrown upon water, it produces violent action, but the metal does not in general inflame; hydrogen is evolved, and a solution of soda is procured. By the quantity of hydrogen evolved, we learn that soda *(protoxide of sodium)* consists of about 74,6 sodium and 25,4 oxygen *per cent.*; and, if soda be considered as the protoxide, the number representing the metal will be 22, and soda will consist of 22 S. + 7,5 O., and be represented by 29,5.

310. By heating sodium in oxygen, an orange-coloured oxide is formed, consisting of 22 S. + 11,25 O., and which, by the action of water, evolves oxygen, and produces a solution of the protoxide.

* The hydrocyanate of potassa, and the action of potassium on cyanogen will be described in the section on Iron.

311. *Soda*, as it usually occurs in the laboratories, is obtained from the subcarbonate, by the action of lime and alcohol, as described under the head *potassa*. It consists of 29,5 oxide of sodium + 8,5 water, and is represented by 38. When soda is exposed to air, it soon becomes covered with an efflorescence of subcarbonate of soda. Its colour is grayish white, and it requires a red heat for fusion.

312. It is distinguished from pure potassa, by forming an *efflorescent* paste when exposed to the atmosphere; potassa under the same circumstances *deliquesces*. If excess of tartaric acid be added to a solution of soda there is no precipitation; but in solution of potassa it occasions a deposit of a number of minute crystals. Solution of soda occasions no precipitate when added to solution of muriate of platinum. Solution of potassa occasions a yellow precipitate in solution of platinum.

313. *Chloride of Sodium.*—Sodium, when heated in chlorine, burns and produces a white compound, of a pure saline flavour, soluble in $2\frac{1}{2}$ parts of water at 60°, and forming cubic crystals. It has all the properties of common salt or muriate of soda, and consists of

1 proportional of chlorine		=	33,5
————————	sodium	=	22,
			55,5

This compound is decomposed, when heated with potassium. Sodium and chloride of potassium are the results.

When soda is heated in chlorine, oxygen is evolved; when heated in muriatic acid, water is formed, and in both cases chloride of sodium is the product.

314. Common salt exists abundantly in nature, both as a solid fossil and dissolved in water. Immense masses of it are found in Cheshire, where it is known under the name of *rock salt*. It is fusible at a red heat, without undergoing any

decomposition, and on cooling concretes into a hard white mass.

315. It is decomposed by moist carbonate of potassa, and chloride of potassium and carbonate of soda are the results. In the common process for obtaining muriatic acid it is decomposed by sulphuric acid. (142) In this decomposition there is a transfer of the oxygen contained in the water of the sulphuric acid to the sodium of the salt, the chlorine of which combines with the hydrogen of the water to produce muriatic acid gas. The oxide of sodium unites with the dry sulphuric acid to produce sulphate of soda. (320.)

Common salt is of most extensive use as a preservative of food, and as a condiment. Glauber first obtained muriatic acid from it, and the existence of soda in it was shewn by Duhamel. Its real nature was first demonstrated by Sir H. Davy.

316. *Sodium and Iodine* act upon each other with the same phenomena as potassium, and an iodide of sodium is obtained. The hydriodic acid and soda produce a similar compound.

317. *Nitrate of Soda* crystallizes in rhombs, soluble in three parts of water at 60°. It has a cool sharp flavour, and is somewhat deliquescent. It consists of 29,5 soda + 50,5 nitric acid.

318. *Sulphuret of Sodium and of Soda.* See *Potassium.* (295.)

319. *Sulphite of Soda* is crystallizable in transparent four and six-sided prisms, soluble in four parts of water at 60°. It consists of 29,5 soda + 30 sulphurous acid. The crystals contain twelve proportionals of water = 102.

320. *Sulphate of Soda—Glauber's Salt*—is abundantly produced in the manufacture of muriatic acid, by the action of sulphuric acid upon common salt.

Common salt consists of 22 sodium + 33,5 chlorine. Sulphuric acid consists of 37,5 dry acid + 8,5 water. The water of the acid, consisting of 1 hydrogen + 7,5 oxygen, is decomposed. Its hydrogen is transferred to the chlorine to produce gaseous muriatic acid (1 H. + 33,5 C. = 34,5 Mur. A.), and its oxygen unites to the sodium, forming dry soda (7,5 Ox. + 22 S. = 29,5 soda). The 37,5 dry acid unite to the 29,5 soda, to produce sulphate of soda, which will be represented by the number 67. Sulphate of soda crystallizes from its aqueous solution in large four-sided prisms, transparent, and efflorescent when exposed to air. They consist of 67 dry sulphate + 85 water.

The taste of sulphate of soda is saline and bitter: it is soluble in rather less than three times its weight of water at 60°. When exposed to heat it undergoes watery fusion, that is, it melts in its own water of crystallization.

Sulphate of soda is sometimes decomposed for the purpose of obtaining soda, by igniting it with chalk and charcoal, or with iron and charcoal. (Of these processes a full account is given in Aikin's *Dictionary*, Art. *Muriate of Soda.*)

321. *Bi-sulphate of Soda* is obtained by adding sulphuric acid to a hot solution of sulphate of soda. It crystallizes in rhomboids soluble in twice their weight of water at 60°. This salt consists of 67 sulphate of soda + 37,5 sulphuric acid = 104,5. (Crell's *Annals*, 1796.)

322. *Ammonio-sulphate of Soda* is a triple salt, formed by saturating the bi-sulphate with ammonia. (Crell's *Annals*, 1796.)

323. *Phosphate of Soda* crystallizes in rhomboidal prisms, soluble in four parts of water at 60°, and efflorescing when exposed. It consists of

29,5	soda.
26	phosphoric acid.
55,5	

The crystals contain about 60 per cent. of water: it is usually obtained for pharmaceutical purposes by saturating the impure phosphoric acid, obtained from calcined bones by sulphuric acid (202) with subcarbonate of soda: the liquor is filtered, evaporated, and set aside to crystallize.

324. *Ammonio-phosphate of Soda* exists in human urine, whence it was procured by the early chemists under the names of *microcosmic* and *fusible salt*. When exposed to heat the ammonia is expelled, and a *bi-phosphate* of soda remains: it appears to consist of two proportionals of phosphoric acid = 52; one of soda = 29,5, and one of ammonia = 16. (Fourcroy, *Annales de Chimie*, VII. 183.)

325. *Subcarbonate of Soda* is chiefly obtained by the combustion of marine plants, the ashes of which afford, by lixiviation, the impure alcali, called *barilla*, or *soda*. In that state it is contaminated by common salt, and other impurities, from which it may be separated by solution in a small portion of water, filtrating the solution, and evaporating it at a low heat: the common salt may be skimmed off as its crystals form upon the surface. The primitive crystalline form of subcarbonate of soda is an octoëdron, with a rhombic base; the solid angles of the summit are always wanting, being replaced by planes parallel to the base, and thus presenting a solid with 10 surfaces. It is soluble in half its weight of water at 60°. Its taste is strongly alcaline, and it greens vegetable blues. It consists of

29,5	soda.
20,7	carbonic acid.
50,2	

Its crystals contain seven proportionals of water = 59,5, which may be expelled by heat. They effloresce by exposure to air.

326. *Bicarbonate of Soda* is formed by passing carbonic

acid through the solution of the subcarbonate. By evaporation a crystalline mass is obtained. This salt consists of

29,5	soda.
41,4	carbonic acid.
70,9	

327. This salt, as well as the bi-carbonate of potassa, may be obtained by treating their respective subcarbonates with subcarbonate of ammonia. (See *London Pharmacopœia.)*

The bi-carbonate of soda has a very slightly alcaline taste, and it is much less soluble in water than the sub-carbonate.

A mixture of the carbonates of soda occurs native in great abundance in Africa, in the province of Gahena, near Fezzan The natives call it *Trona*.

328. *Subborate of Soda—Borax.*—This salt, which has been very long known, is imported from India in an impure state, under the name of *Tincal,* which, when purified, is called *Borax.* It crystallizes in irregular hexaedral prisms, slightly efflorescent. Its taste is alcaline and styptic. It is soluble in 20 parts of water at 60°, and in six parts of boiling water. When heated it loses water of crystallization, and becomes a porous friable mass, called *calcined borax.* It consists, according to Bergman, of

34	acid.
17	soda.
49	water.
100	

Sulphuric acid decomposes this salt, producing sulphate of soda and boracic acid. (244)

329. The salts of sodium are soluble in water. They are not precipitated either by pure or carbonated alcalies, or

hydrosulphuret of ammonia, or ferro-prussiate of potassa; they produce no precipitate in solution of muriate of platinum, and do not convert sulphate of alumina into alum.

330. Potassium and sodium form an alloy, which, if composed of one part of potassium and three of sodium, remains fluid at 32. Equal parts of the metals form a brittle crystallizable alloy.

Section III. *Lithium.*

331. In the analysis of a mineral, called *petalite*, M. Arfwedson discovered about three per cent. of an alcaline substance, which was at first supposed to be soda; but, finding that it required for its neutralization a much larger quantity of acid than soda, he was led to suspect its identity with that alcali, and the further prosecution of his inquiries fully demonstrated that it possessed peculiar properties. The mineral called *triphane*, or *spodumene*, also affords the same substance, to which the term *lithia*, deduced from its lapideous original, has been applied.

The following is the mode of obtaining lithia from the above substances:—Reduce the mineral to a fine powder, and fuse it with about half its weight of potassa; dissolve the fused mass in muriatic acid, filter, and evaporate to dryness; digest the dry mass in alcohol; the only substance present, soluble in that liquid, is the *muriate of lithia*, which is taken up, and by a second solution and evaporation is obtained pure. It may be decomposed by digesting carbonate of silver in its aqueous solution, by which a carbonate of lithia is formed, decomposable by lime, in the way of the other alcaline carbonates.

332. When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phenomena as potassa

and soda; a brilliant white and highly combustible metallic substance is separated, which may be called *lithium*, the term *lithia* being applied to its oxide.

The properties of this metal have not hitherto been investigated, in consequence of the difficulty of procuring any quantity of its oxide.

333. Pure lithia is very soluble in water, and its solution tastes acrid like the other fixed alcalis. It acts powerfully on vegetable blues, converting them to green.

Direct experiments upon the composition of lithia are yet wanting. By calculation from the composition of the sulphate, as analysed by Vauquelin, it would appear to contain about 55,2 lithium + 44,8 oxygen.

334. *Chloride of Lithium*, obtained by evaporating the muriate to dryness, and fusing it, is a white semi-transparent substance. It evidently differs from the chlorides of potassium and sodium, in being extremely deliquescent; in being soluble in alcohol; in being decomposed when strongly heated in the open air, when it loses chlorine, absorbs oxygen, and becomes highly alcaline; in being very difficultly crystallizable; and in tinging the flame of alcohol of a red colour.

335. *Iodide of Lithium.*—The action of iodine and of hydriodic acid on lithia has not been examined.

336. *Nitrate of Lithia* is a very soluble deliquescent salt, fusible and decomposed by heat; its taste is cooling; it crystallizes in rhomboids.

337. *Sulphuret of Lithium.*—The action of sulphur on lithium and lithia appears analogous to its action on potassium and potassa, but the compounds have not been precisely examined.

338. *Sulphate of Lithia* crystallizes in small rectangular prisms, perfectly white, and possessed of much lustre. Their taste is saline, and their solubility intermediate between that

of sulphate of potassa and sulphate of soda. The crystals contain no water, and fuse at a heat below redness. Their solution occasions no change in solution of platinum, nor in tartaric acid. They consist of

Sulphuric acid	69,18
Lithia	30,82
	100

339. *Phosphate of Lithia* has not been examined.

340. *Carbonate of Lithia.*—When a strong solution of carbonate of potassa is added to sulphate of lithia, a white precipitate of *subcarbonate of lithia* is formed. It requires about 100 parts of water at 60° for its solution. It is fusible, alcaline, effervesces with acids, and absorbs carbonic acid from the air. Lithia and its carbonate, when heated upon platinum, act upon that metal.

341. If we assume from Vauquelin's corrected analysis of the sulphate, that lithia contains 45 per cent. of oxygen and 55 of lithium, and that it is a protoxide, then 55 : 45 : : 7,5 : 9,1. So that the number 9 might be assumed as the representative number of lithium; and oxide of lithium, or lithia, would contain—

Lithium	9	+ Oxygen	7,5	=	16,5
Chloride—Lithium	9	+ Chlorine....	33,5	=	42,5
Nitrate of Lithia—Lithia .	16,5	+ Nitr. acid ...	50,5	=	67
Sulphate	16,5	+ Sul. acid ...	37,5	=	54
Subcarbonate	16,5	+ Carb. acid ..	20,7	=	37,2

SECTION IV. *Calcium.*

342. WHEN lime is electrized negatively in contact with mercury, an amalgam is obtained, which, by distillation, affords a white metal. It has been called *calcium*, and when

exposed to air, and gently heated, it burns and produces the *oxide of calcium*, or *lime*.

343. Lime appears to consist of 19 parts of this metallic base united to 7,5 parts of oxygen, so that its representative number will be = 26,5.

The combinations of lime are very abundant natural products, and of these the native carbonate which, more or less pure, constitutes the different kinds of marble, chalk, and limestone, and which is also the leading hardening principle of shell, coral, *&c.*, may be considered as the most important.

Pure lime may be obtained by exposing powdered white marble to a white heat. Its colour is grey; it is acrid and caustic, and converts vegetable blues to green; its specific gravity is 2,3; it is very difficult of fusion. Exposed to air it becomes white by the absorption of water and a little carbonic acid.

When a small quantity of water is poured upon lime, there is a great rise of temperature resulting from the solidification of a portion of the water, and a white powder is obtained, called *slacked lime*, which is a *hydrate*, and which appears to consist of one proportional of water = 8,5 + one proportional of lime = 26,5.

Lime may be obtained in a crystalline form by placing lime-water under the receiver of an air-pump, containing another vessel of sulphuric acid. The water is thus slowly evaporated, and imperfect six-sided crystals of hydrate of lime are formed. (Gay Lussac, *Annales de Chimie et Phys.* I. 334.)

At the temperature of 60°, 750 parts of water are required for the solution of one part of lime.

344. Lime-water is limpid and colourless; its taste is nauseous, acrid, and alcaline, and it converts vegetable blues to green. It is usually prepared by pouring warm water upon powdered lime, and allowing the mixture to cool in a close vessel: the clear part is then decanted from the remaining

undissolved portion of lime. When lime-water is exposed to the air, a pellicle of carbonate of lime forms upon its surface, which if broken, is succeeded by others, until the whole of the lime is thus separated in the form of an insoluble carbonate.

345. *Chloride of Calcium* is produced by heating lime in chlorine, in which case oxygen is evolved; or by evaporating *muriate of lime*, obtained by dissolving carbonate of lime in muriatic acid, to dryness, and exposing the dry mass to a red heat in close vessels. It consists of 19 calcium + 33,5 chlorine = 52,5. This compound has a strong attraction for water; it deliquesces when exposed to air, and is difficultly crystallizable from its aqueous solutions. With care, however, it may be obtained in six-sided prisms, consisting of the chloride combined with water. It is most readily crystallized by exposing its solution to the temperature of 32°. Its taste is bitter and acrid; one part of water at 60° dissolves four parts of the chloride. It is copiously soluble in alcohol, and much heat is evolved during the solution. When fused it acquires a phosphorescent property, as was first observed by Homberg, and hence termed *Homberg's phosphorus*. It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of muriate of ammonia by lime, and hence has sometimes been called *fixed sal ammoniac*. The production of cold by mixing muriate of lime with snow has already been adverted to. (*page* 32.) Chloride of lime absorbs ammoniacal gas in considerable quantities. (Faraday, *Journal of Science*, Vol. V. p. 74.)

346. *Iodate of Lime* is difficultly crystallizable in small quadrangular prisms.

Hydriodate of Lime is very deliquescent; when dried, it becomes iodide of calcium, a white fusible compound.

347. *Nitrate of Lime* is a deliquescent salt, soluble in 4 parts of water at 60°. It is found in old plaster and mortar,

from the washings of which nitre is procured by the addition of subcarbonate of potassa. It is composed of

Lime	26,5
Nitric acid	50,5
	77

The production of this salt in artificial nitre-beds has already been adverted to. It may be crystallized in six-sided prisms. It is soluble in alcohol. When exposed to a moderate heat it undergoes watery fusion; the water then evaporates, and the salt fuses: on cooling it concretes into a semi-transparent phosphorescent substance, called from the discoverer of this property, *Baldwin's Phosphorus*. At a red heat it is decomposed; its acid is dissipated, and pure lime remains. It contains in its crystallized state about 25 per cent. of water, and may hence be considered as composed of

1 proportional dry nitrate	77
3 ——————— water	25,5
	102,5

348. *Sulphuret of Lime* is formed by heating lime with sulphur. It is soluble in water with the same phenomena as sulphuret of potassa.

349. *Sulphate of Lime* occurs native in selenite, gypsum, and plaster stone. It is easily formed artificially, and then affords silky crystals soluble in 350 parts of water. When these, or the native crystallized sulphate are exposed to a red heat, they lose water, and fall into a white powder *(plaster of Paris)*, which, made into a paste with water, soon solidifies. Dry sulphate of lime consists of

26,5	lime.
37,5	sulph. acid
64	

Crystalline selenite contains two proportionals of water, and is consequently represented by 64 + 17, or 81. As sulphate of lime is more soluble in water than pure lime, sulphuric acid affords no precipitate when added to lime-water. Nearly all spring and river water contains this salt, and in those waters which are called *hard* it is abundant. It gives to them a slightly nauseous taste. At a very high temperature sulphate of lime is fusible, but it suffers no decomposition; heated with charcoal it is converted into a sulphuret.

350. Native sulphate of lime occurs in various forms. The crystallized variety is usually called *selenite;* the fibrous and earthy, *gypsum:* and the granular or massive, *alabaster.* The primitive form of selenite is a rhomboidal prism of 113° 8′ and 66° 52′. The crystals are commonly transparent, and of various colours; it is softer than native carbonate of lime, and yields very easily to the nail. It is seldom found in veins, but general disseminated in argillaceous strata. It occurs in Cumberland at Alston, and in Oxfordshire at Shotover Hill, where it is often accompanied by shells and pyrites, and appears to have resulted from their mutual decomposition. A beautiful fibrous variety is found in Derbyshire, applicable to ornamental purposes.

Massive and granular gypsum is found in this country accompanying the salt-deposits in Cheshire. It abounds at Montmartre, near Paris, and contains organic remains; sometimes it forms entire hills. In the Tyrolese, Swiss, and Italian Alps, it is found upon the primitive rocks, often of the purest white, especially at Montier, near Montblanc, and near the summit of Mount Cenis. It is turned by the lathe, and sculptured into a variety of beautiful forms, more especially by the Florentine artists.

There is a variety of sulphate of lime, which has been called *anhydrous gypsum*, or *anhydrite*, in reference to its containing no water. It is harder than selenite, and sometimes contains common salt, and is called *muriacite.* It is rarely crystallized, generally massive and lamellar, and susceptible of division into rectangular prisms. It has been found in Derbyshire and Nottinghamshire of a pale blue tint; sometimes it is pink or reddish, and often white. It has been found at Vulpino, in Italy, and hence called *Vulpinite*. The statuaries of Bergamo and Milan employ it, and artists know it by the name of *Marbre Bardiglio di Bergamo*. A compound of sulphate of lime and sulphate of soda is found in the salt-mines of New Castile, which mineralogists have described under the name of *Glauberite*.

351. *Phosphuret of Lime.*—By passing phosphorus over red-hot lime, a brown compound is produced, which rapidly decomposes water with the evolution of phosphuretted hydrogen gas. Hydrophosphuret and hypo-phosphate of lime are also formed.

352. *Phosphate of Lime* exists abundantly in the bones of animals; it is also found in the mineral world. It may be formed artificially, by mixing solutions of phosphate of soda and muriate of lime. It is insipid and insoluble, but dissolves in dilute nitric and muriatic acid without decomposition. It is decomposed by sulphuric acid, and thus the phosphoric acid for the production of phosphorus is usually procured. (202) It consists of

26,5	lime.
26	phosphoric acid.
52,5	

At a very high temperature phosphate of lime fuses into an opaque white enamel.

353. *Biphosphate of Lime* is formed by digesting the phosphate in phosphoric acid. On evaporation a white deliquescent uncrystallizable mass is obtained, composed of one proportional of lime + two of phosphoric acid.

354. *Native Phosphate of Lime* has by some been regarded as a *sub-phosphate*, in which case it would be composed of

two proportionals of lime + one phosphoric acid. This compound occurs crystallized and massive, and is known under the names of *apatite, asparagus stone*, and *phosphorite*. The crystallized variety is found in Cornwall and Devonshire, of singular beauty. Its primitive form is a six-sided prism: it also occurs in volcanic products; and, what is curious, the former is phosphorescent and the latter not. The massive variety is found in Bohemia and in Spain.

355. *Carbonate of Lime* is the most abundant compound of this earth. When lime-water is exposed to air, it becomes covered with an insoluble film of carbonate of lime, and hence is an excellent test of the presence of carbonic acid. But excess of carbonic acid re-dissolves the precipitate, producing a super-carbonate. Carbonate of lime is precipitated by the carbonated alcalies from solutions of muriate and nitrate of lime. Exposed to a red heat the carbonic acid escapes, and quicklime is obtained. It consists of

26,5	lime.
20,7	carbonic acid.
47,2	

356. Carbonate of lime occurs in nature in great abundance and in various forms. The primitive form of crystallized carbonate of lime, or *calcareous spar*, is an obtuse rhomboid of 105° 5′, and 74° 55′. Its specific gravity is 2,7. It occurs in every kind of rock, and its secondary forms are more numerous than those of any other substance; sometimes it forms fine *stalactites*, of which some of the caverns of Derbyshire furnish magnificent specimens; it is here deposited from its solution in water acidulated by the carbonic acid, and substances immersed in this water become encrusted by carbonate of lime, when the excess of acid flies off, as seen in the *petrifying well of Matlock*. A fibrous variety of carbonate of lime, called *satin spar*, is found in Cumberland. Another variety, originally found in

Arragon in Spain, has been termed *Arragonite;* it occurs in six-sided crystals, of a reddish colour, and harder than the common carbonate. There is an acicular, or fibrous variety, found in France and Germany, and the white radiated substance, improperly called *flos ferri,* is also regarded as of the same species. Some varieties contain about 3 per cent. of strontia.

All the varieties of marble and lime-stone consist essentially of carbonate of lime; of these, *white granular lime-stone,* or *primitive marble,* is most esteemed; there are, also, many coloured varieties of extreme beauty. It is distinguished from secondary lime-stones by the absence of all organic remains, by its granularly foliated structure, and by its association with other primitive substances.

The most celebrated statuary marble is that of Paros and of Mons Pentelicus, near Athens: of these, some of the finest specimens of ancient sculpture are composed. The marble of Carrara, or Luni, on the eastern coast of the Gulf of Genoa, is also much esteemed; it is milk white, and less crystalline than the Parian.

Many beautiful marbles for ornamental purposes are quarried in Derbyshire, and especially the black marble, called also *Lucullite.* Westmorland and Devonshire also afford beautiful varieties, and in Anglesea, a marble, intermixed with green serpentine, is found, little inferior in beauty to the *verd antique*

Among the inferior lime-stones, we enumerate many varieties, such as *common marble, bituminous lime-stone,* abundant upon the Avon, near Bristol, and known under the name of *swine-stone* or *stink-stone,* from the peculiar smell which it affords when rubbed: *Oolite* or *Roestone,* of which the houses of Bath are built; and its variety, called *Portland stone: Pisolite* consists of small rounded masses, composed of concentric layers, with a grain of sand always in the centre: and, lastly, *chalk* and *marl.*

All these substances are more or less useful for ornamenta purposes, or for building; they afford quicklime when burned, and in that state are of great importance as manures.

357. The salts of lime have the following properties:—

Those which are soluble are not altered by pure ammonia, but they are decomposed by potassa and soda. They are also decomposed by the carbonates of potassa, soda, and ammonia, which produce precipitates of carbonate of lime.

Oxalate of ammonia produces in their solutions a white insoluble precipitate of oxalate of lime, which, exposed to a red heat, affords pure lime.

The insoluble salts of lime are decomposed by being boiled with carbonate of potassa, and afford carbonate of lime.

358. *Fluor Spar—Fluate of Lime.*—These terms have been applied to a body containing a peculiar principle which has not hitherto been obtained in an insulated state.

It is a principle which probably belongs to the acidifying electro-negative supporters of combustion, and which in fluor spar is, perhaps, united to calcium. It appears to be united with hydrogen in the *fluoric* or *hydrofluoric* acid. This supposed base has been called *fluorine* by Sir H. Davy; and *phtore* (from φθόριος, *destructive*), by M. Ampère.

359. Fluor Spar is a mineral found in many parts of the world, but in great beauty and abundance in England, and especially in Derbyshire. Here it is commonly called *Derbyshire spar*, or by the miners of that county, *blue John.* It is usually found in cubic crystals, which may easily be cleaved into octoëdra, considered as its primitive form. Its colours are extremely various. Its sp. gr. 3. It phosphoresces when exposed to heat a little below redness. It generally occurs in veins; in the Odin mine at Castleton, in Derbyshire, it is found in detached masses, from an inch to more than a foot in thickness; their structure is divergent, and the colours, which are various, disposed in concentric bands. It is the only variety which affords the beautiful vases and other ornamental articles.

Compact fluor is a scarce variety: the finest specimens come from the Hartz. A third variety is *chlorophane,* so called from the beautiful pale green light which it exhibits when heated.

The nature of the colouring matter of fluor spar is not exactly understood. It is liable to fade, and the blue varieties become red and brown by heat.

360. *Hydrofluoric acid* (hydrophtoric) is procured by distilling a mixture of one part of the purest fluor spar in fine powder, with two of sulphuric acid; the distillatory apparatus and receiver should be of lead or silver; the heat required is not considerable; sulphate of lime remains in the retort, and a highly acrid and corrosive liquid passes over, which requires the assistance of ice for its condensation.

This acid is colourless, of a very pungent smell, and extremely destructive. If applied to the skin it instantly kills the part, produces extreme pain, and extensive ulceration. At 80° it becomes gaseous; it has never been frozen; it produces white fumes when exposed to a moist air.

This acid acts upon potassium and sodium, and some other metals, with great energy; hydrogen is evolved, and a peculiar compound, probably of the basis of the acid, and the metal, results. These compounds might be called *fluorides.*

361. *Fluoboric acid.*—This is probably a compound of fluorine with boron. It is gaseous, and may be obtained by heating in a glass retort twelve parts of sulphuric acid, with a mixture of one part of fused boracic acid and two of fluate of lime, reduced to a very fine powder. The gas must be received over mercury: 100 cubical inches weigh 73,5 grains; so that the specific gravity of fluoboric acid, compared with hydrogen, is 32,68, and with atmospheric air, 23,71. It produces very copious fumes when suffered to escape into a moist atmosphere; and when acted upon by water, which dissolves 700 times its volume, it affords a solution of hydrofluoric and boracic acids, whence it would seem that the hydrogen is transferred to the

fluorine, and the oxygen to the boron. It acts with great energy on vegetable and animal bodies, depriving them of moisture and hydrogen.

362. The fluoboric acid combines with different bases, and produces a class of salts which have been called *fluoborates*.

SECTION V. *Barium.*

363. To obtain this metal, the earth baryta is negatively electrized in contact with mercury; an amalgam is gradually formed, from which the mercury may be expelled by heat, and the metal barium remains; appearing, according to Sir H. Davy, of a dark grey colour, and being more than twice as heavy as water. It greedily absorbs oxygen, and burns with a deep red light when gently heated, producing the oxide of barium.

364. *Oxide of Barium,* or baryta, is obtained by exposing the nitrate of baryta to a bright red heat. It is of a grey colour, and very difficult of fusion; and appears to consist of 65 barium + 7,5 oxygen, and is, consequently, represented by 72,5. It eagerly absorbs water, heat is evolved, and a white solid is formed, containing about 10 per cent. of water; this is the *hydrate of baryta,* and may be considered as a compound of 1 proportional of baryta = 72,5 + 1 proportional of water = 8,5, and is, consequently, represented by 81.

This hydrate dissolves in boiling water; and, as the solution cools, deposits flattened hexagonal prisms, which contain a large quantity of water, and are easily fusible. The solution, or *baryta water,* is limpid, colourless, and acts energetically on vegetable blues and yellows, changing them to green and red; as baryta, like the alcalis, converts vegetable blues to green, and serves as an intermede between oil and water, it has been called an *alcaline earth.* It is highly poisonous. It exists in two natural combinations only, namely, as sulphate and carbonate.

According to M. Gay-Lussac, there is a *peroxide of barium* obtained by heating baryta in oxygen. It is of a grey colour, and gives out oxygen when acted upon by water.

365. *Chloride of Barium* may be obtained by heating baryta in chlorine, in which case oxygen is evolved: or more easily, by dissolving carbonate of baryta in diluted muriatic acid. By evaporation, tabular crystals are obtained, soluble in 5 parts of water at 60°; and consisting, when dry, of 65 barium + 33,5 chlorine = 98,5. Its taste is pungent and acrid; when exposed to heat, the water of crystallization separates, and the dry chloride enters into fusion.

366. *Chlorate of Baryta* is formed in the same way as chlorate of potassa. It crystallizes in quadrangular prisms, soluble in four parts of water, at 60°. It consists of

1 proportional of baryta	= 72,5
1 chloric acid	= 71
	143,5

Or of 1 proportional of barium	= 65
6 ——— of oxygen	= 45
1 ——— of chlorine	= 33,5
	143,5

Gay-Lussac procured chloric acid by the action of sulphuric acid upon this salt.

367. *Iodide of Barium* is easily formed by acting upon baryta, by hydriodic acid, and evaporating the solution. It may also be formed by heating baryta in hydriodic gas.

Iodate of Baryta is a very difficultly soluble compound; the hydriodate is crystallizable and very soluble.

368. *Nitrate of Baryta* may be produced by dissolving the native carbonate in nitric acid, evaporating to dryness, re-dis-

solving and crystallizing; it forms octoëdra. Its taste is acrid and astringent. It is soluble in 12 parts of cold and 4 of boiling water; it is decomposed by heat, furnishing pure baryta. It consists of

72,5	baryta.
50,5	nitric acid.
123	

369. *Sulphuret of Barium* is a brown compound, which acts upon water as already described, producing hydrosulphuret of baryta.

370. *Sulphate of Baryta* is an abundant natural product; it is insoluble, and therefore produced whenever sulphuric acid or a soluble sulphate, is added to any soluble salt of baryta. Hence the solutions of baryta are accurate tests of the presence of sulphuric acid. They are all highly poisonous, and sulphate of soda, or dilute sulphuric acid, are the best antidotes. Sulphate of baryta consists of one proportional of sulphuric acid and one of baryta.

37,5	sul. acid.
72,5	baryta.
110	

When native sulphate of baryta is heated it decrepitates, and at a high temperature fuses into an opaque white enamel: it was employed in the manufacture of jasper ware by the late Mr. Wedgwood. When formed into a thin cake with paste, and heated to redness, it acquires the property of phosphorescence. This was first ascertained by Vincenzo Cascariolo, of Bologna, whence the term *Bologna phosphorus* is applied to it. (118.) The artificial sulphate of baryta is used as a pigment, under the name of *permanent white*. It is very useful for marking phials and jars in a laboratory. Sulphate of baryta is sparingly soluble in sulphuric acid.

Native sulphate of baryta is principally found in the mines of Westmorland and Cumberland, and in Transylvania, Hungary, Saxony, and Hanover. A variety, met with in Derbyshire, is called *cawk*. It occurs massive, and crystallizes in a great variety of forms. Its primitive figure is a rhomboidal prism, the angles of which are 101° 42′, and 78° 18′. It is harder than carbonate of lime, but not so hard as fluate of lime. Its sp. gr. is 4,7.

371. *Phosphuret of Barium* is produced by passing phosphorus over heated baryta; there is an intense action and a phosphuret of a metallic lustre is obtained, which acts upon water, and affords a solution of hydrophosphuret.

372. *Phosphate of Baryta* consists of

26	phosphoric acid.
72,5	baryta.
98,5	

It is insoluble in water; and, therefore, formed by adding a solution of phosphoric acid or phosphate of soda to nitrate or muriate of baryta.

373. *Carbonate of Baryta* is found native. Artificially produced, it is a white compound insoluble in water, containing

20,7	carb. acid.
72,5	baryta.
93,2	

It is poisonous.

374. Native carbonate of baryta was first discovered at Anglesark, in Lancashire, by Dr. Withering, and hence acquired the name of *Witherite*. It has also been found in Wales, Cumberland, Durham, Westmorland, and Shropshire. Its primitive crystal is an obtuse rhomboid: sometimes it forms pyramidal six-sided prisms. That found in Lancashire is in

globular masses of a radiated structure. It is useful as a source of pure baryta and its salts.

375. *Borate of Baryta* is an insoluble white powder.

376. The soluble barytic salts furnish white precipitates of carbonate and sulphate of baryta, upon the addition of carbonate or sulphate of soda. They are poisonous, and give a yellow tinge to the flame of spirit of wine. The sulphate is insoluble in nitric acid and in the alcalis.

Section VI. *Strontium.*

377. This metal is procured from the earth strontia by the same process as barium, which metal it resembles in appearance.

378. *Oxide of Strontium,* or the earth *Strontia,* is procured by the ignition of the pure nitrate; it is of a grey colour; it forms a pulverulent, and a crystallized hydrate. It consists of

44,5	strontium.
7,5	oxygen.
52	

The pulverulent hydrate contains

52	strontia.
8,5	water.
60,5	

1 part of strontia requires about 160 of water at 60° for its solution. Strontia water is transparent and colourless,—it greens vegetable blues, and its taste is styptic and acrid.

379. *Chlorine and Strontium.*—This compound which has also been called *muriate of strontia,* is commonly procured by dissolving carbonate of strontia in muriatic acid. It crystallizes in slender six-sided prisms, soluble in twice their weight of water, at 60°. When chlorine is made to act upon strontia,

it is absorbed, and oxygen evolved. The resulting compound contains

44,5 strontium.
33,5 chlorine.
———
78

It is of a grey colour. It dissolves in alcohol, and the solution burns with a purple-coloured flame.

380. *Iodide of Strontium* may be formed as iodide of barium.

381. *Nitrate of Strontia* crystallizes in dodecaedra; it is soluble in its weight of water at 60°. It consists of

52 strontia
50,5 nitric acid.
———
102,5

Its taste is pungent and cooling. At a red heat the acid is evolved and strontia remains.

382. *Sulphate of Strontia* occurs native. It is nearly insoluble, 1 part requiring 4,000 of water for its solution. When heated with charcoal, its acid is decomposed, and *sulphuret of strontia* is formed, which affords nitrate by the action of nitric acid. This process, equally practicable upon sulphate of baryta, is sometimes adopted to obtain the earth. Sulphate of strontia contains

52 strontia.
37,5 acid.
———
89,5

383. The native sulphate is sometimes of a blue tint, and has hence been called *celestine*. Sometimes it is colourless and transparent. Its primitive form is a prism of 104° 48′. and 75°, 42′. with a rhomboidal basis. It has been found at Strontian in Argyleshire, in the vicinity of Bristol, and at Montmartre near Paris. The finest crystallized specimens are accompanied with native sulphur, from Sicily. Its specific gravity is 3.2.

384. *Phosphate of Strontia* is an insoluble white salt, containing

52	strontia.
26	acid.
78	

It is soluble in excess of phosphoric acid, which is not the case with phosphate of baryta.

By ignition with charcoal, *phosphuret of strontium* is obtained.

385. *Carbonate of Strontia* exists native. Artificially formed, it is a white insoluble body, containing

52	strontia
20,7	carbonic acid.
72,7	

When strongly heated with a little charcoal powder, it is decomposed, carbonic oxide is given off, and pure strontia remains.

386. Native carbonate of strontia is a rare mineral. It has a greenish tint, and occurs in radiated masses, and sometimes in acicular and hexaedral crystals. It was first discovered at Strontian in Argyleshire, whence the name of this earth; it has also been found in Saxony, and in Peru. Its specific gravity is 3,6.

387. There is in many respects a resemblance between strontia and baryta, which has led to confusion in analyses.

The following are some of the most striking points of resemblance. They are both found native in the states of sulphate and carbonate only; both sulphates are soluble in excess of sulphuric acid, and nearly insoluble in water; they are decomposable by similar means, as well as the native carbonates: they are both crystallizable from their hot aqueous solutions, and both attract carbonic acid. The carbonates are each soluble with effervescence in most of the acids; but the native carbonates are not so easily acted on as the artificial. Pure ammonia precipitates neither one nor the other.

The following are essential distinctions. Baryta and all its salts, except the sulphate, are poisonous. The corresponding strontitic salts are innocent. Baryta tinges flame yellow; strontia, red: strontia has less attraction for acids than baryta; hence the strontitic salts are decomposed by baryta. The greater number of the barytic salts are less soluble than those of strontia, and they differ in their respective forms and solubilities. Pure baryta is ten times more soluble in water than pure strontia.

Section VII. *Magnesium.*

388. The metallic base of magnesia has not hitherto been obtained; but, when that earth is negatively electrized with mercury, the resulting compound decomposes water, and gives rise to the formation of *magnesia.*

389. *Magnesia or Oxide of Magnesium*—is concluded, from indirect experiments, to consist of 11 metal + 7,5 oxygen; its representative number, therefore, is 18,5. It may be procured by exposing the carbonate of magnesia to a red heat. Magnesia is a white insipid substance, which slightly greens the blue of violets. Its specific gravity is 2,3; it is almost infusible and insoluble in water. It does not absorb carbonic acid, or moisture, as is the case with the other alcaline earths.

390. *Native Magnesia* is a very rare mineral, and has hitherto been found only at *Hoboken*, in new Jersey. Its colour is greenish white; its texture lamellar and soft. According to the analysis of Dr. Bruce, it consists of

70	magnesia.
30	water.
100	

391. *Chloride of Magnesium* may be obtained by passing chlorine over red-hot magnesia; oxygen is expelled, and a substance obtained which moisture converts into muriate of magnesia.

392. *Muriate of Magnesia* is very deliquescent, and difficultly crystallized. Its solution has a bitter saline taste. Exposed to heat and air, muriatic acid flies off, and the magnesia remains pure. It consists of

Magnesia,	18,5
Muriatic acid,	34,5
	53

393. Muriate of Magnesia is found in a few saline springs, and also in the water of the ocean. By evaporating a pint of sea-water we obtain

Common Salt....................	180,5 grs.
Muriate of Magnesia............	23,
Sulphate of Magnesia	15,5
Sulphate of Lime	7,1
	226,1.

Murray's *Analysis of Sea-Water, Edinb. Phil. Trans.* Vol. VIII. p. 205.

The average specific gravity of sea-water, is 1,026 or 1,028. It freezes at about 28,5° and does not appear materially to differ in composition in different latitudes, provided it be taken from a sufficient depth. Near the mouths of rivers, and in the vicinities of melting ice or snow, its composition will of course vary.

394. *Chlorate of Magnesia* is a bitter deliquescent salt.

395. *Hydriodate of Magnesia* is deliquescent, and loses hydriodic acid, by exposure to heat.

396. *Nitrate of Magnesia* crystallizes in rhomboidal prisms, deliquescent, and soluble in half its weight of water. Its taste is cooling and bitter, and it is decomposed at a red heat. It contains,

Magnesia,	18,5
Nitric acid,	50,5
	69

397. *Sulphuret of Magnesia.*—Sulphur and Magnesia do not combine.

398. *Sulphite of Magnesia* is prepared by passing sulphurous acid through water containing diffused magnesia. It forms tetraedral crystals soluble in 20 parts of water at 60°.

399. *Sulphate of Magnesia* is a commonly occurring compound of this earth, much used in medicine as an aperient. It is largely consumed in the preparation of carbonate of magnesia. It crystallizes in four-sided prisms with reversed dihedral summits, or four-sided pyramid. Its taste is bitter. It is soluble in its own weight of water at 60°. When exposed to a red heat, it loses its water of crystallization, amounting to about 50 *per cent.*, but is not decomposed. It consists of

Magnesia	18,5
Sulphuric acid	37,5
	56

In its crystallized state, it may be considered as composed of 1 proportional of dry sulphate + 7 proportionals of water, or

56	sulphate.
59,5	water.
115,5	

This salt is usually obtained from sea-water, occasionally from saline springs, and sometimes by the action of sulphuric acid on magnesian limestones. It was once procured from the springs of Epsom in Surrey, and hence called *Epsom salt*. It has been found native.

400. *Ammonio Sulphate of Magnesia* may be obtained by mixing solution of sulphate of ammonia, with solution of sulphate of magnesia; or by pouring ammonia into a solution of the sulphate of magnesia, in which case, part only of the magnesia is thrown down, the remainder forming with the sulphate of

ammonia this triple salt. It crystallizes in octoëdra and consists of

68	sulphate of magnesia.
32	sulphate of ammonia.
100	

Fourcroy. *Annales de Chim.* VI.

401. *Phosphuret of Magnesia,* not examined.

402. *Phosphate of Magnesia* is formed by adding the carbonate of magnesia to phosphoric acid. It is insoluble. The bi-phosphate crystallizes in irregular six-sided prisms, soluble in 14 parts of water, at 60°, and is efflorescent.

403. *Ammonio Phosphate of Magnesia* is formed by mixing the solutions of phosphate of ammonia, and phosphate of magnesia; it precipitates in the form of white crystalline powder, or in small four-sided prisms, tasteless, and scarcely soluble in water, but readily soluble in dilute muriatic acid. Exposed to a high temperature it falls into powder, evolves ammonia, and fuses with difficulty. According to Fourcroy, it contains equal weights of phosphate of ammonia, phosphate of magnesia, and water.

404. *Carbonate of Magnesia* is generally procured by adding carbonated alcalies to a solution of sulphate of magnesia. It is a white, insipid, and insoluble powder, which loses its acid at a red heat, and thus affords pure (calcined) magnesia. It contains

18,5	magnesia.
20,7	carbonic acid.
39,2	

Carbonate of magnesia was first used in medicine early in the last century. It is often obtained from sea-water, after the separation of its common salt. It has been found native in Piedmont and Moravia, constituting the mineral called *magnesite.*

405. *Bicarbonate of Magnesia.*—Carbonate of magnesia is soluble in excess of carbonic acid, and this solution affords crystals of *bicarbonate* containing

18,5	magnesia.
41,4	carbonic acid.
59,9	

This solution of magnesia in excess of carbonic acid, is very useful in some calculous complaints.

406. *Borate of Magnesia* may be formed artificially. It occurs native in a mineral called *boracite,* hitherto only found in the duchy of Luneburgh. Its primitive form is the cube, but the edges and angles are generally replaced by secondary planes, and four of the angles are always observed to present a greater number of facets than the other four—these crystals become electric by heat; the most complex angles being rendered positive, and the simplest negative. It sometimes contains lime.

407. The salts of magnesia are for the greater part soluble in water, and afford precipitates of magnesia, and of carbonate of magnesia, upon the addition of pure soda, and of carbonate of soda. Phosphate of soda occasions no immediate precipitate when added to a magnesian salt, but the addition of ammonia causes a white precipitate of the triple ammonio magnesian phosphate.

408. The fossils which contain magnesia are generally soft and apparently unctuous to the touch; they have seldom either lustre or transparency, and are generally more or less of a green colour. The *nephritic stone* or *jade, steatite* or *soapstone, talc,* and *asbestos* may be taken as instances. The *chrysolite* also contains more than half its weight of magnesia. The mineral called *bitter spar,* of which the finest specimens come from the Tyrol, contains 45 per cent. carbonate of magnesia, 52 carbonate of lime, and a little iron and manganese. Its primitive

crystal is a rhomboid nearly allied to that of carbonate of lime; its angles being 106° 15′. and 73° 45′. It is of a yellowish colour, and a pearly lustre; semi-transparent and brittle. A variety found at *Miemo,* in Tuscany, has been called *Miemite.* The species of marble, termed *dolomite,* found in the Alps, and in Icolmkill in Scotland, contains also a large quantity, generally 40 per cent. of carbonate of magnesia.—The same may be said of the magnesian limestone of Derby and Nottingham. It is generally of a yellowish colour, and less rapidly soluble in dilute muriatic acid, than the purer limestones, whence the French have termed it *chaux carbonatée lente.* The lime which it affords is much esteemed for cements, but for agricultural purposes, it is often mischievous in consequence of its remaining caustic for a very long time, and thus injuring the young plant*.

Section VIII. *Manganese.*

409. The common ore of manganese is the black or peroxide, which is found native in great abundance.

The metal may be procured by exposing the protoxide mixed with charcoal to an intense heat. It is of a bluish white colour, very brittle, and difficult of fusion. When exposed to air, it becomes an oxide. Its specific gravity = 8.

410. *Manganese and Oxygen.*—There are three definite oxides of manganese. The *protoxide* may be obtained by digesting the native black oxide in muriatic acid. Chlorine is abundantly evolved, and the hydrogen of the muriatic acid unites with part of the oxygen of the oxide to produce water. The metal thus partly deoxidized, is dissolved by the remaining muriatic acid, forming a *muriate of manganese.* Iron is almost

* For a mode of separating lime from magnesia, see a paper by Mr. Phillips, *Journal of Science and the Arts,* Vol. VI.

always present, which may be easily separated by neutralizing the muriatic solution with ammonia. The oxide of iron is directly precipitated, but oxide of manganese remains in solution and may be separated by *excess* of ammonia*. The solutions of protoxide of manganese furnish a white precipitate with the alcalies, which is a *hydrated oxide of manganese,* and which, when dried in close vessels, acquires a deep olive colour, and is the *protoxide*.

When sulphate of manganese is heated red hot, sulphurous acid is given off, and a dark red *deutoxide* of manganese remains, which forms the red salts of manganese.

The native *peroxide* is not soluble in acids. It is found in Devonshire, Somersetshire, and Aberdeenshire, and occurs compact and crystallized. The crystallized varieties have a grey metallic lustre, and are found acicularly radiated, and in rhomboidal prisms. It is generally blended with sulphate of baryta.

It appears probable that these are the only definite oxides of manganese. Their composition is variously stated by various chemists; but if deduced from their saline combinations, the two first will contain respectively one and two proportionals of oxygen; and if Berzelius's estimate be correct, (*Annales de Chimie,* 87) the number 53,5 will represent the metal, and the

Protoxide will contain of manganese	53,5 +	7,5	oxygen.
Deutoxide	53,5 +	15	ditto.
Peroxide	53,5 +	30	ditto.

According to the experiments of Chevillot and Edwards there is a fourth compound of manganese and oxygen, which they have called *manganesic acid.* (419). (*Annales de Chimie et Physique,* Tom. IV.)

411. *Manganese and Chlorine.*—By burning the metal in

* On the separation of iron from Manganese, see *Journal of Science and the Arts,* Vol. VI. p. 153.

chlorine, or by exposing muriate of manganese to a strong heat, a pink semitransparent flaky substance is obtained, consisting of 53,5 M. + 33,5 C.; when dissolved in water it produces a muriate of manganese.

412. *Nitrate of Manganese.* There are two nitrates; the one containing the protoxide, the other the deutoxide. The solution of the latter, or the *oxynitrate,* is resolved by the action of light into *nitrate,* and peroxide of manganese falls.

413. *Manganese and Sulphur* appear unsusceptible of combination; but a compound of oxide of manganese and sulphur is found in Transylvania and Cornwall. It is of a blackish grey colour and metallic lustre.

414. *Sulphate of Manganese* is formed by dissolving the protoxide in the acid, or by boiling in it the peroxide, in which case oxygen is evolved. There are two sulphates. The one, which contains the protoxide, is white; the other, containing the deutoxide, is red. The former crystallizes in rhomboidal prisms, and consists of

61 protoxide.
37,5 sulphuric acid.

The red sulphate contains

68,5 deutoxide.
75 sulphuric acid.

415. *Phosphuret of Manganese* is of a blue white metallic lustre, and considerably inflammable.

416. *Phosphate of Manganese* is precipitated in the form of a white insoluble powder, by adding phosphate of soda to muriate of manganese.

417. *Carbonate of manganese* is white, insipid, and insoluble in water. It consists of

61 protoxide.
20,7 carbonic acid.

418. The salts of manganese containing the protoxide, are

mostly soluble in water, and the solution becomes turbid and brown by exposure to air. They are not precipitated by hydriodic acid; they furnish white precipitates with the alcalies, which soon become discoloured by exposure to air; they are precipitated white by ferro-prussiate of potassa, and yellow by hydrosulphuret of ammonia.

The salts containing the deutoxide afford a dirty red precipitate with the alcalies.

419. When equal parts of black oxide of manganese and nitre are ignited, a compound results which has been called *cameleon mineral*, in consequence of the changes of colour which its aqueous solution exhibits. M. M. Chevillot and Edwards have ascertained, that in this compound the black oxide of manganese has absorbed an additional proportion of oxygen, and acquired the property of forming a neutral *manganesate of potassa*, which exists in the red cameleon, and may be obtained in crystals. When there is excess of alcali, the cameleon is green. (*Annales de Chimie et Physique*, Tom. IV.)

420. The native peroxide of manganese is used in the laboratory as a source of oxygen, and is largely employed in the preparation of chlorine for the bleachers. It is used in glass-making, and, when added in excess, gives it a red or violet colour. It is also employed in porcelain painting; and it gives common earthen-ware a black colour, by being mixed with the materials before they are formed into vessels.

Section IX. *Iron.*

421. The most important native combinations of iron, whence the immense supplies for the arts of life are drawn, are the oxides. Iron is also found combined with sulphur, and with several acids; it is so abundant that there are few fossils free from it. It is also found in some animal and vegetable bodies; and in several mineral waters.

Iron is a metal of a blue white colour, very malleable and ductile, and fusible at a white heat. Its specific gravity is $= 7{,}78$. It has not been so long known as many of the other metals; it was, however, employed in the time of Moses, for cutting instruments. It is extremely ductile, but cannot be hammered out into very thin leaves.

Iron is sometimes found native, and is usually regarded as of meteoric origin, for it is invariably alloyed by a portion of the metal nickel, and a similar alloy is found in *meteoric stones*. Native iron is flexible, cellular, and often contains a green substance of a vitreous appearance. It has been found in Africa, in America, and in Siberia, where a mass of it weighing 1,600lbs. was discovered by professor Pallas. The mass found in Peru, described by Don Rubin de Celis, weighed 15 tons. In the year 1751, a mass of the same substance was seen to fall from the atmosphere in Croatia. It appeared as a large globe of fire, and is preserved in the imperial museum of Vienna.

422. *Iron and Oxygen.*—Exposed to heat and air, iron quickly oxidizes. It unites with oxygen in at least two proportions. The *protoxide* may be procured by precipitating a solution of sulphate of iron by potassa, washing the precipitate out of the contact of air, and drying it at a red heat. It is black, and consists of 52 iron + 15 oxygen. It may also be obtained by burning iron in oxygen gas.

423. When this oxide is boiled in nitric acid, and precipitated by ammonia, washed, and dried at a low red heat, it in creases in weight, and acquires a brown colour. This is the *peroxide*, composed of 52 iron + 22,5 oxygen. It has sometimes been called *Saffron of Mars*.

The native oxides of iron constitute a very extensive and important class of metallic ores. They vary in colour, depending upon mere texture in some cases; in others, upon the degree of oxydizement. Some varieties are magnetic, and those which contain least oxygen are attracted by the magnet.

Magnetic Iron Ore is generally black, with a slight metallic lustre. It occurs massive and octoedral. It is polar, and often sufficiently magnetic to take up a needle. Its specific gravity is 4,5. It occurs chiefly in primitive countries, and is very abundant at Roslagen in Sweden, where it is manufactured into a bar-iron particularly esteemed for making steel.

Another variety of oxide of iron is called *iron glance*, and *micaceous iron ore*. It is found crystallized of singular beauty, in the Isle of Elba; and occasionally among the volcanic products of Vesuvius and the Lipari Islands.

A third variety is *Hæmatite*, or red iron-stone; it occurs in globular and stalactitic masses, having a fibrous and diverging structure. In this country it abounds near Ulverstone in Lancashire; and most of our iron-plate, and wire, is made from it. Sometimes it is of a brown, black, or ochraceous colour.

A fourth variety of oxide of iron, is known under the term of *clay-iron-stone*, on account of the quantity of argillaceous earth with which it is contaminated. It is found in masses of different shapes and sizes, and sometimes in small rounded nodules like peas. Some of the globular masses are called *ætites*. It is abundant in the coal formations of Shropshire, South Wales, Staffordshire, and Scotland.

Though this is far from the purest iron ore found in this country, it is the chief source of the cast and bar iron, in ordinary use. Its employment is chiefly referable to the coal which accompanies it.

The essential part of the process by which these ores of iron are reduced, consists in decomposing them by the action of charcoal at high temperatures. The argillaceous iron of Wales, Shropshire, *&c.*, is first roasted, and then smelted with lime-stone and coke; the use of the former being to form a fusible compound with the clay of the ore, by which the latter is enabled to act upon the oxide, and to reduce it to the metallic state.

424. The two oxides of iron form distinct salts with the acids.

The salts containing the black oxide are of a green colour, mostly crystallizable, become reddish brown by exposure to air, are insoluble in alcohol, and their solutions absorb nitric oxide gas and become of a deep olive colour.

The salts with the brown oxide do not crystallize; they are brown, soluble in alcohol, and do not absorb nitric oxide.

The alcalies precipitate hydrated oxides from these solutions.

425. *Iron and Chlorine* unite in two proportions—the *chloride* may be obtained by evaporating *green muriate of iron* to dryness, and exposing the residuum to a red heat. A grey brittle substance is formed, consisting of one proportional of iron and two of chlorine; 52 + 67.

When iron wire is heated in chlorine, it burns with a red light, and produces a compound which rises in beautiful brown scales. It is the *perchloride of iron*, and consists of one proportional of iron, and three of chlorine 52 + 100,5. The chloride and perchloride of iron produce *muriate* and *oxymuriate* of iron when acted upon by water. These salts are both deliquescent and uncrystallizable.

426. *Iodine and Iron* readily form a brown compound, fusible at a red heat, and which, when acted upon by water, forms a *hydriodate* of a green colour.

427. The *nitric acid* dissolves the protoxide and peroxide of iron, and produces a green *nitrate* and a red *oxynitrate*, neither of which are crystallizable.

428. *Sulphur and Iron.*—There are two sulphurets of iron —the *black sulphuret* is composed of 52 iron + 30 sulphur; and the *yellow sulphuret*, or *bisulphuret*, of 52 iron + 60 sulphur. The former compound is produced by melting sulphur with iron filings; it exists in nature under the name of *magnetic*

pyrites—the bisulphuret is exclusively a natural product, very abundant, and called *iron pyrites*.

Magnetic pyrites is not found crystallized; it is generally brown, or whitish yellow, and is not a common mineral.

Common pyrites is found massive, and crystallized in a variety of forms; its primitive form is the cube. It often occurs in nodules. Its colour is different shades of brass yellow.

The principal use of pyrites is in the formation of *green vitriol,* for which purpose the ore is gently roasted and exposed to air and moisture. Some varieties are spontaneously decomposed, and furnish this salt. That the magnetic pyrites contains just half the proportion of sulphur existing in the common pyrites was first shewn by Mr. Hatchett. (*Phil. Trans.* 1804).

429. *Sulphates of Iron.*—The sulphuric acid with the protoxide of iron forms a salt which crystallizes in green rhomboidal prisms, of a styptic taste, soluble in twice their weight of cold water. This salt is called *copperas* or *green vitriol,* and is often prepared by exposing roasted pyrites to moisture. It consists of one proportional of protoxide $= 67 +$ two proportionals of acid $= 75$.

430. *Oxysulphate of Iron* is obtained by dissolving the moist red oxide in dilute sulphuric acid; it does not crystallize, but affords, by evaporation, a brown deliquescent mass, consisting of 1 oxide $+$ 3 sulph. acid, or 74,5 oxide $+$ 112,5 sulph. acid. It is formed in the mother waters of the sulphate. Its taste is highly astringent, and when dry it becomes white.

431. *Phosphuret of Iron* may be formed by dropping phosphorus into a crucible containing red-hot iron wire; it is a brittle grey compound, and acts upon the magnet.

432. *Phosphates of Iron.*—These are both insoluble, and may be formed by adding solution of phosphate of soda, to sulphate and oxysulphate of iron. The *phosphate* of iron is of a pale blue colour; the *oxyphosphate* is white. The former is found

native, in the form of a blue earthy powder, and also in green prismatic crystals.

433. *Iron and Carbon.* The different kinds of cast iron contain more or less carbon, which materially affects their properties. *Steel* and *plumbago*, are carburets of iron.

434. *Carbonic Acid* may be combined with the protoxide of iron, by adding carbonate of potassa to sulphate of iron; a green precipitate of *carbonate of iron* falls, which, exposed to air, becomes brown, and evolves carbonic acid.

Spathose Iron Ore is a native carbonate, containing a little manganese and carbonate of lime. It occurs in Germany, and in some parts of Cornwall, crystallized in imperfect rhomboids. Its colour is yellowish, or brownish grey.

435. When hydrocyanate of potassa is added to the solutions of salts of iron, it occasions a white precipitate in those containing the black oxide, and a blue precipitate in those containing the red oxide. The former precipitate is a hydrocyanate of iron, containing the protoxide; the latter, a hydrocyanate, containing the peroxide, and which has been long known under the name of *Prussian blue*.

This compound is usually prepared by the following process: Equal parts of subcarbonate of potassa and some animal substance, such as dried blood, or horn shavings, are heated red hot, in a crucible, and six or eight parts of water are poured upon the mixture when it has quite cooled. The solution is filtered and found to contain *hydrocyanate of potassa*, along with subcarbonate of potassa, and some other products. It is mixed with a solution containing two parts of alum and one of sulphate of iron,—a precipitate falls, at first of a dingy green hue, but which, by copious washings with very dilute muriatic acid, acquires a fine blue tint, and is called *Prussian Blue*, having been discovered by Diesbach a colour-maker of Berlin, in 1710.

In this process the animal matter is decomposed and resolved into a variety of products arising from the re-union of its ultimate component parts. The matter remaining in the crucible contains cyanuret of potassium, and when acted upon by water, hydrocyanate of potassa is formed in consequence of the decomposition of a portion of the water, and consequently the principal salts contained in the washings of the black matter remaining in the crucible, are subcarbonate and hydrocyanate of potassa, which when added to a solution of sulphate of iron, form a precipitate of oxide and hydrocyanate of iron,—the former is removed by the dilute muriatic acid. The aluminous earth of the alum, gives a *body* to the precipitate, which improves it as a pigment.

436. When hydrocyanate of iron is boiled with potassa, it is decomposed; it loses its blue colour, oxide of iron is formed, and on filtering and evaporating the solution, a triple salt is obtained, consisting of hydrocyanic acid, potassa, and oxide of iron; this has been called *triple prussiate of potassa,* and *ferrocyanate of potassa.* It is best formed by adding powdered prussian blue, to a hot solution of potassa, as long as its colour is destroyed. This salt forms yellow cubic and tabular crystals. (For a mode of preparing this salt, see Henry's *Chemistry*, Vol. II. p. 112.)

437. The ferrocyanates of ammonia, soda, lime, magnesia, baryta, and strontia, may be obtained by boiling those alcalies and earths with Prussian blue.

438. Mr. Porrett (*Phil. Trans.* 1814.) considers the ferrocyanates as compounds of the respective bases, with an acid consisting of the elements of the hydrocyanic acid united to the protoxide of iron. He obtained this acid dissolved in water, by adding to a solution of ferrocyanate of baryta, just sulphuric acid enough to precipitate the baryta. It has a pale yellow colour, no smell, and is decomposed by a gentle heat,

or strong light, in which case hydrocyanic acid is formed, and white hydrocyanate of iron is deposited, which becomes blue by exposure.

439. *Borate of iron*, is of a yellow colour and insoluble. It is formed by adding borate of soda to sulphate of iron.

440. The salts of iron are mostly soluble in water, and the solution is reddish brown, or becomes so by exposure to air. It affords a blue precipitate with ferrocyanate of potassa; a black precipitate with hydro-sulphuret of ammonia. Infusion of gall nuts produces a black or deep purple precipitate. The hydriodic acid occasions no change.

441. Of the alloys of iron, *tin-plate* is the only one of consequence. It is made by dipping clean iron plates into melted tin. When washed over with a weak acid, the crystalline texture of the tin becomes beautifully evident, forming an appearance, which has been called *moiré metallique*. (*Journal of Science*, Vol. V. p. 368.)

442. An extremely important part of the chemical history of iron relates to the varieties of the metal which are found in commerce. These are much too numerous to be dwelt upon here; so that we shall limit our observations to the principal of them only, which are *cast iron*, *wrought iron*, and *steel*.

Of cast iron there are two principal varieties distinguished by the terms *white* and *grey*. The first is very hard and brittle, and, when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions. (Daniel, *Journal of Science and Arts*, Vol. II. p. 280.)

Grey or mottled iron, is softer and less brittle: it may be bored, and turned in the lathe. When immersed in dilute muriatic acid it affords a large quantity of black insoluble matter, which Mr. Daniel considers as a triple compound of carbon, iron, and silicium, and which has some very singular properties. The texture of the metal resembles bundles of minute needles.

Cast iron is in this country converted into wrought iron by a curious process, called *puddling*. The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flame. After a time the mass heaves, emits a blue flame, and gradually grows tough and becomes less fusible, and at length congeals. In that state it is passed successively between rollers, by which a large quantity of extraneous matter is squeezed out, and the bars are now malleable. They are cut into pieces, placed in parcels in a very hot reverberatory, and again hammered or rolled out into bars. They are thus rendered more tough, flexible, and malleable, but much less fusible, and may be considered as nearly pure iron.

Analysis shews that cast iron contains oxygen, carbon, often sulphur and phosphorus, either silica or silicium, and it appears very probable that calcium exists in some of the varieties.

By the processes of puddling and rolling, these substances are burned away or squeezed out, and thus malleability is conferred upon the metal by rendering it more pure. A specimen of cast iron analyzed by Berzelius afforded Iron 91,53—Manganese 4,57—Carbon 3,90.

A bar of wrought iron, when its texture is examined in the mode pointed out by Mr. Daniel, presents a fasciculated appearance, the fibres running in a parallel and unbroken course throughout its length. This structure may be well seen by tearing a bar of wrought iron asunder.

443. Steel is a compound of iron with carbon, the proportions being variable. It combines the fusibility of cast with the malleability of bar iron, and when heated and suddenly cooled it becomes very hard, whence its superiority for the manufacture of cutting instruments. If kept for a long time in fusion, it loses carbon and becomes pure iron.

Iron is converted into steel by a process called *cementation*, which consists in heating bars of the purest iron in contact with charcoal: it absorbs carbon and increases in weight, at the same time acquiring a *blistered* surface. This, when drawn down into smaller bars and beaten, forms *tilted steel;* and this broken up, heated, welded, and again drawn out into bars, forms *shear steel. English cast steel* is prepared by fusing blistered steel with a flux composed of carbonaceous and vitrifiable ingredients, casting it into ingots, and afterwards, by gentle heating and careful hammering, giving it the form of bars.

Wootz or *Indian steel* has lately attracted much notice from the permanence of the edge, when made into cutting instruments. The cause of this superiority is unknown.

The texture of steel, as exhibited by the action of an acid, is not fibrous, but appears somewhat lamellated.

444. If steel be heated nearly red hot, and plunged into cold water, it becomes extremely hard and brittle, and is in that state used for files, which are the hardest of all steel instruments.

Different cutting instruments require different degrees of hardness, which is given to them by the process called *tempering*. It consists in heating the hardened steel up to a certain point; and as at different temperatures its surface acquires different colours, in consequence of oxydizement, it was customary to judge of the *temper* by the colour. The first change of colour is between 430° and 450°: it becomes pale yellow, and is used for razors and other instruments in which a strong back supports a very keen edge.

At 470° it becomes full yellow, and is used for penknives.

At 490° it becomes brownish, and is used for scissors.

At 510° slightly purple, for pruning and pocket knives.

At 530° purple, for carving knives.

At 550° blue, for springs, sword blades, &c., and at 600° it becomes nearly black and very soft.

An improved mode of tempering consists in immersing the goods in oil or quicksilver, which is then raised to a due degree of heat indicated by the mercurial thermometer.

Section X. *Zinc.*

445. Zinc is found in the state of oxide and of sulphuret. It may be obtained pure by dissolving the zinc of commerce in dilute sulphuric acid, and immersing a plate of zinc for some hours in the solution, which is then filtered, decomposed by subcarbonate of potassa, and the precipitate ignited with charcoal in an iron or earthen retort.

Zinc is a bluish white metal, sp. gr. 7, malleable at 300°, but very brittle when its temperature approaches that of fusion, which is about 680°.

446. *Oxide of Zinc* is obtained by heating the metal exposed to air. At a red heat it takes fire, burns with a bright flame, and is converted into a white flocculent substance, formerly called *pompholix*, *nihil album*, and *philosopher's wool*. It consists of 33 zinc and 7,5 oxygen. This oxide is white, tasteless, and soluble in the alcalies.

447. *Chloride of Zinc* is formed by heating leaf zinc in chlorine. It is a volatile fusible compound, producing a *muriate of zinc* by the action of water. It consists of 33 zinc + 33,5 chlorine. It was formerly called *butter of zinc*.

448. *Iodine and Zinc* readily combine, and produce a fusible, volatile, and crystalline compound, which, when exposed to air, deliquesces into *hydriodate of zinc*.

The iodide consists of 33 zinc + 117,7 iodine, and the hydriodate may be regarded as consisting of one proportional oxide of zinc = 40,5 + one proportional hydriodic acid = 118,7.

449. *Nitrate of Zinc* is a deliquescent salt, which crystallizes with difficulty in four-sided prisms. They consist of

$$\begin{array}{r l} 40{,}5 & \text{oxide.} \\ 50{,}5 & \text{nitric acid} \\ \hline 91 & \end{array}$$

450. *Sulphuret of Zinc* exists native under the name of *Blende*. It may be formed artificially by heating oxide of zinc with sulphur, and is then of a yellow brown colour. It consists of 33 zinc + 15 sulphur.

Blende is a brittle soft mineral, of different shades of brown and black. Its primitive form is the rhomboidal dodecaëdron. It usually contains traces of iron and lead. It is an abundant mineral, and important as a source of the pure metal, which is obtained by roasting the ore, and afterwards exposing it to heat in proper distillatory vessels, mixed with charcoal. The English miners call it *black jack*.

451. *Sulphate of Zinc.*—The metal is readily oxidized and dissolved by dilute sulphuric acid, hydrogen gas is given off, and a transparent colourless solution of sulphate of zinc results, which, by evaporation, affords crystals in the form of four-sided prisms, terminated by four-sided pyramids. It sometimes is found native.

This salt is soluble in 1,5 parts of water at 60°. It consists of 1 proportional of oxide$=$40,5$+$1 proportional of acid$=$37,5. Its crystals contain 7 proportionals of water $=$ 59,5. Sulphate of zinc is prepared for the purposes of the arts from the native sulphuret, and is usually in the form of a white amorphous mass, called *white vitriol*.

452. *Phosphuret of Zinc* is a brilliant lead-coloured compound.

453. *Phosphate of Zinc* is not crystallizable. It may be obtained by dissolving zinc in phosphoric acid, and evaporation to dryness.

454. *Carbonate of Zinc* occurs native, forming one of the varieties of the mineral called *calamine*. It may be formed by adding carbonate of potassa to sulphate of zinc. It consists of 40,5 oxide of zinc + 20,7 carbonic acid = 61,2. It is white and tasteless.

The primitive form of calamine, which occurs both crystallized and massive, is an obtuse rhomboid. It is often found investing carbonate of lime, which has sometimes been decomposed, and the calamine remains in pseudo-crystals. This mineral abounds in Somersetshire, Flintshire, and Derbyshire. A beautiful variety, coloured by carbonate of copper, is found at Matlock. A variety of calamine, containing silicious earth, is known by the name of *electric calamine*, from its property of becoming electrical when gently heated.

455. *Borate of Zinc* is an insoluble white powder.

456. The salts of zinc are mostly soluble in water, and the solutions are colourless and transparent: they are not precipitated by hydriodic acid. Potassa, soda, and ammonia form white precipitates, soluble in excess of the alcali, and of sulphuric acid. Hydrosulphuret of ammonia produces a yellowish white precipitate. The soluble phosphates, carbonates, and borates, produce white precipitates.

Section XI. *Tin.*

457. This metal has been known from the remotest ages. It was in common use in the time of Moses, and was obtained at a very early period from Spain and Britain by the Phœnicians.

The native oxide is the principal ore of tin; the metal is obtained by heating it to redness with charcoal.

Tin has a silvery white colour; it is malleable, though sparingly ductile. Sp. gr. 7,30 It melts at 440°, and by exposure to heat and air is gradually converted into a white peroxide.

458. *Protoxide of Tin* is obtained by precipitating muriate of tin by ammonia; it falls in the state of hydrate; when dried, it is of a grey colour, and undecomposable by heat. It dissolves in the alcalies; exposed to heat and air it passes into the state of peroxide.

459. *Peroxide of Tin* is formed by treating the metal with nitric acid: there is a violent action attended by the formation of nitrate of ammonia. It dissolves in the alcalies, and hence some chemists have called it *stannic acid.* This is the native oxide.

460. Native oxide of tin is found in Cornwall, in Spain, and in Saxony: it has also been found in Brittany, in France; in the East Indies, and in South America. The specific gravity of the native oxide is 7: its primitive crystal is an obtuse octoëdron, of which the modifications are extremely numerous. In some of the valleys of Cornwall, tin is found in rounded nodules, of various sizes, mixed with pebbles and rounded fragments of rocks. To separate the tin from the alluvial matter, currents of water are passed over it, and hence these deposits have been called *stream works,* and the tin ore, *stream tin.* One of the most extensive of these is a branch of Falmouth Harbour.

A modification of stream tin is called *wood* tin. It usually appears in small banded fragments of globular masses.

461. The number representing tin is 55. The protoxide consists of 55 tin + 7,5 oxygen. The hydrate of 62,5 oxide + 8,5 water; and the peroxide of 55 tin + 15 oxygen.

462. *Chloride of Tin* is procured by heating together an amalgam of tin and calomel; it is a grey semi-transparent crystalline solid, which dissolves in water, forming a muriate of tin; it consists of 55 tin + 33,5 chlorine.

If tin be heated in chlorine, or if amalgam of tin be distilled with corrosive sublimate, a bi-chloride is obtained: it is a transparent colourless fluid, and when poured into water, is instantly converted into oxymuriate of tin. It consists of 55 tin + 67 chlorine. It was formerly called *Libavius's Fuming Liquor:* it exhales fumes when exposed to a moist air, and produces muriatic acid and oxide of tin.

463. The *muriate of tin* used by dyers, may be obtained by boiling one part of tin with two of muriatic acid. This solution quickly absorbs oxygen from the air and from several compounds, and if added to certain metallic solutions, revives or deoxidizes them. With solution of gold it produces a purple precipitate used in painting porcelain. (*Purple of Cassius.*) It crystallizes in small deliquescent needles. With infusion of cochineal it produces a purple precipitate.

The oxymuriate of tin (muriate containing the peroxide) may be formed by dissolving the metal in nitro-muriatic acid, or by adding water to the bichloride, or by exposing the muriate to air. It does not occasion precipitates in the metallic solutions, and produces scarlet with cochineal.

464. *Nitrate of Tin* may be formed by acting upon the metal by dilute nitric acid; a yellow solution which will not crystallize is obtained; exposed to air it absorbs oxygen, and peroxide of tin precipitates.

During the action of stronger nitric acid upon tin, a portion of ammonia is always formed, in consequence of the decomposition of the acid and of water. It may be rendered evident by the addition of potassa to the *nitrate.*

465. *Tin and Sulphur.* There are two sulphurets of tin. That containing 1 proportional of metal + 1 of sulphur, may be procured by heating tin with sulphur; it is of a deep bluish colour and crystallizes in long needles. The bisulphuret is of a bright golden yellow colour, and flaky structure, and has been

termed *Aurum musivum*. It is formed by heating peroxide of tin with sulphur. These sulphurets consist respectively of 55 tin + 15 sulphur, and 55 tin + 30 sulphur.

466. *Sulphate of Tin.*—When tin is boiled in sulphuric acid, a solution is obtained which deposits white acicular crystals.

467. *Hydrosulphuretted Oxide of Tin* is yellow brown.

468. *Phosphate of Tin* is formed by adding phosphate of soda to the solutions of tin. It is not soluble in water.

469. There is no *Carbonate of Tin.*

470. *Borate of Tin* is an insoluble white powder.

471. The salts of tin are mostly soluble in water. They are precipitated, of an orange colour, by hydriodic acid, and by hydrosulphuret of ammonia, provided no excess of acid be present. Solution of muriate of gold and of corrosive sublimate produce purple and black precipitates in the salts of tin containing the protoxide, but none in those containing the peroxide.

SECTION XII. *Cadmium.*

472. THIS metal is contained in certain ores of zinc, and especially in the black fibrous Blende of Bohemia. It may be procured by digesting the ore in muriatic acid, by which a mixed muriate of zinc and cadmium is obtained: it should be evaporated to dryness, and re-dissolved in water. If cadmium be present, the solution affords a bright yellow precipitate with sulphuretted hydrogen; and upon immersing into it a plate of zinc, metallic cadmium is precipitated, which may be fused into a button in the usual way.

The physical properties of cadmium closely resemble those of tin: its specific gravity is 8,63. It fuses and volatilizes at a temperature a little below that required by tin. Air does not act upon it except when heated, when it forms an orange-coloured oxide, not volatile, and easily reducible.

Oxide of Cadmium readily dissolves in acids; it is precipitated by potassa in the state of a white hydrated oxide, soluble in ammonia. Sulphuretted hydrogen forms a yellow precipitate, and zinc throws down metallic cadmium.

From some recent experiments of Mr. Children, it appears that the oxide contains

Cadmium	82,5
Oxygen	7,5

Consequently the representative number of the metal will be 82.5.

The other compounds of cadmium have scarcely been examined.

Section XIII. *Copper.*

473. This metal is found native, and in various states of combination. Of its ores, the oxide, chloride, sulphuret, sulphate, phosphate, carbonate, and arseniate, are the most remarkable. The metal may be obtained perfectly pure by dissolving the copper of commerce in muriatic acid; the solution is diluted, and a plate of iron is immersed upon which the copper is precipitated. It may be fused into a button.

It was known in the early ages of the world, and was the principal ingredient in domestic utensils, and in the instruments of war, previous to the discovery of malleable iron. The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks.

Copper has a fine red colour and much brilliancy; it is very malleable and ductile, and has a peculiar smell when warmed or rubbed. It melts at a cherry red or dull white heat. Its specific gravity = 8,8.

474. Native copper occurs in a variety of forms, massive,

dendritic, granular, and crystallized in cubes, octoëdra, &c. It is found in Cornwall, Siberia, Saxony, Hanover, Sweden, and America; chiefly, but not exclusively, in primitive rocks.

475. *Copper and Oxygen* —There are two oxides of copper. The red or *protoxide* occurs native. It may be formed artificially, by dissolving a mixture of metallic copper, and peroxide of copper, in muriatic acid. When potassa is added to this solution, a hydrated protoxide of an orange colour falls; if quickly dried out of the contact of air, it becomes of a red brown: it consists of 60 copper + 7,5 oxygen.

476. The native oxide, or *ruby copper*, is of a red or steel grey colour, soft and brittle, and occurs massive and crystallized in octoëdra, dodecaëdra, and cubes. There is a beautiful variety in fine capillary crystals; and another, which is compact and earthy, called *tile ore*. Cornwall abounds in fine specimens of this ore.

477. *Peroxide of Copper* is procured by precipitating nitrate of copper by potassa, washing the precipitate, and exposing it to a red heat. It is black, and consists of 60 copper + 15 oxygen

478. *Copper and Chlorine.*—Gaseous chlorine acts upon copper with great energy, and produces two chlorides; the one a fixed fusible substance, which is the chloride, consisting of 1 proportional of copper = 60 + 1 proportional of chlorine = 33,5. The other a volatile yellow substance, which is a bichloride, and contains 60 copper + 67 chlorine.

The *chloride of copper* was first described by Boyle in 1666, under the name of *rosin of copper*. It may be obtained by heating the bichloride. It is insoluble in water, but soluble in muriatic acid, from which potassa throws down a protoxide.

The *bichloride* may be formed by dissolving peroxide of copper in muriatic acid, and evaporating to dryness by a heat below 400°. It is soluble in water, producing a muriate, from which potassa precipitates the peroxide.

Native Chloride of Copper is found in Peru and Chili, sometimes in the form of green sand, and sometimes massive and crystallized. Its primitive form is an octoëdron. It is of a deep green colour, and is said to contain 83 chloride + 17 water.

479. An *iodide of copper* is precipitated from solutions of the metal by hydriodic acid. It is brown and insoluble.

480. *Nitric Acid*, diluted with three parts of water, rapidly peroxidizes copper, forming a bright blue solution, which affords deliquescent prismatic crystals on evaporation. It consists of 75 oxide + 50,5 acid.

481. Potassa forms, in this solution, a bulky blue precipitate of *hydrated peroxide of copper*.

When crystals of nitrate of copper are coarsely powdered, sprinkled with a little water, and quickly rolled up in a sheet of tin foil, there is great heat produced, nitrous gas is rapidly evolved, and the metal often takes fire.

482. If ammonia be added to solution of nitrate of copper, it occasions also a precipitate of hydrate; but if it be added in excess, the precipitate is re-dissolved, and a triple compound produced.

483. *Copper and Sulphur.*—There are two sulphurets of copper, both of which exist native; the one is black, and may be formed artificially, by heating a mixture of copper filings and sulphur: as soon as the latter melts, a violent action ensues, the copper becomes red hot, hydrogen escapes, and a black brittle body is formed, consisting of 60 copper + 15 sulphur.

The *bisulphuret* is a common ore of copper, called *pyrites*. It consists of 60 copper + 30 sulphur, and is of a golden yellow colour.

The native black sulphuret of copper is principally found in

* The hydrogen appears to be derived from the sulphur. (195.)

primitive countries. In England it occurs in great beauty, crystallized and massive, in Cornwall and in Yorkshire. Its colour is grey; its lustre shining and metallic, and it yields easily to the knife. Its primitive form is a six-sided prism, which passes into the dodecaëdron with triangular faces and various modifications of it.

Copper pyrites, or the yellow sulphuret of copper, is the most important and generally occurring ore, from which the largest proportion of the copper of commerce is derived; it occurs in a variety of forms, its primitive crystal being the regular tetraëdron. The Cornish mines are very productive of this ore, and it is the principal product of the Parys mountain mine in Anglesea. A beautiful iridescent variety occurs in the Ecton mine in Staffordshire.

484. *Copper and Sulphurous Acid.—Sulphite of copper* may be obtained by passing sulphurous acid into water, through which oxide of copper is diffused. Small red crystals are formed, composed of protoxide of copper and sulphurous acid.

485. *Copper and Sulphuric Acid—Oxysulphate of Copper—Blue Vitriol.*—This salt is formed by dissolving peroxide of copper in sulphuric acid; it crystallizes in rhomboidal prisms of a fine blue colour. It is produced upon a large scale, by exposing roasted sulphuret of copper to air and moisture. It consists of 75 peroxide + 75 sulphuric acid; when crystallized it contains 10 proportionals of water, and consequently its composition will stand thus:—

1 proportional of peroxide........	75
2 proportionals of sulphuric acid ..	75
10 proportionals of water..........	85
	235

By cautiously adding ammonia to a solution of the foregoing salt, a *subsulphate of copper* is precipitated, consisting of 150 oxide + 37,5 acid. The alcalies precipitate hydrated peroxide from the solution of this salt, and excess of ammonia forms a *triple sulphate of ammonia and copper.*

486. *Phosphorus and Copper* form a grey brittle phosphuret.

487. *Phosphate of Copper* may be formed by mixing solution of sulphate of copper with phosphate of soda; it is a bluish green insoluble powder, composed of 75 oxide + 26 acid.

Native phosphate of copper has been found near Cologne. It is of a green colour, and forms small rhomboidal crystals.

488. *Carbonate of Copper,* artificially prepared, by adding carbonate of potassa to sulphate of copper and drying the precipitate, is a green compound, insoluble in water, consisting, according to Mr. Phillips, of 75 oxide + 20,7 carbonic acid, 8,5 water.

There is a fine blue cupreous preparation, called *Refiners' Verditer,* principally made by silver refiners. It consists, according to Mr. Phillips, of 3 proportionals of oxide, 4 of carbonic acid, and 2 of water. (*Journal of Science,* Vol. IV. p. 277.) There is a very inferior pigment, also called verditer, which is a mixture of subsulphate of copper and chalk.

Both the green and blue carbonate of copper exist native. The former, or *malachite,* is found in various forms, but never regularly crystallized, the octoëdral variety being a pseudo-crystal derived from the decomposition of the red oxide. This mineral occurs in the greatest beauty in the Uralian mountains of Siberia; it is rarely found in Cornwall. It is of various shades of green, and often cut into small slabs, or used as beads and broach stones.

The blue carbonate is found in great perfection at Chessy, near Lyons; also in Bohemia, Saxony, *&c.* It occurs crystallized in rhomboids and imperfect octoëdra; it also is found in small globular masses, massive, and earthy.

489. *Hydrocyanate of Copper* is a brown compound, ob-

tained by adding ferrocyanate of potassa to sulphate or nitrate of copper.

490. Many of the alloys of copper are important. With gold it forms a fine yellow ductile compound, used for coin and ornamental work. Sterling or standard gold consists of 11 gold + 1 copper. The specific gravity of this alloy is 17,157. With silver it forms a white compound, used for plate and coin. Lead and copper require a high red heat for union; the alloy is grey and brittle. (See *Gold and Silver*.)

Of the alloys of copper with the preceding metals the most important are brass and bell metal.

491. *Brass* is an alloy of copper and zinc. The metals are usually united by mixing granulated copper with calamine and charcoal: the mixture is exposed to heat sufficient to reduce the calamine and melt the alloy, which is then cast into plates. The relative proportions of the two metals vary in the different kinds of brass; there is usually from 12 to 18 per cent. of zinc. Brass is very malleable and ductile when cold; its colour and little liability to rust recommend it in preference to copper for many purposes of the arts. In *pinchbeck* the proportion of zinc amounts to about 25 per cent.

Bell metal and *bronze* are alloys of copper and tin; the former consisting of three parts of copper and one of tin; the latter of from 8 to 12 of tin with 100 of copper.

Vessels of copper used for culinary purposes are usually coated with tin, to prevent the food being contaminated with copper. Their interior surface is first cleaned, then rubbed over with sal-ammoniac. The vessel is then heated, and a little pitch spread over the surface; a bit of tin is then rubbed over it, and it instantly unites with and covers the copper.

492. The cupreous salts are nearly all soluble in water, and of a blue or green colour. Ammonia produces a compound of a very deep blue, when added in excess to these solutions; hydrosulphuret of ammonia forms a black precipitate, and a

plate of iron plunged into a liquid salt of copper precipitates metallic copper.

Section XIV. *Lead.*

493. The natural compounds of this metal are very numerous. The most important is the sulphuret, whence the pure metal is chiefly procured. It is also found combined with carbonic, sulphuric, phosphoric, arsenic, molybdic, and chromic acids, and with oxygen and chlorine. To obtain lead perfectly pure, it may be dissolved in nitric acid; the solution evaporated to dryness; the dry mass re-dissolved in water and crystallized; the crystals heated strongly with charcoal afford the metal quite pure.

Lead is of a bluish white tint; it melts at 600°, and by the united action of heat and air is readily converted into an oxide. Its specific gravity = 11,35.

494. *Oxides of Lead.*—There are three oxides of lead. The *protoxide* is the basis of the salts; it may be obtained by heating the nitrate of lead to redness in a close vessel. It is insipid and insoluble in water, of a pale yellow colour, and, when fused, crystallizes on cooling in irregular scales. It is very soluble in solutions of potassa and soda; and when in fusion it readily dissolves several of the earthy bodies, and, of the common metallic oxides; hence the use of lead in *cupellation*. (See *Gold*). If it be considered as a protoxide, consisting of one proportional of lead and one of oxygen, then the number 97 will represent lead, and it will consist of 97 L. + 7,5 oxygen. This oxide is known in commerce under the name of *massicot;* or when mixed with a portion of red oxide, as obtained by calcining lead upon a large scale, it is called *litharge.*

A substance supposed to be native minium has been found in some of the Saxon and French lead mines, also in Yorkshire.

495. If the protoxide be exposed to heat and oxygen, it gradually acquires a bright red colour, and is known under the name of *minium,* or *deutoxide* of lead. This oxide, when exposed to nitric acid, is resolved into protoxide, which is dissolved, and into *peroxide,* which is an insoluble brown substance, consisting of 97 L. + 15 oxygen. Minium affords on analysis 97 L. + 11,25 oxygen, and may, therefore, be regarded as a definite compound of the protoxide and peroxide.

496. *Lead and Chlorine.—Chloride of lead.* When laminated lead is heated in chlorine, the gas is absorbed, and a chloride of lead results, composed of 97 L. + 33,5 C. The same substance is obtained by adding muriatic acid to nitrate of lead; it is white and fusible, and on cooling forms a horn-like substance *(plumbum corneum).* It dissolves in 22 parts of water at 60°.

This substance is sometimes prepared by acting upon a solution of common salt by litharge; solution of soda and chloride of lead are formed; the latter is fused and known under the name of *patent yellow;* it appears to be a compound of oxide and of chloride of lead.

A native chloride of lead has been found in Derbyshire and in Bavaria, crystallized in quadrangular prisms of a greenish yellow colour.

497. *Iodide of Lead,* formed by heating leaf lead with iodine, is a yellow insoluble compound. It is formed by adding hydriodic acid to solution of nitrate of lead. It consists of

Iodine	117,7
Lead	97,0
	214,7

498. *Nitrate of Lead* is obtained by dissolving the metal in dilute nitric acid, and evaporation. The salt crystallizes in

tetraëdra and octoëdra, which are white and semi transparent, and of a styptic taste. It is solúble in 8 parts of water at 212°. It consists of 104,5 oxide of lead + 50,5 nitric acid.

499. *Subnitrate of Lead* may be formed by boiling a mixture of equal weights of nitrate and protoxide of lead in water, filtering while hot, and setting it by to crystallize; it forms pearly crystals, of a sweet astringent taste. (Chevreul, *Annales de Chimie*, LXXXII.) It consists of two proportionals oxide = 209, + one proportional nitric acid 50,5.

Chevreul and Berzelius have described three *nitrites* of lead, but their composition appears doubtful. (*Annales de Chimie*, LXXXIII. and LXXXVIII.)

500. *Sulphuret of Lead* may be formed artificially by fusion. Its lustre and colour much resemble pure lead, but it is brittle: it consists of 97 lead + 15 sulphur. It occurs native in great variety and abundance: it is usually called *galena*, and is the principal source of the vast commercial demands of the metal. Its primitive form is the cube, of which there are several modifications, and among them the octoëdron. It often contains traces of silver, and sometimes in such quantity as to render it worth separating, which is effected by exposing the roasted sulphuret to the action of heat and air in shallow earthen dishes; the lead becomes oxidized and converted into litharge, while the silver is left pure, in consequence of its power of resisting the influence of heat and air. This process is *cupellation*. The litharge is afterwards reduced by fusion with charcoal.

There is a specular variety of galena called, in Derbyshire, *slickensides;* and which, when touched by the miner's pick, often splits asunder with a kind of explosion.

501. *Sulphite of Lead* may be obtained by digesting yellow oxide of lead in sulphurous acid. It is white, insoluble, and tasteless, and consists of one proportional of each of its components; namely, 30 sulphurous acid + 104,5 oxide of lead. When heated it loses sulphurous acid.

502. *Sulphate of Lead.* When metallic lead is boiled in concentrated sulphuric acid, sulphurous acid is evolved, and a white sulphate of lead is formed. It is so nearly insoluble, that it may be formed by adding dilute sulphuric acid, or an alcaline sulphate, to a solution of nitrate of lead. Dr. Thomson found, that after having been dried at a temperature of 400°, it might be heated to redness in a platinum crucible without losing weight. Heated on charcoal by the blowpipe, it is decomposed and reduced. It consists of one proportional of sulphuric acid = 37,5, and one proportional of oxide of lead = 104,5; and its representative number is, therefore, 142.

Sulphate of lead is found native in Anglesea and in Scotland, crystallized in prisms and in octoëdra.

503. *Hydrosulphuretted Oxide of Lead* is of a deep brown colour, and is produced by adding sulphuretted hydrogen, or hydrosulphuret of ammonia, to any solution of lead; hence the use of those compounds as tests of the presence of lead.

504. *Phosphuret of Lead* may be formed by dropping phosphorus into melted lead. It is of the colour of lead, and soon tarnishes.

505. *Phosphate of Lead* is formed by mixing solutions of nitrate of lead and phosphate of soda, or phosphoric acid. It is yellowish white; insoluble in water; soluble in fixed alcaline solutions, and in nitric acid. It fuses before the blowpipe, and crystallizes on cooling. It consists of 104,5 oxide of lead + 26 phosphoric acid = 130,5*.

Native phosphate of lead has been found in the mines of Cumberland, Durham, Yorkshire, and of Wanlock Head, in Scotland. Its colour is various shades of green, yellow, and

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* Berzelius, in the *Annales de Chimie et Physique*, Tom. II. has announced several other compounds of lead and phosphoric acid.

brown. Its primitive form is a rhomboid, but it usually occurs in six-sided prisms. It is semi-transparent and brittle.

506. *Carbonate of Lead.*—When an alcaline carbonate is added to nitrate of lead, a white precipitate of carbonate of lead falls: it is tasteless, insoluble in water, but soluble in fixed alcaline solutions. It is employed as a white paint, under the name of *white lead* or *ceruse*, and is usually prepared by exposing sheet lead to the action of the vapour of vinegar. The process is described in Aikin's *Dictionary, (Art. Lead.)* It consists of 104,5 oxide of lead + 20,7 carbonic acid = 125,2 carbonate of lead.

Native carbonate of lead is one of the most beautiful of the metallic ores: it occurs crystallized and fibrous, the former transparent, the latter generally opaque. It is soft and brittle, and occasionally tinged green with carbonate of copper, or grey by sulphuret of lead. The octoëdron is its primitive form: it also occurs prismatic and tabular. It has been found in Cumberland and Durham, and the acicular variety of great beauty in Cornwall.

507. Ferrocyanate of Potassa produces a white precipitate when added to the soluble salts of lead.

508. *Borate of Lead* is precipitated in the form of a white powder when borate of soda is mixed with nitrate of lead.

509. The soluble salts of lead have a sweetish austere taste, and are characterized by the white precipitate produced by ferrocyanate of potassa, the brown by hydrosulphuret of ammonia, and the yellow by hydriodate of potassa.

The salts insoluble in water are dissolved by soda and potassa, and by nitric acid, when the metal is rendered manifest by sulphuretted hydrogen. Heated by the blowpipe upon charcoal they afford a button of metal.

510. *The Alloys of Lead* with the preceding metals are unimportant.

Section XV. *Antimony.*

511. This metal is found *native* in Sweden, in France, and in the Hartz; but its principal ore is the *sulphuret* which is found massive and crystallized, and of which there are several varieties. The most common is the *radiated*, which is of a grey colour, brittle, and frequently crystallized in four and six-sided prisms. This ore may be decomposed, and the pure metal obtained from it, by the following process: Mix three parts of the powdered sulphuret with two of crude tartar, and throw the mixture by spoonfuls into a red-hot crucible; then heat the mass to redness, and a button of metal will be found at the bottom of the crucible. Reduce this button to fine powder, and dissolve it in nitro-muriatic acid—pour this solution into water, which will occasion the precipitation of a white powder, which is to be washed and mixed with twice its weight of tartar and exposed to a dull red heat in a crucible. The button now obtained is pure antimony.

Antimony is of a silvery white colour, brittle and crystalline in its ordinary texture. It fuses at 800°, and is volatile at a high heat. Its specific gravity is 6,712.

512. *Antimony and Oxygen.*—These bodies form two well defined compounds, the history of which is of great importance to the pharmaceutical chemist. (See Phillips on the *Pharmacopœia*, p. 58.)

The *Protoxide of Antimony* is thus obtained: To 200 parts of sulphuric acid add 50 parts of powdered metallic antimony. Boil the mixture to dryness, wash the dry mass, first in water, and then with a weak solution of subcarbonate of potassa, a white powder remains, which, when thoroughly washed with hot water, is *Protoxide of Antimony*. It may also be procured by dissolving antimony in muriatic acid, pouring the solution into water, and washing the white precipitate with weak solution of potassa.

This protoxide exists in all the active antimonial preparations—in emetic tartar, kermes, glass of antimony, golden sulphuret, &c. It is fusible at a red heat, decomposed by sulphur and charcoal; and when acted on by nitric acid, is converted into peroxide.

513. *Peroxide of Antimony* is procured by acting for a considerable time upon the powdered metal, by excess of hot nitric acid, and exposing the product to a red heat. It is of a yellow white, difficultly fusible, and does not form soluble salts with acids. The *diaphoretic antimony* of old Pharmacopœiæ consisted of this oxide, which compared with the protoxide is nearly inert.

When metallic antimony in fusion is exposed to a bright red heat, it is converted into an oxide which appears to be the protoxide, and which condenses in long and delicate needles when sublimed. It was formerly called *argentine flowers of antimony**.

Native Oxide of Antimony is occasionally found incrusting the native metal and the sulphuret.

I have found by experiment that the oxygen in the protoxide is to that in the peroxide as 1 to 2, and if we consider these as

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* Berzelius, *Annales de Chimie*, 86, 225., has described four oxides of antimony; but it is probable that the first and the fourth are not distinct compounds: they are said to be constituted as follows:

1 Suboxide consisting of	100 antimony	+ 4,65	oxygen.
2 Oxidule	100	+ 18,60	„
3 White oxide	100	+ 27,90	
4 Yellow oxide	100	+ 37,20	

The two last oxides are called by Berzelius, stibious and stibic acids.

The second and fourth are probably the oxides described in the text, but their composition is by no means satisfactorily ascertained.

the second and fourth oxide described by Berzelius, we obtain the number 40 as the representative of antimony. Dr. John Davy's valuable Researches on the composition of the chlorides, (*Phil. Trans.* 1812) give the number 42,5 as the representative of antimony; and this nearly agrees with my own experiments upon the composition of the protoxide, (obtained by precipitation from emetic tartar), which give 45, and which I shall therefore adopt.

The protoxide of antimony will then consist of

Antimony 45 + Oxygen 7,5 = 52,5.

And the peroxide will be composed of

Antimony 45 + Oxygen 15 = 60.

514. *Antimony and Chlorine* combine in one proportion only to produce the *chloride of antimony*. (Butter of Antimony.) The powdered metal takes fire when thrown into the gas, and a compound, at first liquid, but afterwards concreting, is formed. It may also be produced by the distillation of antimony with bichloride of mercury, or by dissolving the protoxide of antimony in muriatic acid. It consists of 45 A. + 33,5 C. When water is added to the chloride of antimony, a mutual decomposition ensues, and hydrated protoxide of antimony, formerly called *Algarotti's powder*, and muriatic acid result.

515. *Iodide of antimony* is of a dark red colour; acted upon by water, it produces hydriodic acid and oxide of antimony.

516. *Sulphuret of Antimony* is easily formed by fusing the metal with sulphur. It consists of 45 A. + 15 S. Its colour is dark grey and metallic. Its specific gravity 4,36. It closely resembles the native sulphuret. (506.)

When the native sulphuret is exposed under a muffle to a dull red heat, it gradually loses sulphur and absorbs oxygen, being converted into a grey powder, which consists of a mixture of protoxide of antimony and sulphuret. If the heat be increased, this fuses into a transparent substance, formerly called *glass of antimony*. Its composition is variable; it generally contains about 85 per cent of protoxide and 15 of sulphuret. In that which is imported for pharmaceutical purposes, from Germany and Holland, there is usually a considerable portion of siliceous earth. Compounds of the protoxide with larger quantities of the sulphuret have been termed *saffron of antimony*, or *crocus metallorum*, and *liver of antimony*.

517. *Sulphate of Antimony*.—When sulphuric acid is boiled upon finely-powdered antimony, the metal is oxidized, and an acid sulphate and a subsulphate of antimony are the results. In both these salts the metal is in a state of protoxide.

518. *Nitrate of Antimony* may be formed by boiling the protoxide in nitric acid. It crystallizes in small brilliant scales.

519. *Hydrosulphuretted Oxide of Antimony*. This compound has long been known under the name of *kermes mineral*; it is commonly prepared as follows: Equal parts of sulphuret of antimony and common potash are fused together; the resulting mass is finely powdered, and boiled in ten times its weight of water. The liquor is filtered while hot; and, during cooling, it deposits *kermes*. The mother liquor of kermes deposits a copious yellowish red precipitate upon the addition of dilute sulphuric acid, which, when washed and dried, is known under the name of *golden sulphur of antimony*. It is improperly called in the London Pharmacopœia *antimonii sulphuretum præcipitatum*.

In forming these compounds, the following changes seem to have taken place. The sulphuret of antimony and potassa acts upon the water, a portion of which is decomposed; hydrogen is transferred to the alcaline sulphuret, to form hydrosulphuret of potassa; hydrogen and oxygen unite to the sulphuret of antimony, producing a hydrosulphuretted oxide of that metal, *(kermes)*, which remains dissolved in the hot alcaline hydrosulphuret, and of which one portion is precipitated as that solution cools. When dilute sulphuric acid is added, the hydrosulphuret of potassa is decomposed, sulphate of potassa is formed, and sulphur and sulphuretted hydrogen are liberated; the sulphur falls in combination with the *kermes*, producing the *golden sulphur*, or sulphuretted hydrosulphuret.

520. *Phosphuret of Antimony* is formed by heating together equal parts of oxide of antimony, phosphoric acid, and charcoal. It is white and brittle.

521. *Phosphate of Antimony* has not been formed : in the *London Pharmacopœia* there is a preparation called *pulvis antimonialis*, formed by heating one part of sulphuret of antimony with two of hartshorn shavings. The action of heat upon the sulphuret has already been described (516). Its effect upon the hartshorn shavings is to destroy the animal matter, leaving little else than phosphate of lime. So that the pulvis antimonialis consists essentially of protoxide of antimony, mixed with phosphate of lime. This preparation is usually considered analogous to, if not identical with *James's powder*, which, according to Dr. Pearson's analysis (*Phil. Trans.* 1791) consists of 43 phosphate of lime, 57 oxide of antimony in 100.

522. Neither *carbonate*, *hydrocyanate*, nor *borate* of antimony exist.

523. The solutions of antimony afford orange-coloured precipitates with sulphuretted hydrogen, and those which are acid are precipitated when largely diluted with water.

524. Antimony forms brittle alloys with the malleable metals. When gold was alloyed with $\frac{1}{1920}$ its weight of antimony, the compound was perfectly brittle; and even the fumes of antimony in the vicinity of melted gold are sufficient to destroy its ductility. (Hatchett, *Phil. Trans.* 1803.) Alloyed with lead in the proportion of 1 to 16, antimony forms the alloy used for printers' types. With iron it forms a hard whitish alloy formerly called martial regulus, which may be obtained by fusing two parts of sulphuret of antimony with one

of iron filings; a scoria consisting chiefly of sulphuret of iron is formed, and the fused alloy beneath usually presents a stellated appearance in consequence of its crystallization. This star was much admired by the alchemists, who considered it a mysterious guide to transmutation. With lead, a white and rather brittle compound is formed, used for the plates upon which music is engraved, and which is also often contained in pewter.

Section XVI. *Bismuth.*

525. This metal is found native; combined with oxygen; and with arsenic and sulphur.

Native bismuth occurs crystallized in octoëdra and cubes, and generally contains arsenic and sometimes cobalt. It has been found in Cornwall, and in Germany, France, and Sweden.

The metal may be obtained pure, by dissolving the bismuth of commerce in nitric acid; water is added to the nitric solution, which separates oxide of bismuth. This oxide is easily reduced in the usual way.

Bismuth is a brittle white metal, with a slight tint of red: its specific gravity $= 9.8$. It fuses at 476°, and always crystallizes on cooling.

526. When bismuth is exposed to heat and air it oxidizes, forming a fusible *white oxide*. It consists of 66,5 bismuth + 7,5 oxygen. It occurs, though very rarely, native. It has been found in Cornwall, and Saxony.

527. *Chloride of Bismuth*, is procured by heating the metal in the gas, or by evaporating the muriate to dryness and submitting the residue to distillation, when the chloride sublimes, and afterwards deliquesces into what was called *butter of bismuth*. (John Davy, *Phil. Trans.* 1812.) It consists of 66,5 bismuth + 33,5 chlorine.

528. *Iodide of Bismuth* is of an orange-colour, and insoluble in water.

529. *Nitrate of Bismuth* crystallizes in small four-sided prisms, consisting of 74 oxide + 50,5 acid. It is decomposed by water, and the oxide of bismuth is thrown down in the form of a fine white powder, called *magistery of bismuth*, or *pearl white*.

530. *Sulphuret of Bismuth* is of a bluish colour and metallic lustre; it consists of 66,5 B. + 15 sulphur. This compound has been found native in Cornwall, Bohemia, Saxony, and Sweden. It occurs massive and acicular, its lustre is metallic, and its colour bluish grey. It is a very rare mineral.

531. *Sulphate of Bismuth* consists of 74 oxide + 37,5 acid; it is a white compound insoluble in, but decomposed by, water, which converts it into a *subsulphate* and *supersulphate*.

532. *Hydrosulphuretted Oxide of Bismuth* is of a deep brown approaching to black.

533. *Phosphuret of Bismuth* does not, according to Pelletier, exist; at least, it cannot be formed by the usual process.

534. Neither the *phosphate, carbonate, hydrocyanate*, nor *borate* of bismuth have been sufficiently examined.

535. Bismuth forms *alloys*, some of which are remarkable for their fusibility. With gold, platinum, and silver, it forms brittle compounds. A compound of eight parts of bismuth, five of lead, and three of tin, liquefies at 212°; it is called *fusible metal*. The addition of one part of quicksilver renders it yet more fusible. Bismuth enters into the composition of *soft solders*.

Section XVII. *Cobalt.*

536. The native combinations of cobalt are the oxide, and compounds of the metal with iron, nickel, arsenic, and sulphur. It is also found combined with arsenic acid. In the white and

grey cobalt ores, the metal is combined with iron, and with arsenic: Some of the varieties are crystallized in cubes, octoëdrons and dodecaëdrons. The red ore is an arseniate. The finest specimens are the produce of Saxony.

To obtain pure cobalt, the cobalt of commerce, in fine powder, may be calcined with four parts of nitre, and washed in hot water, by which arsenic is separated: then digest in dilute nitric acid, and immerse a plate of iron, which will separate the copper; filter and evaporate to dryness; digest the dry mass in ammonia; expel the excess of ammonia by heat, taking care not to produce a precipitate, and then add solution of potassa, which throws down oxide of nickel; filter immediately, and boil, which will occasion the separation of oxide of cobalt, and which, ignited with charcoal, furnishes the pure metal.

Cobalt is of a reddish grey colour, brittle, and difficultly fusible. Its specific gravity is 7,7.

537. *Cobalt and Oxygen* unite in two proportions. The *protoxide* is formed by adding potassa to the nitrate, and drying the precipitate; it appears very dark blue or nearly black. By exposure to heat and air, it absorbs an additional portion of oxygen, and is thus converted into black *peroxide*. The protoxide, when recently precipitated and moist, is *blue;* and, if left in contact of water, becomes a *red hydrate*. The composition of the protoxide of cobalt, deduced from an experiment upon the sulphate, is 100 cobalt + 17 oxygen, hence the representative number of the metal may be considered 43, and the protoxide, consisting of one proportional of each of its components, will contain 43 cobalt + 7,5 oxygen = 50,5.

This result is nearly the same as that published by Proust. (*Annales de Chimie,* Vol. LX.) but widely different from that of Rothoff; (*Annals. of Phil.* Vol. III). It appears, however, from the experiments of the latter chemist, that the peroxide of cobalt contains 100 metal + 36,7 oxygen, which, in reference to the above deduction from the sulphate, would lead us to consider it as containing one proportional of cobalt and two of oxygen, or 43 + 15 = 58.

538. Cobalt burns when heated in chlorine; but the *chloride of cobalt* has not been examined.

539. *Iodide of Cobalt* also remains unexamined.

540. *Muriate of Cobalt* is a deliquescent salt, of a blue green colour; it may be formed by digesting either oxide in muriatic acid; when a little diluted, it becomes pink; the pale pink solution when written with, is scarcely visible; but if gently heated the writing appears in brilliant green, which soon vanishes as the paper cools, in consequence of the salt absorbing the aërial moisture. This solution has been termed *sympathetic ink.*

541. With nitric acid the oxide of cobalt furnishes a red deliquescent *nitrate of cobalt.*

542. *Sulphuret of Cobalt* is formed by heating the oxide with sulphur. It is yellowish white.

43. *Sulphate of Cobalt* forms red rhombic crystals, soluble in 24 parts of water at 60°. It may be made by dissolving the protoxide in dilute sulphuric acid. In its crystallized state it consists of one proportional of oxide, one of acid, and seven of water; or

50,5	protoxide of cobalt.
37,5	sulphuric acid.
59,5	water.
147,5	

This sulphate forms triple compounds with potassa and with ammonia, which have not been examined.

544. *Phosphuret of Cobalt* is a white brittle compound.

545. *Phosphate of Cobalt* may be formed by double decomposition, as by adding phosphate of soda to muriate of cobalt; it is insoluble, of a purple colour, and, if mixed with eight parts of gelatinous alumina, and heated, it produces a beautiful blue, which may sometimes be employed by painters as a substitute for ultramarine. (*Thenard.* Tom. II. p. 419.)

546. *Carbonate of Cobalt* is formed by decomposing the nitrate, muriate, or sulphate of cobalt by carbonate of potassa, or soda; a reddish blue powder is precipitated.

547. *Hydrocyanate of Potassa* forms a grass-green precipitate in solutions of cobalt.

548. The salts of cobalt all contain the protoxide; they are decomposed by ammonia, which, if added in excess, re-dissolves the oxide: phosphoric, carbonic, arsenic, and oxalic acids, produce by double decomposition, insoluble red compounds in these solutions.

549. The alloys of cobalt are unimportant. The chief use of cobalt is as a colouring material for porcelain, earthenware, and glass; it is principally imported from Germany in the state of *zaffre*, and *smalt* or *azure*.

Zaffre is prepared by calcining the ores of cobalt, by which sulphur and arsenic are volatilized, and an impure oxide of cobalt remains, which is mixed with about twice its weight of finely-powdered flints.

Smalt and azure blue are made by fuzing zaffre with glass; or by calcining a mixture of equal parts of roasted cobalt ore, common potash, and ground flints. In this way a blue glass is formed, which, while hot, is dropped into water, and afterwards reduced to a very fine powder.

Section XVIII. *Uranium.*

550. The native oxide has been termed *uranite*. Its crystalline form is the cube and several modifications; it often occurs in thin quadrangular plates. It exhibits various shades of yellow and green. It has been found in France, and of great beauty near Callington, in Cornwall. The native sulphuret of uranium was formerly mistaken for an ore of zinc, and called *pechblende*, till Klaproth, in 1789, demonstrated it to contain uranium combined with sulphur. From this ore

uranium may be obtained by the following process:—Reduce it to powder, and expose it to heat in a muffle; then digest in dilute nitro-muriatic acid, and precipitate by excess of ammonia; collect and wash the precipitate, and dry it at a heat approaching redness.

When exposed to a violent heat with a small quantity of charcoal powder, metallic uranium is obtained.

Uranium is of a grey colour, brittle, and very difficult of fusion; its specific gravity has not been ascertained with precision. Bucholz states it as = 9,0. (Gehlen's *Journal*, IV.)

551. Very few experiments have hitherto been made upon this metal. The oxide precipitated from its nitric solution by alcalies is yellow, but by heating with charcoal it becomes black. The uranitic ore, called by the Germans *uran glimmer*, is a hydrate of the yellow oxide. The salts of uranium have a yellow colour and an astringent metallic taste. Potassa forms in their solutions a yellow precipitate, and carbonate of potassa a white precipitate; both these precipitates are insoluble in excess of pure alcali, but dissolve in the carbonate.

According to Bucholz, the peroxide of uranium consists of 80 metal + 20 oxygen = 100; so that if we consider it as containing one proportional of metal and two of oxygen, we obtain 60 as the representative number of uranium; and as it is probable that the protoxide contains half the quantity of oxygen, the oxides would consist respectively of 60 uranium + 7,5 oxygen, and 60 uranium + 15 oxygen.

SECTION XIX. *Titanium.*

55. TITANIUM exists in the state of oxide in two minerals, in titanite and in menachanite.

Titanite is a nearly pure oxide of titanium; it is of a brown colour, and occurs embedded in the quartz and granite of primitive countries, and sometimes traverses rock crystals in fine hair-like filaments. In this country it occurs at Bedgellert, in Caernarvonshire; and near Killin, in Scotland. The finest specimens are those from the vicinity of Mont Blanc and St. Gothard.

The mineral known by the name of *anatase, octoëdrite,* and *oysanite,* is nearly of the same nature as titanite. It is found in Bavaria, Norway, Switzerland, and in the valley of Oysans in France.

Menachanite consists principally of oxides of titanium and iron; it is found in the bed of a small stream at Menachan, in Cornwall. *Nigrine, iserine,* and *rutilite,* or *sphene,* are also ores of titanium.

553. The metal may be obtained from titanite by fusion with potassa; the fused mass, washed with water, leaves oxide of titanium, containing a little iron; it is to be dissolved in muriatic acid, and precipitated by oxalic acid. The oxalate affords the metal by intense ignition with charcoal.

From menachanite, white oxide of titanium may be obtained by fusing it with potassa, and adding muriatic acid to the alcaline solution.

554. Titanium is of the colour of copper. It is said to be susceptible of three degrees of oxidizement, the colours of the oxides being blue, red, and white.

The blue is formed by exposing the metal to heat and air; the red is the native oxide; and the white is that which is precipitated from the alcaline solution of titanite or menachanite by muriatic acid. According to Vauquelin and Hecht, (*Journal des Mines,* No. xv.), the white oxide contains 89 parts of red oxide and 11 of oxygen.

555. The action of chlorine and of iodine upon titanium, have not been examined. The carbonate of titanium dissolves in muriatic, nitric, and sulphuric acids, and phosphoric acid occasions a white precipitate in these solutions. Neither the *muriate, nitrate,* nor *sulphate,* are crystallizable.

When the native oxides of titanium are fused with carbonate of potassa, a white *carbonate of titanium* is formed.

556. The solutions of titanium are colourless, and afford white precipitates with the alcalies; ferrocyanate of potassa gives a green precipitate, and infusion of galls a red one. Hydrosulphuret of ammonia occasions a greenish precipitate.

Section XX. *Cerium.*

557. This metal has been obtained by Hisinger and Berzelius, from a mineral found at Bastnas in Sweden, to which they have given the name of *cerite*. It is also contained in *allanite*, a mineral from Greenland, first distinguished as a peculiar species by Mr. Thomas Allan, of Edinburgh. It contains, according to Dr. Thomson's analysis, about 40 per cent. of oxide of cerium.

The ore is calcined, pulverized, and digested in nitro-muriatic acid. To the filtered solution, saturated with potassa, oxalic acid is added, which occasions a precipitate; this, when dried and ignited, is oxide of cerium.

This oxide is extremely difficult of reduction. Mr. Children succeeded in fusing it by the aid of his powerful voltaic apparatus, and when intensely heated it burned with a vivid flame, and was partly volatilized. Vauquelin describes it as a hard white brittle metal. (*Annales de Chimie*, Vol. IV.)

558. Vauquelin and Hisinger have described two oxides of cerium. The protoxide is white, and consists of cerium 100 + oxygen 17,41. The peroxide is brown, and contains cerium 100 + oxygen 26,11. If we regard the first oxide as containing 1 proportional of metal + 2 of oxygen, and the second, 1 + 3, then the number representing cerium will be 86,2, and the oxides will consist respectively of 86,2 cerium + 15 oxygen, and 86,2 cerium + 22,5 oxygen.

559. Muriatic and sulphuric acids dissolve the red peroxide of cerium: they afford yellow crystals. The muriate is deliquescent; the sulphate difficultly soluble. The sulphate of the protoxide forms white crystals of a sweet taste. Nitric acid forms with the protoxide a deliquescent compound, of a sweet taste. The carbonate is precipitated from these solutions in the form of a white powder.

560. The salts of cerium are either white or yellow, as they contain either the protoxide or peroxide. Their neutral solutions taste sweet. Ferrocyanate of potassa, and oxalate of ammonia, produce white precipitates, soluble in nitric and muriatic acids. Neither sulphuretted hydrogen, nor gallic acid, occasion any precipitate.

Section XXI. *Tellurium.*

561. The ores of tellurium are, 1. *Native,* in which the metal is combined with iron and a little gold. 2. *Graphic ore,* which consists of tellurium, gold, and silver. 3. *Yellow ore,* a compound of tellurium, gold, lead, and silver; and 4. *Black ore,* consisting of the same metals with copper and sulphur.

These ores have only been found in the Transylvanian mines, and in Siberia.

The metal is extracted from them by precipitating their diluted nitro-muriatic solution by potassa, which is added in excess: the clear liquor is poured off and saturated with muriatic acid, which affords a precipitate of oxide of tellurium. This, heated in a glass retort with charcoal, furnishes the metal. Tellurium is of a bright grey colour, brittle, easily fusible, and very volatile. Its specific gravity = 6,1.

562. *Oxide of Tellurium.*—Exposed to heat and air, tellurium readily burns, exhaling a peculiar odour, and forming

a yellowish white oxide, consisting, according to Klaproth, (*Bieträge*, Vol. III.) of

Tellurium ..	100
Oxygen	20,5

Hence the number 36,5 may be adopted as the representative of the metal; and if the above be considered a protoxide, it will contain

1 proportional of tellurium =	36,5
1 ———— of oxygen.. =	7,5
Oxide of Tellurium .. =	44

563. *Chloride of Tellurium* is a white fusible compound, formed by heating the metal in chlorine. According to Davy, (*Elements*, p. 410.) it consists of 2 tellurium + 1,85 chlorine, which would give 1 proportional of each of its components, or

Tellurium	36,5
Chlorine	33,5
Chloride of tellurium ..	70

564. Iodine readily combines with tellurium, forming a deep brown *iodide*, which dissolves in water, forming the *hydriodate of tellurium*.

565. Tellurium combines with hydrogen, producing *telluretted hydrogen gas*. The soluble salts of tellurium furnish white precipitates, when neutrallized by alcalies, which are soluble in excess either of the solvent or precipitant.

566. The oxide of tellurium is readily soluble in muriatic, nitric, and sulphuric acids. The muriate affords a precipitate on the addition of water. (Berzelius, Nicholson's *Journal*, XXXVI.)

The salts of tellurium are decomposed by the alcalies, and the precipitate is re-dissolved when they are added in excess. Hydrosulphuret of ammonia forms a brown precipitate; ferrocyanate of potassa occasions no change. Zinc or iron immersed into the solutions cause the separation of metallic tellurium.

567. The oxide of tellurium combines with many of the metallic oxides, acting the part of an acid, and producing a class of compounds which have been called *tellurates*.

Tellurate of potassa may be formed by heating oxide of tellurium with nitre, and dissolving the residuum in boiling water, which, on cooling, deposits an imperfectly crystallized white powder, difficultly soluble in water.

Solution of tellurate of potassa added to solutions of lime, baryta, strontia, copper, and lead, forms insoluble tellurates of the oxides of those metals.

Section XXII. *Selenium.*

568. This body is placed, rather from analogy than experiment, among the metals. It was discovered by Berzelius in the sulphur of Fahlun in Sweden, and was first suspected to be tellurium. Its colour is grey; its lustre bright metallic. It fuses at a few degrees above the boiling point of water, and when slowly cooled, assumes a granular fracture. It boils and evaporates in close vessels at a temperature a little below redness. Heated before the blow-pipe it volatilizes with a very powerful and peculiar smell, somewhat like that of horseradish.

Selenium unites with the metals. With potassium it combines with great energy, producing a greyish compound, with metallic lustre, and which, when thrown into water, evolves *selenuretted hydrogen gas*, which is highly irritating to the nostrils. It combines both in the dry and humid way with the fixed alcalis, and forms red compounds. Heated to dryness with nitric acid it forms a volatile and crystallizable compound, called *selenic acid*, which unites to some of the metallic oxides, producing a distinct class of *seleniates*. (*Annales de Chymie et Physique*, Tom. VII. *Thomson's Annals*, Vol. XI. and XII.)

SECTION XXIII. *Arsenic.*

569. THIS metal may be obtained from the white arsenic of commerce, by mixing it with half its weight of black flux*, and introducing the mixture into a Florence flask, placed in a sand bath, gradually raised to a red heat: a brilliant metallic sublimate of pure arsenic collects in the upper part of the flask. The volatility of white arsenic prevents its easy reduction by charcoal alone; but the potassa in the flux enables it to acquire a temperature sufficient for its perfect reduction.

Arsenic is of a steel blue colour, quite brittle, and of a specific gravity = 8,3. It readily fuses, and in close vessels may be distilled at a temperature of 360°, which is lower than its fusing point. Its vapour has a very strong smell, resembling that of garlic. Heated in the air it easily takes fire, burns with a blue flame, and produces copious white fumes of oxide. Exposed to a moist air it gradually becomes incrusted with a grey powder, which is an imperfect oxide. This metal and all its compounds are virulent poisons.

Native arsenic has been found in Saxony, Hanover, France, Bohemia, and Cornwall. It usually occurs in rounded masses, or nodules, of a foliated lamellar texture, in the veins of primi-

* This is an extremely useful compound for effecting the reduction of many of the metallic oxides. It consists of charcoal and subcarbonate of potassa, and is best prepared by deflagrating in a crucible a mixture of one part of nitre and two of powdered tartar. The mixture remains in fusion at a red heat, and thus suffers the small globules of reduced metal to coalesce into a button.

tive rocks, and is often associated with silver, cobalt, lead, and nickel ores.

570. *Arsenic and oxygen.*—There are two definite compounds of arsenic and oxygen, which are both capable of forming combinations with other metallic oxides. They are sour and soluble in water, and have thence been properly termed *arsenious* and *arsenic acids.*

The arsenious acid, or as it is commonly called, *white arsenic,* or *white oxide of arsenic,* is the best known, and most commonly occurring compound of this metal; and as cases of poisoning by it are frequent, every person should be well acquainted with its characteristic properties.

Arsenious acid may easily be procured by the combustion of the metal; but as it is formed during certain metallurgic processes, that mode is rarely resorted to. It is abundantly prepared at Joachimstahl, in Bohemia, from arsenical cobalt ores, which are roasted in reverberatory furnaces, and the vapours condensed in a long chimney, the contents of which, submitted to a second sublimation, afford the white arsenic of commerce. It is white, semi-transparent, brittle, and of a vitreous fracture. Its specific gravity is 3,7. Its taste is acrid, accompanied by a very nauseous sweetness, and it is virulently poisonous, producing inflammation and gangrene of the stomach and intestines: it also proves fatal when applied to a wound; and as the local injury is in neither case sufficient to cause death, it is probable that an induced affection of the nervous system and of the heart is the cause of the mischief. (Brodie's *Observations and Experiments on the Action of Poisons, Phil. Trans.* 1812.) To get rid of the poison by producing copious vomiting and purging, and to pursue the usual means for subduing and preventing inflammation, are the principal points of treatment to be adopted in cases where this poison has been taken. (*Orfila Traité des Poisons,* Tom. I. p. 123.)

By slow sublimation arsenious acid forms tetraëdral crystals: it is volatile at 380°, and has no smell when perfectly free from metallic arsenic. (Dr. Paris, *Journal of Science and Arts*, Vol. VI.) According to Klaproth, 1000 parts of water at 60° dissolve 2,5 of white arsenic, and 1000 parts of water at 212°, dissolve rather more than 77 parts, and about 30 parts are retained in permanent solution. The solutions taste acrid and nauseous, and redden vegetable blues. 80 parts of alcohol at 60°, dissolve one part of this acid. Its aqueous solution furnishes tetraëdral crystals by slow evaporation.

571. The composition of the arsenious acid, as estimated by Proust, Thenard, and Thomson (Thomson's *System*, Vol. I. p. 295) furnishes the following mean:

Arsenic.		Oxygen.		Arsenious Acid.
100	+	34	=	134.

If we consider this acid as a compound of one proportional of arsenic and one of oxygen, we obtain the number 44,11 as the representative of arsenic for

$$34 : 100 :: 15 : 44{,}11.$$

Without material error, therefore, we may adopt 44 as the representative of arsenic, and the arsenious acid will then consist of 44 arsenic + 15 oxygen = 59.

This acid occurs native in prismatic crystals, and in a pulverulent form: it is found in Saxony and Hungary.

572. The arsenious acid forms a distinct class of salts, called *arsenites*, which have been little examined.

The arsenites of ammonia, potassa, and soda, are easily soluble and uncrystallizable: they are formed by boiling the acid in the alcaline solutions. Those of lime, baryta, strontia, and magnesia, are difficultly soluble, and formed in the same way.

Arsenite of potassa produces a white precipitate in the white salts of manganese; a dingy green precipitate in the solutions of iron; a white precipitate in solutions of zinc and tin. Mixed with a solution of sulphate of copper, a precipitate of a fine apple-green colour falls, called from its discoverer, *Scheele's green*, and useful as a pigment. In the solutions of lead, antimony, and bismuth, it forms white precipitates: added to nitrate of cobalt it forms a pink precipitate; and bright yellow, with nitrate of uranium. With nitrate of silver it forms a white precipitate, soon becoming yellow, and very soluble in ammonia. All these precipitates are probably arsenites of the respective metals, and, heated by a blow-pipe on charcoal, they exhale the smell of arsenic. The arsenite of lead is found native in France, in Spain, and in Siberia.

573. *Arsenic acid* is obtained by distilling a mixture of 4 parts of muriatic and 24 of nitric acid off 8 parts of arsenious acid, gradually raising the bottom of the retort to a red heat at the end of the operation. It may also be procured by distilling nitric acid off powdered metallic arsenic.

Arsenic acid is a white substance, of a sour taste; it is deliquescent and uncrystallizable. Its specific gravity is 3,4. It requires for solution 6 parts of cold and 2 of boiling water; its solution reddens vegetable blues, and tastes acrid and metallic.

574. It appears, from the experiments of Proust and Thomson, that the oxygen in the arsenic acid is, to that in the arsenious acid, as 3 to 2; hence we regard it as a compound of 1 proportional of arsenic $= 44$, and 3 proportionals of oxygen $= 22{,}5$, and its representative number will be 66,5.

575. The *arseniates* are produced by the union of this acid with the metallic oxides; and many which are insoluble may be formed by adding arseniate of potassa to their respective solutions. The *arseniate of potassa* is formed by detonating in a crucible a mixture of arsenious acid and nitre. It may be crystallized, and is used in pharmacy. The *arsenite* of potassa

constitutes the active ingredient in *Fowler's mineral solution*, or *tasteless ague drop*.

Several of the metallic arseniates are found native; of these the most important are, 1. The *arseniate of iron*, which occurs in Cornwall, usually in cubic crystals of various shades of green. 2. *Arseniate of copper*, of which there are two principal varieties, the green and blue. The green is found in flattened octoëdra, in hexaëdral tables, and in prisms with dihëdral summits. Sometimes it is massive, or fibrous, and radiated. The blue variety is tetraëdral, octoëdral, and rhombic. These beautiful minerals are almost peculiar to Cornwall. 3. *Arseniate of lead* occurs in small hexaëdral crystals, of a yellow, green, or brown colour, transparent, and of a resinous lustre. It has been found in Cornwall, France, and Spain. 4. *Arseniate of cobalt*, or *peachblossom cobalt ore*, is a rare mineral found in Saxony and Cornwall.

576. *Arsenic and Chlorine.—Chloride of arsenic* is formed by throwing finely-powdered arsenic into chlorine; the metal burns and forms a whitish deliquescent and volatile compound; it may also be obtained by distilling 6 parts of corrosive sublimate with 1 of powdered arsenic; the chloride passes into the receiver in the form of an unctuous fluid, formerly called *butter of arsenic*. Mixed with water, the chloride of arsenic is decomposed, and white oxide or arsenious acid is deposited, muriatic acid being at the same time produced. Hence it may be inferred, that the chlorine is to the arsenic in the same proportion as the oxygen, and, consequently, that it consists of 1 proportional of arsenic + 2 proportionals of chlorine, which, from Dr. Davy's experiments, appears to be the case. Chloride of arsenic, therefore, is composed of

44 Arsenic + 67 Chlorine = 111 Chloride of Arsenic.

577. *Iodide of arsenic*, obtained by heating the metal with excess of iodine, is of a deep red colour, and volatile. When

acted upon by water, it produces hydriodic and arsenic acids, whence it appears probable that it contains 1 proportional of arsenic and 3 of iodine.

578. *Arsenic and hydrogen.—Arsenuretted hydrogen gas.*— When arsenic is presented to nascent hydrogen, a portion of the metal combines with the gas. The compound is best obtained by adding a portion of metallic arsenic, or of white arsenic, to the mixture of zinc filings and dilute sulphuric acid, usually employed for the production of hydrogen. (136) The gas may be collected over water, by which it is not sensibly absorbed.

The specific gravity of this gas is liable to vary according to the mode by which it is procured. I have always found it heaviest when obtained from a mixture of 4 parts of zinc, 1 of arsenic, and 3 of sulphuric acid, diluted with 4 or 5 of water. After standing a day over water, it deposits a small quantity of brown matter, which appears to be a *hydruret of arsenic*, and then has a specific gravity of from 12 to 14, hydrogen being = 1. This is considerably heavier than the usual estimation. If the gas were composed of 1 proportional of arsenic and 2 of hydrogen, without condensation, 100 cubical inches should weigh 51,75 grains, and its specific gravity to hydrogen would be 20,7. But Gay-Lussac and Thenard, (*Recherches Physico-Chimiques*, Tom. I. p. 230) have shewn by decomposing it by tin, that 100 parts expand to 140, which would still increase its specific gravity, it being probable that 3 volumes of hydrogen are condensed into 2. It is probable, therefore, that the gas, hitherto described under the name of arsenuretted hydrogen, is a mixture of the real compound with hydrogen.

The gas obtained by the above-described process smells strongly alliaceous; it extinguishes a taper, and burns with a pale blue flame, and deposits arsenic and its oxide. If detonated with about 4 volumes of oxygen, arsenious acid and water are formed. According to Stromeyer, (Nicholson's *Journal*, Vol. XIX.) it requires for its perfect combustion 0,72 parts of its bulk of oxygen; but this is probably not sufficient to burn the arsenic.

If bubbles of chlorine be passed up into a jar of arsenuretted hydrogen, standing over warm water, flame and explosion are often produced, muriatic acid is formed, and a brown hydruret is deposited; but if the gas be passed in the same way by successive bubbles into chlorine, no inflammation results, absorption takes place, and muriatic acid and chloride of arsenic are formed. If the chlorine be not very pure, and when the gases are cold, inflammation seldom follows their mixture.

Chlorine, added to a mixture of sulphuretted and arsenuretted hydrogen, causes a deposit of red sulphuret of arsenic.

Nitric acid suddenly decomposes arsenuretted hydrogen; water, oxide of arsenic, nitrous acid, and nitric oxide are the results.

579. *Arsenic and Sulphur.*—By slowly fusing a mixture of metallic arsenic and sulphur, or by heating white arsenic with sulphur, a *red sulphuret of arsenic* is obtained. It is crystallizable, and of a vitreous fracture: its specific gravity is 3,4. It is usually known under the name of *realgar,* and occurs native in Germany and Switzerland. Its primitive form is an acute octoëdron.

If white arsenic be dissolved in muriatic acid, and precipitated by hydrosulphuret of ammonia, a fine yellow sulphuret of arsenic falls, which it appears only differs in form from realgar: it is usually called *orpiment.* According to Laugier, (*Annales de Chimie,* LXXXV.) these sulphurets are composed of about 58 arsenic and 42 sulphur, which differs little from 1 proportional and 2, or

$$44 \text{ arsenic} + 30 \text{ sulphur} = 74 \text{ sulphuret of arsenic.}$$

Native orpiment is of a bright lemon or golden colour. It is generally massive and lamellar.

Sulphuret of Arsenic and Iron is found native in many parts of Europe. It is of a more silvery colour than iron pyrites, and when heated exhales the odour of arsenic. It is called *arsenical pyrites*, or *mispickel*.

580. Sulphuric acid is slowly decomposed when boiled upon arsenic. Sulphurous acid is evolved, and difficultly soluble crystalline grains of *sulphate of arsenic* are deposited as the solution cools.

581. *Phosphuret of Arsenic* is formed by heating the metal, or its oxide, with phosphorus; it is grey and brittle.

582. *Phosphate of Arsenic* is formed in difficultly soluble crystalline grains, by boiling white arsenic in phosphoric acid.

583. There appears to be no *Carbonate of Arsenic*.

584. Arsenic forms alloys with most of the metals, and they are generally brittle; with copper, however, it forms a white malleable alloy. It readily combines with cobalt, and most of the ores of that metal contain it, and it is difficultly separable.

585. As arsenic, either accidentally or intentionally taken, is a very frequent cause of death, and often the subject of judicial inquiry, it becomes of importance to point out the most effectual modes of discovering its presence. Where arsenic proves fatal, it is very seldom found in the contents of the stomach after death, but is generally previously voided by vomiting or by stool; and we often can detect it in the matter thrown off the stomach, in the form of a white powder, subsiding in water. The inflammation of stomach which results is generally a secondary effect, and takes place equally, whether the poison be swallowed or applied to a wound.

If minute quantities of white powder be detected, however, in the stomach after death, or in the matter vomited, it is to be carefully collected, and treated as follows:

(*a*.) Mix a small portion of it with about two parts of black flux; introduce the mixture into a glass tube, and gradually heat it red hot in the flame of a spirit lamp. If arsenic be present, a *steel-coloured sublimate* will attach itself to the cooler part of the tube, which, heated in contact of air, evaporates in a *white smoke strongly smelling of garlic.*

(*b.*) Boil the suspected matter in a little distilled water: and when the solution has cooled, add a few drops of solution of sulphuretted hydrogen. If arsenic be present, a *yellow precipitate* will appear.

(*c.*) To the solution *b* add a drop of solution of subcarbonate of potassa, and then a drop or two of solution of sulphate of copper. An *apple-green precipitate* indicates arsenic.

(*d.*) Add to the solution with potassa *c*, a drop of nitrate of silver. A *yellow precipitate* indicates arsenic.

It must be observed, in regard to these tests, that the first only is unequivocal, and that the appearances produced by the others may originate from the presence of other substances. When, however, all the above appearances ensue, no doubt of the existence of arsenic can be entertained. The several precipitates should be collected, and will, when placed upon a red-hot iron, exhale the peculiar smell of arsenic. The reader is referred for further particulars on this subject to Henry's *Elements of Chemistry*, Vol. II. p. 480, 8th Edit.: to Murray's *System*, Vol. III. p. 441, 4th Edit.: to Dr. Bostock's *Paper*, in the *Edinb. Med. and Surg. Journal*, Vol. v. p. 166: to Mr. Hume's *Essay*, in the *Phil. Mag.* Vol. XXXIII.; and *London Med. and Phys. Journal*, Vol. XXIII.: to Dr. Marcet's *Paper*, in the *Medico-Chirurgical Transactions*, Vol. II., and to Mr. Sylvester's *Observations*, in Nicholson's *Journal*, Vol. XXXIII.

SECTION XXIV. *Molybdenum.*

586. THE sulphuret is the most common natural compound of this metal. To procure the metal, the native sulphuret is powdered and exposed under a red-hot muffle, till converted into a grey powder, which is to be digested in ammonia, and the

solution filtered and evaporated to dryness. The residuum is dissolved in nitric acid, re-evaporated to dryness, and violently heated with charcoal. The metal is of a whitish grey colour, and of excessively difficult fusion. According to Hielm, its specific gravity is 7,4: according to Bucholz, it is as high as 8,6.

587. *Molybdenum and Oxygen.*—When exposed to heat, and oxygen molybdenum is acidified, a white crystalline sublimate of *molybdic acid* being formed.

There are two other compounds of molybdenum with oxygen; the one *brownish black,* obtained by heating molybdic acid with charcoal; the other *blue,* and procured by immersing tin in solution of molybdic acid; the black oxide consists of

	44 M. + 7,5 oxygen
the blue (molybdous acid)	44 M. + 15
the white (molybdic acid)..	44 M. + 22,5

Mr. Hatchett, in his "*Experiments on the Native Molybdate of Lead,*" concluded the metal to be susceptible of four degrees of oxidizement, but his third oxide is probably a mixture of the two acids.

The above numbers are taken from the analyses of Bucholz, corrected by some experiments of my own, on the molybdic acid; our results are very nearly similar.

These acids combine with certain bases, forming *molybdites* and *molybdates.* Molybdate of silver, of mercury, of lead, and of nickel, may be procured by adding molybdic acid to the respective nitrates of those metals.

The native molybdate of lead occurs principally in crystals of different shades of yellow. It was first discovered in Carinthia, and has since been found in Mexico, Hungary, and Saxony. According to Mr. Hatchett's analysis, (*Phil. Trans.* 1796) it contains 38 molybdic acid + 58,4 oxide of lead; and these numbers closely correspond with its theoretical composition, which should be 1 proportional of molybdic acid = 66,5 + 1 proportional of oxide of lead = 104,5.

Other molybdates may be obtained by adding molybdate of potassa to the metallic solutions. *Molybdate of tin,* thus precipitated from muriate of tin, is of a fine blue colour, and it is probable that some of these compounds, were the metal more abundant, would be useful in the arts.

588. *Sulphuret of Molybdenum* is a sectile compound of a metallic lustre, composed of 44 M. + 30 S.

The native sulphuret is found in Bohemia, Sweden, and near Mont Blanc, disseminated in a grey granite. It has been found in England, chiefly in Cornwall; and in Scotland, in Inverness-shire. It rarely occurs crystallized; generally massive, and made up of easily separable laminæ. It is soft and unctuous to the touch, and in colour much like lead. It is found exclusively in primitive rocks; generally in granite and with quartz.

589. Little is known concerning the salts of molybdenum.

Sulphuric acid dissolves molybdic acid, and the solution is colourless while hot, but becomes blue on cooling. Muriatic acid forms a yellowish green solution of molybdic acid. The nitric acid does not dissolve it. (Hatchett, *Phil. Trans.* LXXXVI.) Its alloys are unimportant.

SECTION XXV. *Chrome.*

590. CHROME was discovered by Vauquelin in 1797. It may be obtained by intensely igniting its oxide with charcoal. Its colour resembles that of iron, and its specific gravity is 5,9. It is brittle, and difficult of fusion.

591. *Chrome and Oxygen.*—When chrome is exposed to the action of heat and air, it combines with oxygen, and a *green protoxide* is obtained. This oxide easily dissolves in acids.

When nitrate of chrome is decomposed at a red heat, an insoluble *brown deutoxide* is formed. It does not dissolve in the acids; but when heated with muriatic acid, chlorine is evolved, and a muriate, containing the protoxide, is formed.

The *red peroxide*, or *chromic acid*, is most easily procured by the decomposition of the native *chromate of lead*, which may be effected by reducing it to a very fine powder, and boiling it in a solution of potassa or soda. An orange-coloured solution of the alcaline chromate is thus formed, to which sulphuric acid is to be added. On evaporation red crystals of chromic acid are formed, along with the sulphate of soda or of potassa.

Chromic acid may also be procured by the following process from native *chromate of iron*, which is a more common mineral than the chromate of lead. Reduce it to a fine powder and expose it to a red heat for two hours, mixed with half its weight of nitre; wash the contents of the crucible, and add to the lixivium nitric acid sufficient to neutralize the excess of potassa; in this way a solution of nitrate and of chromate of potassa is obtained. Upon adding nitrate of mercury to this solution, *chromate of mercury* is precipitated in the form of a red powder, which, when washed, dried, and heated, is decomposed, and either chromic acid or oxide is obtained.

The protoxide of chrome has been found native in France, in the department of the Rhone, in the form of a green incrustation. It is the colouring matter of the emerald, and exists in a few other minerals.

Chromic acid imparts the red tint to the ruby, and is found combined with oxide of iron and of lead.

Chromate of iron has been found in small crystalline grains, of an octoëdral form. It commonly occurs massive, of a black colour, with a slight metallic lustre, and hard enough to cut glass. It has been found in Siberia, France, and America, and promises to become useful in the arts as a source of some fine pigments.

Chromate of lead is a very rare mineral, hitherto only found in the Uralian mountains in Siberia; it occurs in prismatic crystals, of a fine orange red colour, and is occasionally accompanied by small green crystals, supposed to be *chromite of lead*, or a combination of oxide of chrome and oxide of lead.

Satisfactory experiments on the composition of the oxides of chrome are still wanting. According to Vauquelin, chromate of baryta consists of 62,2 baryta + 37,4 chromic acid, or, speaking in the equivalent numbers adopted in this work, of 1 proportional of baryta = 72,5 + 1 proportional of chromic acid 43,5.

According to Berzelius, the green oxide of chrome contains half the quantity of oxygen existing in the chromic acid. If, therefore, the latter be regarded as a deutoxide, the number 28,5 will represent chrome, and

Protoxide of chrome would consist of 28,5 chrome + 7,5 oxygen: and chromic acid of 28,5 chrome + 15 oxygen.

592. The chromates of ammonia, potassa, soda, lime, and magnesia are soluble and crystallizable. The chromates of baryta and strontia are insoluble, and may be formed by adding chromate of potassa or soda to their soluble saline compounds. The other insoluble metallic chromates may be formed in the same way, and their colours, which are various and beautiful, often enable us to judge of the nature of the metal present. Thus chromate of soda forms insoluble precipitates in solutions of silver, mercury, lead, copper, iron, and uranium; the colours are crimson, red, orange or yellow, apple-green, brown, and yellow. It forms no precipitate in solutions of nickel, zinc, tin, cobalt, gold, or platinum; whence, perhaps, it may be inferred, that the chromates of the latter metals are soluble.

The green oxide of chrome is occasionally used in porcelain and enamel painting; and the artificial chromate of lead forms a rich and durable yellow.

The remaining compounds of chrome are as yet unexamined.

Section XXVI. *Tungsten.*

593. This metal is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. It is difficult of fusion, very hard, brittle, and of an iron colour. Its specific gravity 17,5. By the action of heat and air, tungsten is converted into an oxide which is of a yellow colour. It has been called by some *scheelium*, by others *wolframium*.

594. *Peroxide of Tungsten* or *Tungstic Acid*, may be obtained from two native combinations; the one called *wolfram*, the other *tungstate of lime*.

Wolfram is found in primitive countries generally accompanying tin ores; its colour is brownish black, it occurs massive and crystallized, its primitive form being a rectangular parallelopiped. It abounds in Cornwall. It consists of tungstic acid united with iron and manganese. It may be decomposed by ignition with three times its weight of nitre; the fused mass digested in boiling water and filtered, furnishes a precipitate of *peroxide* of tungsten upon the addition of muriatic acid.

Tungstate of lime is a whitish semi-transparent substance, found in England, Saxony, Bohemia, and Sweden, and occurring crystallized and massive. Its most usual form is the octoedron. It may be decomposed by fusion with four parts of carbonate of potassa, the fused mass is digested in about twelve parts of boiling water, and filtered. Nitric acid precipitates the peroxide.

Peroxide of Tungsten is tasteless and insoluble in water; its specific gravity is 6. When violently heated it becomes green, grey, and black, probably from the loss of oxygen. It combines with several of the metallic oxides, and was found by Guyton to give considerable permanence to vegetable colours; hence it probably might prove useful in the art of dyeing, were it more abundantly procurable.

According to Dr. Thomson (*System,* Vol. I. p. 553) Tungstic acid is a compound of

Tungsten	100
Oxygen	25

and he regards it as containing one proportional of metal and three of oxygen. Upon these data the number 90 would represent tungsten and the peroxide would contain

90	Tungsten
22,5	Oxygen
112,5	Tungstic acid.

and tungstate of lime would consist of

one proportional of tungstic acid	= 112,5
——— lime ———	= 26,5
	139

but this does not agree with Klaproth's experiments, who found tungstate of lime to consist of

77,5	acid
22,5	lime
100	

though it is consistent with Berzelius's statement, as reported by Thomson, and which probably is founded on calculation.

The remaining compounds of tungsten have scarcely been investigated, and appear of little interest or importance.

Section XXVII. *Columbium.*

595. This metal was first discovered by Mr. Hatchett in a mineral from North America. It is found combined with the oxides of iron and manganese, and also with yttria, in the minerals called tantalite and yttro-tantalite. Tantalite is chiefly found in octoedral crystals, and in masses of a black or gray colour, in Finland. Its specific gravity is 7,9 and it contains, according to Ekeberg,

80 oxide of columbium
12 oxide of iron
8 oxide of manganese.

Yttro-tantalite is found at Ytterby in Sweden, accompanying Gadolinite (*Section* XLI.) It contains about 45 per cent of oxide of columbium. Its colour is dark grey, its lustre shining and somewhat metallic.

Columbium was discovered in these minerals by M. Ekeberg, and considering it as a *new* metal he called it tantalum. In 1809. *(Phil. Trans.)* Dr. Wollaston examined these and the original mineral in the British Museum, and demonstrated the identity of columbium, and tantalum. As the former name was given to this body by its original discoverer, it is here retained.

Columbium may be procured from columbite or tantalite, by the following process. Mix 5 parts of the finely-powdered mineral with 25 of carbonate of potassa, and 10 of borax, fuse the mixture, and when cold digest it in muriatic acid, which dissolves every thing except the oxide of columbium, which remains in the form of a white powder (Wollaston, *Phil. Trans.* 1809. p. 248). From 5 grains of columbite, Dr. Wollaston obtained

Oxide of Columbium 4 grains
——— Iron——— $\frac{3}{4}$
——— Manganese $\frac{1}{4}$

From five grains of tantalite he procured

Oxide of Columbium $4\frac{1}{4}$ grains
——— Iron——— $\frac{1}{2}$
——— Manganese $\frac{2}{10}$

596. Berzelius is the only person who has obtained metallic columbium. He describes it as of iron colour, very hard and brittle, and burning at a red heat into a whitish oxide.

597. The characters of white oxide of columbium are very well marked. It is nearly insoluble in muriatic, nitric, and sulphuric acids; it is very soluble in potassa, and carbonate of potassa; 8 grains of the latter, fused with 1 of the oxide, render it soluble in water. It is much less soluble in soda, and only retained while hot. Acids precipitate the white oxide from its alcaline solution.

If the excess of alcali be carefully neutralized with nitric acid, infusion of galls, added to the solution, produces a very characteristic orange-coloured precipitate. Neither ferrocyanate of potassa, nor hydrosulphurets, occasion any change.

There is another character very peculiar to the oxide of columbium, which is its ready solubility in tartaric, citric, and oxalic acids. In all these cases the newly-precipitated oxide must be used, for when dried it becomes very intractable.

From the readiness with which this oxide combines with potassa, Mr. Hatchett called it *columbic acid.*

According to Berzelius, 100 parts of columbium combine with 5,485 of oxygen; so that the representative of the metal in our numbers will be 139, and of the oxide $139 + 7{,}5 = 146{,}5$. (Thomson, Vol. I. p. 558.)

The remaining properties of columbium have not been investigated.

Section XXVIII. *Nickel.*

598. Nickel is found native, combined with arsenic, and with arsenic acid. It is procured pure by the following process: Dissolve the metal sold under the name of nickel, in dilute nitric acid to saturation, and evaporate to dryness; redissolve in water, and add nitrate of lead sufficient to precipitate the arsenic acid*: filter, and immerse a plate of iron to separate copper; filter again, and add solution of carbonate of potassa; wash the precipitate thus occasioned, and put it, while moist, into liquid ammonia, which dissolves the oxides of nickel and cobalt, leaving impurities to be separated by a filter; add potassa to the ammoniacal solution, which precipitates the oxide of nickel, and which, by ignition with charcoal, affords a globule of the pure metal. Nickel is a white metal, which acts upon the magnetic needle, and is itself capable of becoming a magnet. It is difficultly fusible, but absorbs oxygen readily when heated red-hot. It is malleable, and its specific gravity is about 8,5.

599. *Nickel and Oxygen.—Oxide of Nickel* is obtained by adding potassa to the solution of the nitrate—a precipitate falls of a pale green colour, which is a *hydrate*, or compound of oxide of nickel with water; this, heated to redness, affords a grey oxide, consisting of 28 nickel + 7,5 oxygen = 35,5.

According to Thenard, if chlorine be passed through a mixture of the hydrate of nickel and water, a black *peroxide* is formed, which, when acted upon by the acids, evolves oxygen, and returns to the state of protoxide.

The oxide of nickel dissolves in ammonia, forming a blue

* The arsenic acid is more easily separated by boiling the evaporated nitrate with the potassa.

solution; of this property we sometimes avail ourselves to separate nickel from other metals, of which the oxides are insoluble in ammonia.

600. *Chloride of Nickel.*—When nickel is heated in chlorine a *chloride* results. This compound may also be obtained by heating muriate of nickel to redness in a glass tube; a yellow scaly body is obtained, consisting of 55,5 nickel +67 chlorine.

601. *Iodide of Nickel* may be formed by adding solution of iodide of potassium to sulphate or nitrate of nickel; it is of a greenish yellow colour and insoluble.

602. *Nitrate of Nickel* is a green deliquescent salt, difficultly crystallizable in rhomboids. The analyses of this salt are much at variance, but it probably consists of 1 proportional of each of its components, or

35,5	oxide of nickel.
50,5	nitric acid
86	

603. *Sulphuret of Nickel* may be formed by fusion. It is a brittle yellow compound.

604. *Sulphate of Nickel* is formed by digesting the oxide in dilute sulphuric acid. A bright green solution is formed, which affords quadrangular prismatic crystals, very soluble in water, and which effloresce by exposure. The crystallized salt contains 7 proportionals of water, and consequently is composed of

1	proportional of oxide	= 35,5
1	———— acid	= 37,5
7	———— water	= 59,5
		132,5

605. Sulphuretted hydrogen and hydrosulphuret of ammonia produce a black precipitate of *hydrosulphuretted oxide of nickel*, when added to the solution of the metal.

606. *Phosphuret of Nickel* is a brittle whitish compound.

607. *Phosphate of Nickel* being nearly insoluble, is preci-

pitated upon adding phosphate of soda to a solution of nickel. It is of a pale green colour.

608. *Carbonate of Nickel* is precipitated in the form of a green powder, when carbonate of potassa is added to sulphate of nickel. It is probably a compound of 1 proportional of each of its components.

35,5	oxide of nickel.
20,7	carbonic acid.
56,2	

609. *Borate of Nickel* is a pale green insoluble compound.

610. The salts of nickel are distinguished by the fine green colour of their solutions, and by affording a green precipitate with ammonia soluble in excess of that alcali. The yellow green precipitate afforded by hydriodate of potassa is very characteristic of nickel; but the nicest test of its presence is the ferrocyanate of potassa, which produces a greenish white precipitate in all the solutions of the metal.

611. There is only one alloy of nickel which requires notice, namely, that with iron, which forms the principal metallic ingredient in those lapideous masses, which, in different countries, have fallen upon our globe, and which have been termed *meteoric stones*. Though we really know nothing of the source or origin of these bodies, it has been ascertained upon the most satisfactory and indisputable evidence, that they are not of terrestrial formation; and, consequently, since men began to think and reason correctly, their visits to our planet have awakened much speculation, and some experimental research.

In the first place, it deserves to be remarked, that we have very distinct evidence of the falling of stony bodies from the atmosphere in various countries, and at very remote periods. For, to say nothing of the fabulous narrations which encumber the annals of ancient Rome, or the extended catalogue of wonders flowing from the lively imagination of oriental writers, such events are recorded in holy writ, and have been set down by the most accredited of the early historians; and although philosophic scepticism long contended against the admission of the fact, it has in modern times received such unanswerable proofs, as to be allowed by all who have candidly considered the evidence, and is only rejected by the really ignorant, or by those who, for the sake of singularity, affect disbelief.

The first tolerably accurate narration of the fall of a meteoric stone relates to that of Ensisheim, near Basle, upon the Rhine. The account which is deposited in the church runs thus: A.D. 1492, Wednesday, 7 November, there was a loud clap of thunder, and a child saw a stone fall from heaven: it struck into a field of wheat, and did no harm, but made a hole there. The noise it made was heard at Lucerne, Villing, and other places; on the Monday, King Maximilian ordered the stone to be brought to the castle, and after having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Royal Excellency strictly forbade any body to take any thing from it. *His Excellency, however, took two pieces himself, and sent another to Duke Sigismund of Austria.* This stone weighed 255 lbs.

In 1627, 27th November, the celebrated Gassendi saw a burning stone fall on Mount Vaisir, in Provence: he found it to weigh 59 lbs.

In 1672, a stone fell near Verona, weighing 300 lbs. And Lucas, when at Larissa, in 1706, describes the falling of a stone, with a loud hissing noise, and smelling of sulphur.

In September, 1753, de Lalande witnessed this extraordinary phenomenon, near Pont de Vesle. In 1768, no less than three stones fell in different parts of France. In 1790, there was a shower of stones near Agen, witnessed by M. Darcet, and several other respectable persons. And on the 18th of December, 1795, a stone fell near Major Topham's house, in Yorkshire; it was seen by a ploughman and two other persons, who immediately dug it out of the hole it had buried itself in; it weighed 56 lbs.

We have various other, and equally satisfactory accounts of the same kind. All concur in describing a luminous meteor, moving through the air in a more or less oblique direction, attended by a hissing noise, and the fall of stony or semi-metallic masses, in a state of ignition. We have, however, evidence of another kind, amply proving the peculiarities of these bodies. It is, that although they have fallen in very different countries, and at distant periods, when submitted to chemical analysis they all agree in component parts; the metallic particles being composed of nickel and iron; the earthy, of silica and magnesia.

Large masses of *native iron* (See Section IX.) have been found in different parts of the world, of the history and origin of which nothing very accurate is known. Such are the great block of iron at Elbogen, in Bohemia; the large mass discovered by Pallas, weighing 1,600 lbs. near Krasnorjark in Siberia; that found by Goldberry, in the great desert of Zahra, in Africa; probably, also, that mentioned by Mr. Barrow, on the banks of the great fish river in Southern Africa; and those noticed by Celis, Bruce, Bougainville, Humboldt, and others in America, of enormous magnitude, exceeding 30 tons in weight. That these should be of the same source as the other meteoric stones, seems at first to startle belief; but when they are submitted to analysis, and the iron they contain found alloyed by nickel, it no longer seems credulous to regard them as of meteoric origin. We find nothing of the kind in the earth.

To account for these uncommon visitations of metallic and lapideous bodies, a variety of hypotheses have been suggested.

Are they merely earthly matter, fused by lightning? Are they the offspring of any terrestrial volcano? These were once favourite notions; but we know of no instance in which similar bodies have in that way been produced, nor do the lavas of known volcanos in the least resemble these bodies, to say nothing of the inexplicable projectile force that would here be wanted. This is merely explaining what is puzzling, by assuming what is impossible; and the persons who have taken up this conjecture, have assumed one impossibility to account for what they conceive to be another, namely, that the stony bodies should come from any other source than our own globe.

The notion that these bodies come from the moon, is, when impartially considered, neither absurd nor impossible. It is quite true, that the quiet way in which they visit us is against such an origin; it seems, however, that any power which would move a body 6,000 feet in a second, that is, about three times the velocity of a cannon-ball, would throw it from the sphere of the moon's attraction into that of our earth. The cause of this projective force may be a volcano, and if thus impelled, the body would reach us in about two days, and enter our atmosphere with a velocity of about 25,000 feet in a second. Their ignition may be accounted for, either by supposing the heat generated by their motion in our atmosphere sufficient to ignite them, or by considering them as combustibles, ignited by the mere contact of air.

While we are considering the *possibility* of these opinions, it may be remembered, that in the great laboratory of the atmosphere, chemical changes *may* happen, attended by the *production* of iron and other metals; that at all events such a circumstance is within the range of possible occurrences; and that the meteoric bodies which thus salute the earth with stony showers, may be children of the air, created by the union of simpler forms of matter. The singular relationship between iron and nickel, and magnetism, and the uniform influence of meteoric phenomena, on the magnetic needle, should be taken into account in these hypotheses.

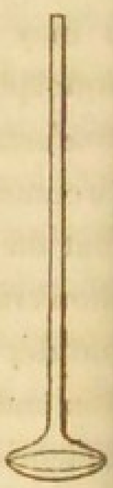
SECTION XXIX. *Mercury.*

612. THE principal ore of this metal is the sulphuret, or *native cinnabar*, from which the mercury is separated by distillation with quicklime, or iron filings.

Mercury is a brilliant white metal, having much of the colour of silver, whence the terms *hydrargyrum*, *argentum vivum*, and *quicksilver*. It has been known from very remote ages. It is liquid at all common temperatures, solid and malleable at—40°, and gaseous at 670°. Its specific gravity is 13,5.

613. *Mercury and Oxygen.*—There are two oxides of mercury. The *black*, or *protoxide*, may be obtained by long agitation of the metal in contact with oxygen, or by washing the *chloride of mercury* (calomel) with hot lime-water. It is insipid, and insoluble in water, and was called in old pharmacy, *Ethiops per se.*

The *red* or *peroxide* of mercury is produced by exposing the metal heated nearly to its boiling point to the action of air. It becomes coated with red scales, spangles, and crystals, and is ultimately entirely converted into a red shining mass, called in old pharmaceutical works, *precipitate per se.* It is most easily obtained by introducing into a flat-bottomed matrass, of the annexed shape, about 4 oz. of mercury, and placing it in a sand bath, heated nearly to the boiling point of the metal. In about a month's time the whole is converted into oxide. Air is freely admitted by the tube, while its length prevents the escape of mercurial vapour, which condenses and falls back into the body of the vessel.



Peroxide of mercury has an acrid metallic taste, and is poisonous: it dissolves very sparingly in water. When heated, it acquires a black colour, but becomes again red on cooling; at a red heat it evolves oxygen, and is reduced to the metallic state. It should be entirely volatilized when placed upon a red-hot iron.

614. Though it is difficult to obtain a perfectly pure black oxide of mercury, it appears to have been demonstrated that it contains just half the quantity of oxygen contained in the red oxide.

The best analyses of the red oxide give as its component parts,

Mercury....	92,7
Oxygen	7,3
	100.0

If we consider this as a compound of 1 proportional of mercury and 2 of oxygen, we obtain the number 190 as the representative of mercury; for

$$7{,}3 : 92{,}7 :: 15 : 190.$$

The protoxide, therefore will consist of

$$190 \text{ Mercury} + 7{,}5 \text{ Oxygen} = 197{,}5 \text{ Protoxide.}$$

And the peroxide of

$$190 \text{ Mercury} + 15 \text{ Oxygen} = 205 \text{ Peroxide.}$$

The black oxide exists in the *pilula hydrargyri*, and in the mercurial ointment of the *Pharmacopœia*.

615. *Mercury and Chlorine* combine in 2 proportions, and a chloride and bi-chloride of mercury are the results. These compounds are usually called *calomel* and *corrosive sublimate*. In the *London Pharmacopœia* they have received the improper names of *submuriate of mercury* and *oxymuriate of mercury*.

616. *Chloride of Mercury*.—This compound, commonly termed *calomel*, is first mentioned by Crollius, early in the

seventeenth century. The first directions for its preparation are given by Beguin, in the *Tirocinium Chemicum*, published in 1608. He calls it *draco mitigatus*. Several other fanciful names have been applied to it, such as *aquila mitigata, manna metallorum, panchymagogum minerale, sublimatum dulce, &c.*

The most usual mode of preparing calomel consists in triturating two parts of corrosive sublimate with one of mercury, until the globules disappear, and the whole assumes the appearance of an homogeneous grey powder, which is introduced into a matrass, placed in a sand heat, and gradually raised to redness. The calomel sublimes, mixed with a little corrosive sublimate, the greater part of which, however, being more volatile than the calomel, rises higher in the matrass; that which adheres to the calomel may be separated, by reducing the whole to a fine powder, and washing in large quantities of hot distilled water. Pure calomel, in the form of a yellowish white insipid powder, remains.

It was formerly the custom to submit calomel to very numerous sublimations, under the idea of rendering it *mild;* but these often tended to the production of corrosive sublimate; and the calomel of the first sublimation, especially if a little excess of mercury be found in it, is often more pure than that afforded by subsequent operations.

The following are the directions given in the last *London Pharmacopœia:*

" Take of oxymuriate of mercury 1 lb.
——— purified mercury, *by weight*, 9 oz.

Rub them together, until the metallic globules disappear; then sublime: take out the sublimed mass, reduce it to powder, and sublime it in the same manner twice more successively. Lastly, bring it to the state of a very fine powder; throw this into a large vessel, full of water; then stir it, and after a short interval, pour the supernatant turbid solution into another vessel, and set it by, that the powder may subside. Lastly, having poured away the water, dry the powder." (Powel's *Translation of the London Pharmacopœia*, Lond. 1815. p. 144 and 99.)

It will be observed, that in these processes the operation consists in reducing the bichloride to the state of chloride by the addition of mercury. Various modes have, however, been adopted for the direct formation of calomel: two of these may here be noticed, of which the first is in the humid way, as devised by Scheele and Chenevix. It is as follows:

Form a nitrate of mercury, by dissolving as much mercury as possible in hot nitric acid; then dissolve in boiling water a quantity of common salt, equal to half the weight of the mercury used, and render the solution sensibly sour by muriatic acid, and pour the hot nitrate of mercury into it. Wash and dry the precipitate.

If this process be carefully performed, and the precipitate thoroughly edulcorated, the calomel is sufficiently pure.

The second process, however, or that by which calomel is directly formed in the dry way, appears, on the whole, the least exceptionable for the production of this very important article of pharmacy; it is the method followed at Apothecaries' Hall, sanction having been obtained for its adoption from the College of Physicians.

50 lbs. of mercury are boiled with 70 lbs. of sulphuric acid, to dryness, in a cast-iron vessel: 62 lbs. of the dry salt are triturated with 40½ lbs. of mercury, until the globules disappear, and 34 lbs. of common salt are then added. This mixture is submitted to heat in earthen vessels, and from 95 to 100 lbs. of calomel are the result. It is to be washed in large quantities of distilled water, after having been ground to a fine and impalpable powder.

617. Chloride of mercury is usually seen in the form of a white mass, of a crystalline texture; and when very slowly sublimed, it often presents regular four-sided prisms, perfectly transparent and colourless. Its specific gravity is 7,2. It is tasteless, and very nearly insoluble in water. It can scarcely be called poisonous, since in considerable doses it only proves purgative. By exposure to light it becomes brown upon its surface. If scratched, it gives a yellow streak, which is very characteristic, and does not belong to sublimate.

It consists of 1 proportional of mercury 190 + 1 proportional of chlorine 33,5 and its representative number is 223,5.

Native chloride of mercury, or *mercurial horn ore*, has been found in Germany, France, and Spain, usually crystallized, and sometimes incrusting and massive.

618. *Bichloride of Mercury*, or *corrosive sublimate*, may be obtained by a variety of processes.

When mercury is heated in chlorine, it burns with a pale flame; the gas is absorbed, and a white volatile substance rises, which is the bi-chloride.

It may also be obtained by dissolving peroxide of mercury in muriatic acid, evaporating to dryness, re-dissolving in water, and crystallizing.

The ordinary process for making corrosive sublimate, consists in exposing a mixture of chloride of sodium, (common salt) and oxysulphate of mercury, to heat in a flask, or other proper subliming vessel; a mutual decomposition ensues. The chlorine of the common salt unites to the mercury of the sulphate, and forms bi-chloride of mercury. The oxygen of the oxide of mercury converts the sodium of the salt into soda, which, with the sulphuric acid produces sulphate of soda. This decomposition is exhibited by the following diagram.

1 proportional of Bi-chloride of Mercury = 257.

2 proportionals of common salt = 111 consist of	Chlorine 67	Mercury 190	1 proportional of oxysulphate of mercury = 280 consists of
		Oxygen 15	
	Sodium 44	Sulphuric acid .. 75	

2 proportionals of Sulphate of Soda = 134.

The following are the official directions of the *London Pharmacopœia,* for the preparation of corrosive sublimate, there termed *oxymuriate of mercury.*

"Take of purified mercury, *by weight*, 2 lbs.
——— sulphuric acid, *by weight*, 30 oz.
——— dried muriate of soda, 4 lbs.

Boil the mercury with the sulphuric acid in a glass vessel, until the sulphate of mercury is left dry. Rub this when it is cold with the muriate of soda in an earthen-ware mortar; then sublime it in a glass cucurbit, increasing the heat gradually." (Powell's *Translation.*)

The quantity of common salt employed in this process is obviously too large; in practice, however, we find that more than the real quantity decomposed, and shewn in the above table, is required.

By the quantity of chlorine absorbed by a given weight of mercury, we learn that the bi-chloride of mercury consists of 1 proportional of mercury = 190 + 2 proportionals of chlorine = 67, consequently, its representative number is 257.

619. Bi-chloride of mercury is usually seen in the form of a perfectly white semi-transparent mass, exhibiting the appear-

ance of imperfect crystallization. It is sometimes procured in quadrangular prisms. Its specific gravity is 5,2. Its taste acrid and nauseous, and leaving a peculiar metallic and astringent flavour upon the tongue. It dissolves in 20 parts of water at 60°, and in about half its weight at 212°. It is more soluble in alcohol than in water. When heated, it readily sublimes in the form of a dense white vapour, strongly affecting the nose and mouth. It dissolves without decomposition in muriatic, nitric, and sulphuric acids: the alcalis and several of the metals decompose it. It produces, with muriate of ammonia, a very soluble compound; hence a solution of sal-ammoniac is used with advantage in washing calomel to free it from corrosive sublimate.

620. Chloride and bi-chloride of mercury are decomposed by potassa, soda, and lime; the former affords *black*, the latter *red*, oxide of mercury; and the chlorides of potassium, sodium, and calcium, are produced. The following diagrams shew the interchange of elements that takes place in the case of adding a solution of potassa to chloride and bi-chloride of mercury.

1 proportional of Chloride of Potassium = 71.

1 proportional of chloride of mercury 223,5.	Chlorine 33,5	+	Potassium 37,5	1 proportional of potassa = 45.
	Mercury 190	+	Oxygen 7,5	

1 proportional of Protoxide of Mercury = 197,5.

2 proportionals of Chloride of Potassium = 142.

1 proportional of bichloride of mercury = 257.	Chlorine 67	+	Potassium 75	2 proportionals of potassa = 90.
	Mercury 19	+	Oxygen 15	

1 proportional of Peroxide of Mercury = 205.

621. When solution of ammonia is poured upon calomel, protoxide of mercury, and muriate of ammonia, are the results; but ammonia, added to a solution of corrosive sublimate, occasions a white precipitate of a *triple muriate of ammonia and mercury*.

A compound of this kind has long been used in pharmacy, under the name of *calx hydrargyri alba*, or *white precipitate*. The *London Pharmacopœia* directs the following process for its formation.

"Take of oxymuriate mercury ½ lb.
——— muriate of ammonia 4 oz.
——— solution of subcarbonate of potassa ½ pint.
——— distilled water 4 pints.

First dissolve the muriate of ammonia, then the oxymuriate of mercury, in the distilled water, and add thereto the solution of subcarbonate of potassa. Wash the precipitated powder until it becomes tasteless: then dry it."

Muriate of ammonia renders corrosive sublimate more soluble in water, one part rendering five parts soluble in rather less than five of water. By evaporation a triple salt is obtained, formerly called *sal alembroth*. The addition of potassa or soda throws down the above-mentioned white precipitate.

622. *Mercury and Iodine* unite in two proportions. These

compounds may be procured either by gently heating mercury with iodine, or by adding hydriodic acid to solutions of mercury. The *protiodide* is yellow, and the *periodide* red. They respectively consist of 1 proportional of mercury + 1 of iodine and 1 + 2. They are both insoluble in water.

623. *Mercury and Nitric Acid.* Nitric acid is rapidly decomposed by mercury; nitrous acid, and nitric oxide gases are evolved, and either a nitrate or an oxynitrate of mercury are obtained, according to the mode in which the solution is performed.

624. *Nitrate of Mercury* is best obtained by dissolving the metal in a cold and dilute acid, consisting of one part of acid and three of water; the metal should be added in small successive portions until the acid ceases to act upon it, and care should be taken to keep the whole cold. This solution deposits transparent crystals which appear to be modified octoëdra, and which consist of the protoxide of mercury combined with nitric acid They are soluble without decomposition in cold water, and the solution affords black precipitates of protoxide, upon the addition of the alcalis.

625. *Oxynitrate of Mercury.* When mercury is dissolved in hot and concentrated nitric acid, it becomes peroxidized, and furnishes prismatic crystals of oxynitrate. Their solution furnishes yellow or red precipitates of peroxide of mercury, upon the addition of potassa or soda, and ammonia forms a white precipitate, which is a *triple nitrate of mercury and ammonia.*

626. When hot water is poured upon oxynitrate of mercury, a yellow insoluble powder separates from it, which is a *sub-oxynitrate*, and a *superoxynitrate* remains in solution. It seems probable that the nitrate is also capable of affording a sub and a super nitrate; but all these compounds have hitherto been but imperfectly investigated, and new researches are wanting to establish their nature and composition.

If the nitrate and oxynitrate be composed of one proportional of each of the oxides with one of acid and with two of acid, the following will be their component parts.

197,5 protoxide.	205 peroxide.
50,5 nitric acid.	101 nitric acid.
248. nitrate of mercury.	306 oxynitrate of mercury.

The suboxynitrate has been analysed by M. M. Braamcamp and Oliva, (Thomson, Vol. II. p. 635), and they report its composition at

12 acid.
88 peroxide.

100

If its composition in theory be 2 proportionals of peroxide $= 410 + 1$ proportional of nitric acid $= 50{,}5$, these numbers are not much at variance with the above experimental result.

When these nitrates of mercury are exposed to heat gradually raised to dull redness, nitric acid is given off; and a brilliant red substance remains, consisting of peroxide of mercury with a small portion of adhering nitrate. This is used in pharmacy as an escharotic, and is called in the *London Pharmacopœia, hydrargyri nitrico oxidum.*

When the precautions in forming the nitrates above described are not attended to, the solution usually contains a mixture of the two nitrates, and furnishes a precipitate with the alcalis, composed of both oxides. The oxynitrate is most certainly formed by dissolving the red oxide in nitric acid.

627. *Mercury and Sulphur.* When mercury is triturated with sulphur, a black tasteless compound is obtained, which was called in old pharmacy *Ethiops Mineral.* The same substance is more readily formed by pouring mercury into

melted sulphur. According to Guibourt, (*Annales de Chimie et Phys.* Tom. I.) it consists of 100 mercury + 8,2 sulphur, numbers which correspond to

1 proportional mercury	=	190
1 ——— sulphur	=	15
Sulphuret of mercury	=	205

628. When this black sulphuret is heated red hot in a flask, a portion of mercury evaporates, and a sublimate of a steel gray colour is obtained, which, when reduced to a fine powder, assumes a brilliant red colour, and is called *vermilion*, or *cinnabar*. It is, in fact, a *bisulphuret of mercury*, and consists of

1 proportional of mercury	=	190
2 ——————— sulphur	=	30
Bisulphuret of mercury	=	220

Native cinnabar is the principal ore of mercury: it occurs massive and crystallised in six-sided prisms, rhombs, and octoëdra. It is of various colours, sometimes appearing steel gray, at others bright red. It occurs in Hungary, France, and Spain, in Europe: in Siberia, and Japan, in Asia: and in considerable quantities in South America. The mines of Almaden and of New Spain are the most productive, and furnish the finest cabinet specimens. Native mercury and native amalgam of silver sometimes accompany it.

629. *Mercury and Sulphuric Acid.* When mercury is boiled in its weight of sulphuric acid, sulphurous acid gas is evolved, a part of the metal is oxydized and dissolved, and a white deliquescent mass is obtained, which, washed with cold water, affords a very difficultly soluble white salt, which is a *sulphate of mercury*. It requires 500 parts of water for its solution, and

crystallizes in prisms. According to Fourcroy (*Annales de Chimie* X.), it consists of

12 sulphuric acid
83 protoxide of mercury
5 water

According to theory, it should consist of one proportional of sulphuric acid + 1 of protoxide, or

37,5 sulphuric acid
197,5 protoxide of mercury

235 sulphate of mercury.

The alcalis precipitate black oxide of mercury from this salt.

630. If three parts of sulphuric acid be boiled to dryness with one of mercury, a white mass of *oxysulphate of mercury* is obtained; it is more soluble than the sulphate, and crystallizes in prisms. According to Braamcamp and Oliva, it is composed of

31,8 acid
63,8 peroxide
4,4 water

100,0

It should consist, according to theory, of 1 proportional of peroxide + 2 proportionals of acid.

631. When hot water is poured upon oxysulphate of mercury, a yellow insoluble *suboxysulphate* is formed, which used to be called *Turpeth mineral*. It appears to consist of 1 proportional of peroxide + 1 of acid, or

205 peroxide of mercury
37,5 sulphuric acid

242,5 suboxysulphate of mercury.

A *superoxysulphate* remains in solution.

The solutions of oxysulphate of mercury furnish red precipitates with the fixed alcalis, and white with ammonia, the latter being a triple *sulphate of ammonia and mercury*.

632. Sulphuretted hydrogen produces a black precipitate in solutions of mercury.

633. *Phosphuret of Mercury* may be formed by heating phosphorus with oxide of mercury. It is a sectile solid of a bluish black colour.

634. *Mercury and Phosphoric Acid.* When phosphate of soda is added either to nitrate or oxynitrate of mercury, a white precipitate is formed. There is probably a *phosphate* and an *oxyphosphate*. The latter is soluble in excess of acid.

635. *Mercury and Carbonic Acid.* Alcaline carbonates produce white precipitates in solutions of both oxides of mercury. These are probably the *carbonate* and the *oxycarbonate*.

636. *Mercury and Cyanogen.* By boiling red oxide of mercury with hydrocyanate of iron, a solution is obtained which deposits yellowish white crystals, consisting, according to Gay-Lussac, of 80 mercury + 20 cyanogen. They are, therefore, a *cyanuret of mercury*. They are decomposed by heat, as in the process for obtaining cyanogen (p. 160); and if distilled with muriatic acid, hydrocyanic acid and chloride of mercury are formed. Cyanuret of mercury is probably a compound of 1 proportional of mercury = 190 + 2 of cyanogen = 48,8.

637. *Borate of Mercury*, obtained by a double decomposition, is a yellow insoluble powder.

638. The soluble salts of mercury furnish whitish precipitates with ferrocyanate of potassa, and black with sulphuretted hydrogen. A plate of copper, immersed into their solutions, occasions the separation of metallic mercury.

The insoluble mercurial salts are volatile at a red heat; and, if distilled with charcoal, afford metallic mercury.

639. Mercury combines with most of the other metals, and forms a class of compounds which have been called *amalgams*. These are generally brittle or soft. One part of potassium with 70 of mercury produce a hard brittle compound. If

mercury be added to the liquid alloy of potassium and sodium, an instant solidification ensues, and heat enough to inflame the latter metals is evolved. The use of an amalgam of zinc and mercury has already been adverted to for the excitation of electrical machines, p. 41. The amalgams of gold and silver are employed in gilding and plating *.

Section XXX. *Osmium.*

640. Osmium, and the metals described in the three following sections, are contained in the ore of platinum. This ore is digested in nitro-muriatic acid, by which the greater portion is dissolved, and there remains a black powder, which, when fused with potassa and washed, furnishes a yellow alcaline solution of oxide of osmium. Saturate the alcali with sulphuric acid, pour the mixture into a retort, and distil. A colourless solution of the *oxide of osmium* passes into the receiver; it has a sweetish taste and a very peculiar smell, somewhat like that of new bread. When mercury is shaken with this solution it becomes an amalgam, which is decomposed by distillation, and pure osmium remains.

Osmium has a dark grey colour, and is not volatile when heated in close vessels. But heated in the air it absorbs oxygen, and forms a volatile oxide. It has not been fused.

The leading characters of osmium are its insolubility in the acids, its ready solubility in potassa, the facility with which it is

* When mercury is negatively electrized in a solution of ammonia, or when an amalgam of potassium and mercury is placed upon moistened muriate of ammonia, the metal increases in volume, and becomes of the consistency of butter, an appearance which has sometimes been called the *metallization of ammonia*. The compound appears only to contain ammonia and mercury, though its real nature has not been satisfactorily ascertained. It has suggested some hypotheses concerning the nature of ammonia and the metals, which are not worth recording.

oxidized, the singular smell of its oxide, its great volatility, and the purple or blue colour produced in its solution by tincture of galls. The other compounds have scarcely been examined.

Section XXXI. *Iridium.*

641. The black powder mentioned in the last section contains iridium, which resists the action of potassa, and consequently remains after the separation of osmium. A solution of its oxide may be procured by digesting it in muriatic acid, which first becomes blue, then olive-green, and, lastly, red. By alternate treatment with potassa and muriatic acid, the whole of the black powder will be dissolved. By evaporating the muriatic solution to dryness, dissolving the dry mass in water, and evaporating a second time, octoëdral crystals of muriate of iridium are obtained.

Iridium is obtained by immersing a plate of zinc into a solution of the muriate, or by violently heating the octoëdral crystals. It is of a whitish colour, and, according to Mr. Children, who succeeded in fusing it by means of his large galvanic apparatus, its specific gravity is above 18. Its most marked character is extremely difficult solubility in the acids.

In crude platinum Dr. Wollaston discovered some flat white grains which resisted the action of the acids, and which he ascertained to consist of osmium and iridium.

Osmium and iridium were discovered by Mr. Tennant in 1803. The name of the former is derived from the peculiar smell of its oxide; that of the latter, from the variety of colours exhibited by its solution. (*Phil. Trans.* 1804.)

Section XXXII. *Rhodium.*

642. Rhodium and Palladium were discovered by Dr. Wollaston in 1803. These, like the two last-described metals,

exist in the ore of platinum, from which Rhodium may be obtained by the following process. Digest crude platinum in a small quantity of nitromuriatic acid, filter the saturated solution, and pour it into a solution of sal ammoniac, by which the greater proportion of the platinum is precipitated. Decant the clear liquor and immerse a plate of zinc, which becomes coated with a black powder. Separate this and digest it in dilute nitric acid, by which a little copper and lead are taken up. Then wash and digest in dilute nitro-muriatic acid, to which add some common salt, evaporate to dryness, and wash the dry mass repeatedly with alcohol. A deep red substance remains, which, when dissolved in water, furnishes a black precipitate upon the immersion of a plate of zinc. This, strongly heated with borax, assumes a white metallic lustre, and is rhodium.

Rhodium is very difficult of fusion; its specific gravity is 10,6. When an alloy of lead and rhodium is digested in nitro-muriatic acid, it is dissolved, and by evaporation a red compound is obtained, from which muriate of rhodium may be separated by water, or more perfectly by alcohol. The rose-colour of this compound suggested the name which has been applied to the metal.

Rhodium forms malleable alloys with the malleable metals, several of which have been examined by Dr. Wollaston. (*Phil. Trans.* 1804. Thomson's *System*, Vols. I. and II.)

Section XXXIII. *Palladium.*

643. Palladium is most easily obtained by the following process. (Wollaston *Phil. Trans.*, 1805.) Digest the ore of platinum in nitro-muriatic acid, neutralize the redundant acid by soda, throw down the platinum by muriate of ammonia, and filter. To the filtered liquor add a solution of cyanuret of mercury (636); a yellow flocculent precipitate is soon deposited which yields palladium on exposure to heat.

Dr. Wollaston has ascertained the existence of native palladium in the ore of platinum. It is in small fibrous grains. Palladium is of a dull white colour, malleable and ductile. Its specific gravity is about 11. It is hard. It fuses at a temperature above that required for the fusion of gold.

644. Muriatic acid boiled upon palladium acquires a fine réd colour. Sulphuric acid becomes blue. Nitric acid readily dissolves it, but its best solvent is the nitro-muriatic, which forms a fine red solution. The alcalis throw down an orange-coloured precipitate from these solutions, sparingly soluble in the alcalis. Ferrocyanate of potassa gives an olive-green precipitate, and sulphuretted hydrogen, one of a dark brown colour.

Section XXXIV. *Silver.*

645. Silver is found native, and in a variety of combinations.

Native silver has the general characters of the pure metal. It occurs in masses; and arborescent, capillary, and, sometimes, crystallized in cubes and octoëdra. It is seldom pure, but contains small portions of other metals, which affect its colour and ductility. It is chiefly found in primitive countries. In Peru and Mexico are the richest known mines of native silver. The mines of Saxony, Bohemia, and Swabia, and those of Kongsberg in Norway, are the richest in Europe. It has been found in Cornwall and Devonshire.

Pure silver may be procured by dissolving the standard silver of commerce in pure nitric acid, diluted with an equal measure of water. Immerse a plate of clean copper into the solution, which soon occasions a precipitate of metallic silver; collect it upon a filter; wash it with solution of ammonia, and then with water, and fuse it into a button.

It may also be procured by adding to the above solution of standard silver a solution of common salt; collect, wash, and dry the precipitate, and fuse it with its weight of subcarbonate of potassa. A button of the pure metal is thus obtained.

Silver has a pure white colour, and considerable brilliancy. Its specific gravity is 10,5. It is so malleable and ductile, that it may be extended into leaves not exceeding a ten thousandth of an inch in thickness, and drawn into wire considerably finer than a human hair.

Silver melts at a bright red heat, and when in fusion appears extremely brilliant. It resists the action of air at high temperatures for a long time, and does not oxidize; but if an electric explosion be passed through fine silver wire, it burns into a black powder, which is an oxide of silver. Exposed to an intense white heat, it boils and evaporates. If suddenly cooled, it crystallizes during congelation, often shooting out like a small cauliflower, and throwing small particles of the metal out of the crucible.

646. *Oxide of silver* may be obtained by adding lime-water to the solution of nitrate of silver, and washing the precipitate. It is of a dark olive colour, tasteless, insoluble in water, and, when gently heated, is reduced to the metallic state.

The composition of oxide of silver has been very variously given, probably from the difficulty of obtaining it of similar purity. If its composition be inferred from the chloride, or from the sulphuret, we obtain the number 102,5 as the representative of silver, and the oxide will consist of

102,5	silver.
7,5	oxygen.
110	oxide of silver*

* Mr. Faraday has rendered it probable that there is another combination of silver and oxygen containing a smaller proportion of oxygen than the above, but it is not capable of combining with the acids. By a direct

647. This oxide of silver readily dissolves in ammonia, and by particular management, a *fulminating silver*, composed of the oxide combined with ammonia, may be obtained. It was discovered by Berthollet, (*Annales de Chimie*, Tom. I.) The best process for obtaining it, is to pour a small quantity of liquid ammonia upon the oxide; a portion is dissolved, and a black powder remains, which is the detonating compound. It explodes when gently heated; nitrogen and water are instantaneously evolved, and the silver is reduced. (Faraday, *Journal of Science and the Arts*, Vol. IV. p. 270.)

648. *Silver and Chlorine—Chloride of Silver.*—This compound is easily procured by adding a solution of chlorine, of muriatic acid, or of common salt, to a solution of nitrate of silver: it falls in the form of a heavy insoluble tasteless powder, of a white colour, but which, by exposure to light, becomes brown, and ultimately black. When moist, it is rapidly reduced by hydrogen. When dry chloride of silver is heated in a silver crucible it does not lose weight, but fuses; and, on cooling, concretes into a grey semi-transparent substance, which has been called *horn silver*, or *luna cornea*. If fused with twice its weight of potassa or soda, it is decomposed, and a globule of metallic silver is obtained.

Chloride of silver is very soluble in ammonia, a circumstance by which it is usefully distinguished from some other chlorides, which, like it, are white, and formed by precipitation. The

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experiment upon the oxide of silver, precipitated by potassa from the nitrate, he found that 40 grains gave 7,9 cubical inches of oxygen, and 36,4 grains of silver remained; the 7,9 cubic inches would weigh 2,686 grains, and

Oxygen.		Silver.		Oxygen.		Silver.
2,686	:	36,4	: :	7,5	:	101,6.

I have preferred the number 102,5 as being deduced from the chloride, which is a more uniform compound than the oxide.

solution furnishes crystals, which, when exposed to air, or put into water, lose their transparency, ammonia is evolved, and they crumble into chloride of silver. The fused chloride, exposed to ammoniacal gas, absorbs a considerable portion, which is given off by heat. If the dry chloride, thus saturated with ammonia, be thrown into chlorine, the ammonia spontaneously inflames. (Faraday, *Journal of Science and Arts*, Vol. v. p. 75.)

649. As chloride of silver is insoluble, and very readily formed, it is often employed in analysis, as a means of ascertaining the proportion of chlorine present in various compounds.

The following are three of the best analyses, and their close correspondence is no small test of their accuracy.

	Marcet.	Gay-Lussac.	John Davy.
Silver....	75,47	75,25	75,5
Chlorine..	24,53	24,75	24,5
	100,00	100,00	100,0

The mean composition deduced from these experiments may be called

Silver..........	75,4
Chlorine	24,6
	100.

And we may accordingly, without material error, consider the chloride of silver as composed of

1 proportional of silver	= 102,5
1 ——— chlorine	33,5
	136 chloride of silver.

Native chloride of silver has been found in most of the silver mines; it occurs massive and crystallized in small cubes.

650. *Iodide of Silver* is precipitated upon adding hydriodic acid to a solution of nitrate of silver. It is of a greenish yellow colour, insoluble, and decomposed when heated with potassa.

651. *Nitrate of Silver.*—Nitric acid, diluted with three parts of water, readily dissolves silver, with the disengagement of nitric oxide gas. If the acid contain the least portion of muriatic, the solution will be turbid, and deposit a white powder; and if the silver contain copper, it will have a greenish hue, or if gold, that metal will remain undissolved in the form of a black powder.

The solution should be perfectly clear and colourless; it is caustic, and tinges animal substances of a deep yellow, which, by exposure to light, becomes deep purple, or black, and is indelible. It may be obtained in white crystals, in the form of four and six-sided tables, of a bitter and metallic taste, and soluble in their own weight of water at 60°. It blackens when exposed to light.

652. When heated in a silver crucible it fuses, and if cast into small cylinders, forms the *lapis infernalis*, or *lunar caustic* of pharmacy, the *argenti nitras* of the *Pharmacopœia*. In forming this preparation, care should be taken not to overheat the salt, and the moulds should be warmed. Exposed to a red heat, the acid is partly evolved and partly decomposed, and metallic silver obtained.

653. Sulphur, phosphorus, and charcoal, readily decompose this salt. A few grains mixed with a little sulphur, and struck upon an anvil with a heavy hammer, produces a detonation; phosphorus, in the same way, occasions a violent explosion; and if heated with charcoal, it deflagrates, and the metal is reduced.

A stick of phosphorus, introduced into a solution of nitrate f silver, soon becomes beautifully incrusted with the metal. ι plate of copper occasions a brilliant precipitation of silver; nd if mercury be introduced into it, a beautiful crystalline eposit of silver ensues, called the *arbor Dianæ*.

The alcaline metallic oxides decompose this salt of silver: is also decomposed by muriatic, sulphuric, phosphoric, and oracic acids.

Nitrate of silver is of much use, as a test for chlorine, uriatic acid, and their compounds. It is employed for riting upon linen, under the name of *indelible* or *marking ink*, ıd is an ingredient in many of the liquids, which are sold for ıe purpose of changing the colour of hair.

654. *Sulphuret of Silver.*—Silver readily combines with sulhur, and produces a grey crystallizable compound, considerably ore fusible than silver. It is this which forms the *tarnish* pon silver plate. It consists of 1 proportional of each of its omponents.

Silver..	102,5
Sulphur	15
	117,5 sulphuret of silver.

Sulphuret of silver occurs native, forming the *vitreous silver e*. It is found in various forms, and when crystallized, is in ıbes, octoëdra, and dodecaëdra. It is soft and sectile. The ıest specimens are from Siberia.

A triple combination of silver and antimony with sulphur, onstitutes the *red* or *ruby silver ore*; it is found massive and ystallized in hexaëdral prisms. It consists of about 70 parts sulphuret of silver, and 30 sulphuret of antimony. It occurs all the silver mines, and is sometimes accompanied by the *ittle sulphuret of silver*, or *silver glance*.

655. *Sulphate of Silver* is deposited when sulphate of soda mixed with nitrate of silver. It requires about 90 parts of ater at 60° for its solution; in boiling water it is more soluble

and is deposited, as the solution cools, in small prismatic crystals: it is decomposed at a red heat. It consists of

1 proportional of oxide of silver	=	110
1 ——————— sulphuric acid	=	37,5
		147,5 sulphate of silver.

656. Hydrosulphuret of ammonia forms a black precipitate in solutions of silver.

657. *Phosphuret of Silver* is a white brittle compound.

658. *Phosphate of Silver* is formed by dropping a solution of phosphate of soda into nitrate of silver. It is of a yellow colour, and consists, according to Berzelius, (*Annales de Chim. et Phys.* Tom. II.) of

83	oxide of silver.
17	phosphoric acid.
100	

so that it may be considered as a compound of 1 proportional of oxide of silver = 110 + 1 proportional of phosphoric acid = 26.

659. *Carbonate of Silver* is precipitated in the form of a white insoluble powder, by adding carbonate of potassa to nitrate of silver. It blackens by exposure to light. It consists of

1 proportional of carbonic acid	=	20,7
1 ——————— oxide of silver	=	110
Carbonate of silver	=	130,7

660. Ferrocyanate of potassa causes a white precipitate in solutions of silver.

661. *Borate of Silver*, formed by double decomposition, is an insoluble white powder.

662. The soluble salts of silver are recognized by furnishing a white precipitate with muriatic acid, which blackens by exposure to light, and which is readily soluble in ammonia;

and by affording metallic silver upon the immersion of a plate of copper. The salts insoluble in water are soluble in liquid ammonia, and when heated on charcoal before the blowpipe they afford a globule of silver.

663. *Alloys of Silver.*—Silver readily combines with the greater number of the metals; of these the alloy with copper is of the most importance, as it constitutes plate and coin. By the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous, while its colour is scarcely impaired.

The *standard silver* of this country consists of $11\frac{2}{20}$ pure silver and $\frac{18}{20}$ copper. A pound troy, therefore, is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper, and it is is coined into 66 shillings.

664. The analysis of alloyed silver is a very important process, and in continual practice by refiners and assayers. It may be performed in the humid way by dissolving the alloy in nitric acid, precipitating with muriatic acid, and either reducing the chloride in the way above-described, (648) or estimating the quantity of silver which it contains. The usual method, however, which is employed at the mint, and by the refiners, is *cupellation.*

Of the useful metals, there are three only which are capable of resisting the action of air at high temperatures; these are silver, gold, and platinum; the others, under the same circumstances, become oxidized; it might, therefore, be supposed, that an alloy, containing one or more of the former metals, would suffer decomposition by mere exposure to heat and air, and that the oxidable metal would burn away. This, however, is not the case; for if the proportion of the latter be small, it is protected as it were by the former; or, in other cases, a film of oxide coats the fused globule, and prevents the further action of the air. These two difficulties are overcome by increasing the relative proportion of the oxidable metal, or by adding to the alloy some highly oxidable metal, the oxide of which is fusible. Lead is the metal usually selected for this purpose, though bismuth will also answer. Supposing, therefore, that an alloy of silver and copper is to be *assayed*, or analyzed by cupellation: the following is the mode of proceeding.

A clean piece of the metal, weighing about 30 grains, is laminated, and accurately weighed in a very sensible balance. It is then wrapped up in the requisite quantity of sheet lead, (pure and reduced from litharge) and placed upon a small *cupel*, or shallow crucible, made of bone earth, which has been previously heated. The whole is then placed under the muffle, heated to bright redness; the metals melt, and by the action of the air which plays over the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains, the completion of the process being judged of by the cessation of the oxidation and motion upon the surface of the globule, and by the very brilliant appearance assumed by the silver when the oxidation of its alloy ceases. The button of pure metal is then suffered to cool gradually, and its loss of weight will be equivalent to the alloy, which has been separated by oxidation.

To perform this process with accuracy, many precautions are requisite, and nothing but practice can teach these, so as to enable the operator to gain certain results. An excellent article upon the subject will be found in Aikin's *Chemical Dictionary*.

Amalgam of silver is sometimes employed for *plating*; it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished. The better kind of plating, however, is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

A mixture of chloride of silver, chalk, and pearlash, is employed for silvering brass: the metal is rendered very clean, and the above mixture, moistened with water, rubbed upon its surface. In this way, thermometer scales and clock dials are usually silvered.

Section XXXV. *Gold.*

665. Gold occurs in nature in a metallic state, alloyed with a little silver or copper, and in this state is called *native gold.* Its colour is various shades of yellow; its forms massive, ramose, and crystallized in cubes, and octoëdra. The veins of gold are confined to primitive countries, but large quantities of this metal are collected in alluvial soils and in the beds of certain rivers, more especially those of the west coast of Africa, and of Peru, Brazil, and Mexico. In Europe, the streams of Hungary and Transylvania have afforded a respectable quantity of gold; it has been found also in the Rhine, the Rhone, and the Danube. Small quantities have been collected in Cornwall, and in the county of Wicklow in Ireland.

Gold may be obtained pure by dissolving it in nitro-muriatic acid, evaporating the solution to dryness, redissolving the dry mass in distilled water, filtering and adding to it a solution of sulphate of iron; a black powder falls, which, after having been washed with dilute muriatic acid and distilled water, affords on fusion a button of pure gold.

Gold is of a deep yellow colour. It melts at a bright red heat, and, when in fusion, appears of a brilliant green colour. It shows no tendency to unite to oxygen when exposed to its action in a state of fusion; but if an electric discharge be passed through a very fine wire of gold, a purple powder is produced, which has been considered as an oxide.

Gold is so malleable that it may be extended into leaves which do not exceed $\frac{1}{280,000}$ of an inch in thickness. It is also very ductile.

666. *Oxide of gold* may be obtained by adding a solution of potassa to a solution of muriate of gold; the precipitate must be washed first with weak solution of potassa, and then with water, and dried at a temperature of 100°. If this be regarded as a protoxide, that is, as consisting of 1 proportional of gold + 1 of oxygen, then the number 97 will represent gold, and this oxide will consist of 97 gold, + 7,5 oxygen = 104,5 *.

667. *Chloride of Gold.* When gold in a state of minute division is heated in chlorine, a compound of a deep yellow colour results, which consists of 97 gold + 33,5 chlorine. When acted upon by water, *a muriate of gold* is produced.

668. The action of *iodine* on gold has scarcely been examined.

669. *Nitrate of Gold.* The nitric acid has scarcely any action upon gold, but it readily dissolves the oxide, forming a yellow styptic deliquescent salt.

The true solvents of gold are solution of chlorine and nitro-muriatic acid; the latter is usually employed, composed of two parts of muriatic and one of nitric acid. By evaporation, the saturated solution affords prismatic crystals of *muriate of gold.* These solutions are of a yellow colour; they tinge the skin deep yellow, which becomes purple by exposure; they afford a precipitate of a purple colour with muriate of tin, which has been called *purple of Cassius;* sulphate of iron produces a greenish brown precipitate of finely-divided metallic gold; the fixed alcalis throw down oxide of gold; and ammonia furnishes a yellow precipitate of *fulminating gold.* It appears to be a compound of ammonia and oxide of gold, and detonates when gently heated. The results of its decomposition are metallic gold, water, and nitrogen.

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* These numbers are deduced from Proust's experiments. (Nicholson's *Journal.* Vol. xiv.)

If a solution of muriate of gold be mixed with sulphuric ether it combines with the oxide, and an *ethereal solution of gold*, is obtained. Polished steel dipped into this solution acquires a coat of gold, and it has hence been employed for gilding delicate cutting instruments. The combinations of oxide of gold with the other acids have scarcely been examined.

670. *Sulphuret of Gold* is procured by passing sulphuretted hydrogen through an aqueous solution of muriate of gold. It is a black substance consisting of 97 gold + 30 sulphur. (Oberkampf. *Ann. de Chim.* Tom. LXXX.)

671. *Phosphuret of Gold* is obtained by heating gold leaf with phosphorus, in a tube deprived of air. It is a grey substance of a metallic lustre, and consists probably of 97 gold + 11 phosphorus.

672. *Alloys of Gold.* Gold coin is an alloy of eleven parts of gold and one of copper; of this alloy, twenty troy pounds are coined into 934 sovereigns and one-half sovereign; one pound used to produce $44\frac{1}{2}$ guineas; it now produces $46\frac{29}{40}$ sovereigns.

A very curious detail of an extended and accurate series of experiments upon the alloys of gold has been published in the *Philosophical Transactions* for 1803, by Mr. Hatchett.

The assay of gold is more complicated than that of silver, in consequence of the high attraction which it has for copper, and which prevents its complete separation by mere cupellation. An alloy, therefore, of copper with gold, is combined with a certain quantity of silver, previous to cupellation; this is then cupelled with lead in the usual way, and the silver is afterwards separated by the action of nitric acid.

The real quantity of gold or silver taken for an assay is very small; from 18 to 36 grains, for instance, for silver, and from 6 to 12 for gold; whatever the quantity may be it is called the *assay pound.* The silver assay pound is divided into 12 ounces, and each ounce into 20 penny-weights. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains. (Aikin's *Dictionary*. Art. ASSAY.)

Mercury and gold combine with great ease, and produce a white amalgam much used in gilding. For this purpose the amalgam is applied to the surface of the silver; the mercury is then driven off by heat, and the gold remains adhering to the silver, and is burnished. This process is called *water gilding*.

In gilding porcelain *gold powder* is generally employed, obtained from the decomposition of the muriate; it is applied with a pencil, and burnished after it has been exposed to the heat of the porcelain furnace.

SECTION XXXVI. *Platinum.*

673. THIS metal is found in small grains in South America, confined to alluvial strata in New Granada. These grains, besides platinum, contain generally gold, iron, lead, palladium, rhodium, iridium, and osmium.

The pure metal may be obtained by dissolving crude platinum in nitro-muriatic acid, and precipitating by a solution of muriate of ammonia. This first precipitate is dissolved in nitro-muriatic acid, and again precipitated as before. The second precipitate is heated white hot, and pure platinum remains. It is a white metal, extremely difficult of fusion, and unaltered by the joint action of heat and air. Its specific gravity is 21,5. It is very ductile, malleable, and tenacious.

674. *Platinum and Oxygen.* When nitrate of mercury is added to a dilute solution of muriate of platinum, a black powder falls, which, when carefully heated, gives off calomel, and leaves a *black oxide of platinum*, composed, according to Mr. Cooper, of 100 platinum + 4,5 oxygen. (*Journal of Science and the Arts.* Vol. III.)

Berzelius obtained an oxide of platinum by decomposing the muriate by sulphuric acid, and adding excess of potassa to the sulphate; a yellowish brown powder was obtained, which became nearly black on being dried, and consisted of 100 platinum + 16,4 oxygen. (Thomson, Vol. I. p. 501.); but, according to Mr. Davy, the oxide which is contained in the salts of platinum, consists of platinum 100, oxygen 11,8.

675. *Chloride of Platinum* is obtained by evaporating the muriate and exposing it nearly to a red heat. Its colour is brown, and it is scarcely soluble in water. It gives off chlorine by a red heat. According to Mr. Edmund Davy, to whom we are principally indebted for our knowledge of the combinations of platinum, (*Phil. Mag.* Vol. XL.), it consists of 100 platinum, + 37,9 chlorine.

676. Nitro-muriatic acid is the readiest solvent of platinum. The solution affords crystals which are very deliquescent and acrid; they are a *muriate of platinum*. The solution of this muriate is distinguished from all other metallic solutions by affording a precipitate upon the addition of muriate of ammonia, which is an *ammonio-muriate of platinum*. Prussiate of potassa affords no precipitate. The addition of potassa occasions a precipitate of a triple compound of the alcali and muriate. Sulphuretted hydrogen occasions a black precipitate: ether separates the oxide of platinum in the same way as that of gold. Muriate of tin occasions a very characteristic red precipitate in very dilute solution of platinum.

677. There are, according to Mr. Davy, three *sulphurets of platinum*. The first formed by heating the finely-divided metal with sulphur; the second by precipitating nitro-muriate of platinum by sulphuretted hydrogen, and the third by heating 3 parts of the ammonio-muriate with 2 of sulphur.

678. According to the same authority there are two phosphurets. The first obtained by heating phosphorus with the

metal; the second, by heating phosphorus with the ammonio-muriate of platinum.

679. The salts of platinum have been but little examined. Proust and Davy have described a *sulphate*, obtained by acidifying the sulphur in the sulphuret by means of nitric acid. It is of a brown colour, and very soluble, and with soda, potassa, and ammonia, it forms triple salts.

Mr. E. Davy found that the precipitate, by a slight excess of ammonia, when boiled in potassa, washed and dried, was a fulminating platinum; it explodes at about 420°, with a very loud report, and appears to be a compound of oxide of platinum, ammonia, and water. (*Phil. Trans.* 1817.)

680. Experiments upon the composition of the various combinations of platinum are so entirely at variance with theory, that in the present state of our knowledge it is scarcely possible to deduce the number for platinum.

If the black oxide described by Mr. Cooper be considered as a protoxide, the number 176 will represent platinum, and the chloride (674) will contain 1 proportional of platinum and 2 of chlorine. But the peroxide, the phosphurets, and the sulphurets, will not accord with this number.

681. The alloys of platinum have not been applied to any useful purposes. By combining 7 parts of platinum with 16 of copper and 1 of zinc, Mr. Cooper obtained a mixture much resembling gold.) *Journal of Science and Arts.* Vol. III. p. 119.)

Zinc, bismuth, tin, and arsenic readily combine with platinum, and form fusible alloys. It also unites, though less readily, with copper, lead, and iron. It combines with gold, and unless there be great excess of the latter, the colour of the alloy resembles platinum.

Section XXXVII. *Silicium.*

682. It has been assumed that the earth silica consists of a metallic basis, united with oxygen, and that it contains 50 *per cent.* of each of its components; so that, if the earth be considered a deutoxide, it will consist of

15 Silicium
15 Oxygen

30*.

683. *Oxide of Silicium, Silica, or Siliceous Earth,* is a very abundant natural product. It exists pure in rock-crystal, and nearly pure in flint. It may be obtained by heating rock-crystal to redness, quenching it in water, and reducing it to a fine powder. Fuse 1 part of this powder with 3 of potassa in a silver crucible. Dissolve the mass formed in water, and evaporate to dryness. Wash the dry mass in boiling distilled water upon a filter, and the white substance which remains is pure silica †. Its colour is white; its specific gravity 2,66. It fuses at a very high temperature. In its ordinary state it is insoluble in water; but it dissolves in very minute portions in that fluid, when recently precipitated in the form of hydrate; and in the same state it dissolves sparingly in the acids. It readily unites with the fixed alcalis, and forms *glass;* or, if the alcali be in excess, a liquid solution of the earth may be obtained, *(liquor silicum)* whence it is precipitated in the state of a gelatinous hydrate by acids.

684. The only body which acts energetically upon silica is

* This estimate of the composition of Silica is deduced from the quantity of potassium which is required for its decomposition, but the subject requires farther elucidation.

† This is the usual process, but the silica always retains potassa, and the earth obtained by simply reducing the colourless rock crystal to powder, is more pure

the hydrofluoric acid. The result of this action is a gaseous compound, which has been called *silicated fluoric acid;* or *fluo-silicic acid*; it is probably a compound of silicium and fluorine. To obtain this gas, three parts of fluor spar, and one of silica finely powdered, are mixed in a retort with an equal weight of sulphuric acid; a gentle heat is applied, and the gas evolved is to be collected over mercury.

Silicated fluoric acid is a colourless gas; its odour is acrid, much resembling muriatic acid; its taste very sour; its specific gravity 3,574, compared with air; 100 cubic inches = 110,78 grains, so that its specific gravity to hydrogen is 49,2. It extinguishes burning bodies. It produces white fumes when in contact with damp air; and when exposed to water, two compounds of silica with fluoric acid are formed; the one *acid,* and dissolved in the water; the other containing excess of earth, and insoluble. The dry compound contains 62 *per cent.* of silica; the aqueous solution only retains 55 *per cent.* Water dissolves 260 times its bulk of this gas.

When one volume of silicated fluoric acid is mixed with two of ammonia, a total condensation ensues, and a dry *silico-fluate of ammonia* results.

Potassium, when heated in this gas, burns and produces a brown compound, which, when dissolved in water, affords *fluate of potassa.*

685. The uses of silica are numerous and important; it forms an ingredient in pottery and porcelain, and with alcali it forms glass.

It appears from the experiments of Mr. J. F. Daniell, that silicium exists in some of the varieties of cast iron: (*Journal of Science and Arts*, Vol. II.), and an alloy containing it has been formed by M. M. Stromeyer and Berzelius, (Gilberts *Annalen*, XXXVIII.) by exposing a mixture of pure iron, silica, and charcoal, to an intense heat.

686. The fossils consisting of silica, pure, or nearly so, are principally the following:—

Rock-crystal, or Quartz, which may be considered as pure silica. It crystallizes in the form of a six-sided prism, ended by six-sided pyramids; some varieties are perfectly transparent and colourless; others white and more or less opaque. Its specific gravity is 2,6. It is so hard as to give sparks when struck with steel, and is nearly infusible. The primitive crystal, which is very rare, is an obtuse rhomboid, the angles of which are 94° 24′, and 85° 36′. The finest specimens are brought from Madagascar and the Alps. Some of the perfectly transparent crystals found near Bristol, and in Cornwall, are sometimes called Bristol and Cornish diamonds. The fine crystals are cut into ornaments, and sometimes used as a substitute for glass in spectacles; they are then termed *pebbles,* and do not so readily become scratched as glass.

Brown and yellow crystals of Quartz are found in great beauty in the mountain of Cairn Gorm in Scotland, and are much admired for seal stones, *&c.*: they are sometimes improperly termed topazes.

Purple quartz or amethyst is tinged with a little iron and manganese. *Rose quartz* derives its colour from manganese. *Prase,* or *green quartz,* contains actinolite; and *chrysoprase* is tinged of a delicate apple-green by oxide of nickel. *Avanturine* is a beautiful variety of quartz, of a rich brown colour, which, from a peculiarity of texture, appears filled with bright spangles; the finest specimens are from Spain; it is often imitated. Small crystals of quartz, tinged with iron, are found in Spain, and have been termed *hyacinths of Compostella.*

Flint, Chalcedony, Cornelian, Onyx, Bloodstone, and the numerous varieties of *Agates* are principally composed of quartz, with various tinging materials.

Opal is among the most beautiful productions of the mineral world; it is a compound of about 90 silica and 10 water, and is distinguished by its very brilliant play of colours. The finest specimens come exclusively from Hungary. There is a variety of opal called *Hydrophane*, which is white and opaque till immersed in water; it then resembles the former.

Common opal is usually of a dirty white, and does not exhibit the colours of the noble opal; it contains silica and water, with a little oxide of iron, and is not of unfrequent occurrence. The substance called *menilite* from Menil Montant, near Paris, is nearly allied to common opal. It is found in irregular masses in a bed of clay.

Pitchstone, so called from its resinous appearance, contains 73 *per cent*. of silica. *Obsidian*, probably a volcanic product, contains 78 *per cent* of silica, and much resembles glass in appearance; and the different kinds of *pumice* are nearly of similar composition.

Section XXXVIII. *Alumium.*

687. The earth alumina constitutes some of the hardest gems, such as the sapphire and ruby, and it gives a peculiar softness and plasticity to some earthy compounds, such as the different kinds of clay. It is analogically considered as a metallic oxide.

To obtain pure alumina we add carbonate of ammonia to a solution of alum, wash and ignite the precipitate; it is a tasteless white substance, forming a cohesive mass with water, and retaining water even at a red heat. Its specific gravity is 2. It is soluble in soda and potassa, and forms compounds with baryta, strontia, lime, and silica. It is an essential ingredient in pottery and porcelain.

688. One of its saline combinations is of important use in the arts, namely, *alum;* a *triple sulphate of alumina and*

potassa. This salt is usually prepared by roasting and lixiviating certain clays containing pyrites; to the lyes, a certain quantity of potassa is added, and the triple salt is obtained by crystallization*.

Alum has a sweetish astringent taste. It dissolves in 5 parts of water at 60°, and the solution reddens blues. It furnishes octoëdral crystals. When heated, it loses water of crystallization, and a part of its acid, and becomes a white spongy mass. In its crystalline form it consists, according to some recent experiments made by Mr. R. Phillips, of

Sulphate of alumina	123,00
Bisulphate of potassa	119,32
Water	187,00
	429,32

Mr. Phillips adopts the number 24 as the representative of alumina, and considers alum as a compound of 2 proportionals of sulphate of alumina, 1 of bi-sulphate of potassa, and 22 of water. These proportions, therefore, would be

Bisulphate of potassa	$= 120$
Sulphate of alumina $61{,}5 \times 2$	$= 123$
Water .... $8{,}5 \times 22$	$= 187$
	430

689. When alum is ignited with charcoal, a spontaneously inflammable compound results, which has long been known under the name of *Homberg's pyrophorus*. The potassa is probably decomposed in this process, along with the acid of the alum, and pyrophorus is a compound of sulphur, charcoal, and potassium, with alumina.

Pyrophorus is most successfully prepared by the following

* Sulphate of alumina will not crystallize; but if a solution of sulphate of potassa be added to solution of sulphate of alumina, small octoëdral crystals of alum are precipitated.

process. Mix equal parts of honey, or of brown sugar and powdered alum, in an iron ladle, melt the mixture over fire, and keep it stirred till dry: reduce the dry mass to powder, and introduce it into a common phial coated with clay, and placed in a crucible of sand. Give the whole a red heat, and when a blue flame appears at the neck of the phial, allow it to burn about five minutes, then remove it from the fire; stop the phial, and allow it to cool, taking care that air cannot enter it.

690. When alum is exposed to an intense heat, it loses water and a portion of acid; but the whole of the acid cannot be expelled. It becomes light and spongy; and in this state is called in the Pharmacopœia, *alumen ustum*, or *exsiccatum.*

Alum is of extensive use in the arts, more especially in dyeing and calico-printing, in consequence of the attraction which alumina has for colouring matter.

The remaining salts of alumina, with the exception of the acetate which remains to be described, are of little importance; what is known respecting them is fully detailed by Dr. Thomson, (*System*, Vol. II. p. 510.)

691. Under the term *corundum*, certain mineral substances have been included, composed of alumina, nearly pure. *Perfect corundum* occurs crystallized in six-sided prisms, transparent and colourless. Its specific gravity is about 4. When blue, it constitutes the *sapphire;* when red, the *ruby;* when yellow, the *oriental topaz*, or *chrysolite*. These gems are principally found in alluvial deposits. They are mostly procured from Ceylon and Pegu; they have also been found in France and in Bohemia.

Imperfect corundum, or *adamantine spar* and *emery*, are analogous in composition to the former; they contain from 3 to 5 per cent. of silica and 1 to 2 of oxide of iron.

Spinelle, or *balass ruby*, is found in octoëdral crystals, of a red colour. It is composed of 74,5 alumina, 15,5 silica, 3,25 magnesia, 1,5 oxide of iron, and traces of lime and oxide of chrome. The *ceylanite*, or *pleonaste*, is a variety of spinelle. A variety, containing oxide of zinc, is called, *zinc spinelle*, or *automalite*.

The mineral, called *wavellite*, or *hydrargillite*, is a compound of alumina and water. It is found in Devonshire, in small radiated nodules upon clay-slate.

The *occidental topaz*, found chiefly in Saxony, Siberia, Brazil, and Scotland, consists of alumina, silica, and fluoric acid. The *schorlous beryl* or *pycnite*, and the *pyrophysalite*, are nearly of the same composition.

Cryolite, a rare substance hitherto only found in Greenland, consists of alumina, soda, and fluoric acid. It is white, amorphous, and translucent.

A mineral, called *native alumina*, is found upon the Sussex coast, near Newhaven. It is white and friable, and occurs massive and incrusting. It contains alumina and sulphate of lime.

692. A very numerous and important class of minerals consist of a combination of silica with alumina, in various proportions, and with the occasional addition of the fixed alcalis or alcaline earths, and a few of the other metallic oxides: the principal of these, which are not elsewhere mentioned, are the following:

Zeolite.—Of this mineral there are several varieties. The principal are the *radiated* or *mesotype*; the *nacreous* or *stilbite*; the *efflorescent* or *laumonite*, and the *cubic* or *analcime*. These minerals fuse and intumesce before the blowpipe, and mostly form gelatinous solutions in the acids. The following is Vauquelin's analysis of a radiated or acicular zeolite.

Silica	50,24
Alumina	29,30
Lime	9,46
Water	10,00

Apophyllite and *Chabasite* are nearly of the same composition; except that the latter contains about 9 per cent. of potassa and soda.

Garnet occurs massive, but generally crystallized in dodecaëdra. The *precious garnet* is red and transparent; the *common garnet*, red, brown, or green. According to Vauquelin, the precious garnet consists of

Silica	36
Alumina	20
Oxide of iron	41
Lime	3

Melanite, or *black garnet*, contains, upon the same authority,

Silica	35
Alumina	6
Lime	32
Oxides of iron and manganese	25

The *cinnamon stone* of Ceylon is nearly of similar composition.

Leucite, or *white volcanic garnet*, contains, according to Klaproth,

Silica	54
Alumina	24
Potassa	21

Vesuvian, or *idocrase*, is brown or yellow red, and is found crystallized in the masses of rock ejected by Vesuvius and Etna. It has also been found in the Alps and in Siberia. The Neapolitan lapidaries call it *chrysolite of Vesuvius*. In composition it differs little from melanite.

Staurotide, or *grenatite*, crystallizes in four and six-sided prisms often crossing each other. It consists of

Silica	33
Alumina	44
Lime	3,8
Oxides of iron and manganese	14

Sodalite, or *natrolite*, has hitherto only been found in Greenland. Its colour is light green, and it occurs massive and crystallized in rhomboidal dodecaëdra. It consists, according to Dr. Thomson, of

38,42 silica.
27,48 alumina.
23,50 soda.
2,70 lime.
3.00 muriatic acid.
1.00 oxide of iron.
2.10 volatile matter.

Prehnite is of a greenish colour, and radiated fracture. It occurs massive and crystallized in prisms. A lamellar variety has been called *koupholite*. It is found near the Cape of Good Hope, and in France and Scotland.

Spodumene, or *triphane*, is a mineral already alluded to in the section on Lithium. It is nearly allied to feldspar, and consists of

65 silica.
25 alumina.
8 lithia.
2 oxide of iron.

100

Scapolite, and *Elaolite*, or *Fettstein*, are minerals hitherto found only in Norway: they contain about 45 *per cent.* of silica, and 33 of alumina. The scapolite contains about 18 *per cent.* of lime; the *elaolite*, the same proportion of potassa and soda.

Nephritic stone, or *jade*, which is found in the Alps, and in China and India, contains, according to Saussure,

53,7	silica.
12,7	lime.
7	oxide of iron and manganese.
10,7	soda.
8,5	potassa.
7,4	water and loss.
100,0*	

The Chinese cut this substance into figures, and it is sometimes used for the handles of cutting instruments. In New Zealand, and other islands of the Pacific Ocean, it is used for cutting instruments, in consequence of its hardness and toughness. Hence it has been called *axe stone*.

Schorl and *Tourmalin* consist principally of silica, alumina, and oxide of iron. They occur in prismatic crystals of a black colour.

Thallite, epidote, or *pistacite,* is nearly allied in composition to schorl. It occurs in green prismatic crystals.

Axinite, or *thumerstone,* is found crystallized in flat oblique rhombs, of a brown, bluish, or grey tint, and transparent. It consists, according to Vauquelin, of

Silica	44
Alumina	18
Lime	19
Oxide of iron	14
Oxide of manganese	4

Cyanite is of a blue and grey colour, translucent, and occurs massive and prismatic. It consists, according to Klaproth, of

Alumina	55,5
Silica	43,0
Oxide of iron	0,5

* At page 244, par. 408, this mineral is erroneously stated to contain magnesia.

Lepidolite occurs massive, and of a purplish colour and lamellar texture. According to Klaproth, it contains

Silica	54,5
Alumina	38,25
Potassa	4,
Oxide of iron and manganese	0,75

Actinolite is of a green colour, and generally occurs in aggregated masses of prismatic crystals. It contains

Silica	50
Lime	9,7
Magnesia	19,2
Alumina	0,7
Oxides of chrome and iron	8

Tremolite is nearly white, fibrous and semi-transparent. It contains

Silica	62
Lime	14
Magnesia	18
Oxide of iron	6

Asbestos is a soft fibrous flexible mineral, of a white or greenish tint, composed of

Silica	60
Magnesia	30
Lime	6
Alumina	4

Amianthus, mountain cork, and *mountain wood*, are varieties of asbestos.

Lapis lazuli consists of

Silica	46
Carbonate of lime	28
Alumina	14
Sulphate of lime	6,5
Oxide of iron and water	5

The blue colour is probably derived from some principle which has hitherto escaped analysis.

Harmotome, Staurolite, or *Cross-stone,* occurs in small quadrangular prisms, terminated by four rhombic planes crossing each other. It is also found in single crystals. It is found at Andreasberg, in the Hartz, and at Strontian, in Scotland. It consists, according to Klaproth, of

Silica	49
Alumina	16
Baryta	18
Water	15

Augite is a mineral of a black or brownish green colour, found in volcanic products, and in some basalts. *Sahlite* and *coccolite* are varieties of augite. It is composed of

Silica	52
Lime	13
Oxide of iron and manganese	16
Magnesia	10
Alumina	9

The different kinds of *ochre* and *clay* consist essentially of siliceous and aluminous earth; they often contain lime, magnesia, and oxide of iron.

Datholite is a combination of

Silica	38
Lime	34
Boracic acid	22
Water	4

It has only been found in Norway.

SECTION XXXIX. *Zirconium.*

693. THE earth *zircon,* or the *oxide of zirconium,* is a white insipid substance; specific gravity 4,3: it is found in the zircon or *jargon* of Ceylon. It is characterized by insolubility in pure alcalies, but is soluble in alcaline carbonates. Its combinations

with the acids are of difficult solubility or insoluble, and have been very little inquired into.

The *zircon*, or *jargon*, is a mineral, usually of a grey, yellowish, or reddish-brown colour, crystallized in octoëdrons and four-sided prisms, and generally semi-transparent.

Zirconia is contained in the *hyacinth*, which is also found in Ceylon, and in various parts of Europe. Its usual colour is red, or reddish, and its crystals small flattened octoëdra, or four-sided prisms. These minerals contain about 70 per cent. of zirconia each, the remainder being silica, with a trace of oxide of iron. (Klaproth's *Beiträge*, Vol. I. pp. 222 and 231.)

694. Zirconia is obtained by the following process:—

Reduce the stone to a fine powder, having previously heated it to redness, and quenched it in water. Mix the powder with nine times its weight of pure potassa, and gradually project it into a red-hot silver crucible, and keep it in perfect fusion for two hours. When the crucible has cooled, reduce the mass to a fine powder, and boil it in distilled water. Boil the undissolved residue in muriatic acid; filter, and evaporate to dryness; re-dissolve the dry mass in distilled water, and precipitate by carbonate of soda. The carbonate of zirconia which falls may be decomposed by heat.

The composition of zirconia has been estimated by Sir H. Davy, (*Elements of Chemistry, Phil.* p. 361) at

35	zirconium.
7,5	oxygen.
42.5	

Section XL. *Glucinum.*

695. The earth *glucine* was discovered by Vauquelin in the beryl; it also exists in the emerald of Peru. It is white and

insipid; its specific gravity = 2,97. It dissolves in caustic, potassa and soda, and thus resembles alumine, but differs from yttria. Again it differs from alumine, but resembles yttria, in being soluble in carbonate of ammonia; it is much more soluble in this solution than yttria. With the acids it forms saline compounds of a sweetish astringent taste.

The *beryl* is found in primitive rocks in many parts of the world, but especially fine in Siberia. It is usually transparent, and pale green or blue. It crystallizes in six-sided prisms.

The *emerald* is principally found in Peru, crystallized in regular six-sided prisms, the edges or angles of which are sometimes replaced by facets. Its colour is green, and it is either transparent or translucent. The following are their component parts. (Vauquelin, *Journal des Mines*, No. XXXVI. and No. XLIII.)

	Beryl.	Emerald.
Silica	68	64,5
Alumina	15	16
Glucina	14	13
Oxide of chrome	—	3
Oxide of iron	1	—
Lime	2	1,5
Water	—	2
	100	100

696. To obtain glucine from either of these minerals proceed as follows:—Reduce it to a fine powder, and fuse it with thrice its weight of potassa; dissolve in a dilute muriatic acid; evaporate to dryness; re-dissolve in water, and precipitate by carbonate of potassa. Dissolve this precipitate in sulphuric acid and add a little sulphate of potassa, and on evaporation crystals of alum will be obtained. These being separated, add excess of carbonate of ammonia to the residuary liquor, which will retain glucina in solution, but the alumina will be precipitated; filter, and evaporate to dryness, and apply a red heat; glucina remains.

From the experiments of Davy this earth may be regarded as consisting of

20	glucinum.
7,5	oxygen.
27,5	glucina.

Glucine is also found in the *euclase*, a very scarce Peruvian mineral.

SECTION XLI. *Yttrium.*

697. IN 1794 Professor Gadolin discovered a new earth in a mineral from the quarry of Ytterby in Sweden, to which Ekeberg, in 1797, gave the name of *Yttria*. The mineral has since been termed *gadolinite*. Oxide of yttrium, or yttria, may be obtained by the following process. Pulverise the mineral and boil in repeated portions of nitro-muriatic acid; evaporate nearly to dryness, dilute with water, and filter; evaporate to dryness, ignite the residue for some hours in a close vessel, re-dissolve and filter. To this solution add ammonia, which throws down yttria and oxide of cerium; heat the precipitate red hot, and dissolve in nitric acid, and evaporate to dryness; dilute with 150 parts of water and put crystals of sulphate of potassa into the liquid. The crystals gradually dissolve, and, after some hours, a white precipitate appears of oxide of cerium, the whole of which must be separated by a repetition of this process. The liquor is then to be filtered, and the addition of pure ammonia forms a precipitate of yttria, which is to be washed and heated red hot. (Berzelius in Thomson's *Chemistry*. Vol. I. 357.)

Ittria is insipid, white, and without action on vegetable colours. It is insoluble in water, but very retentive of it. Insoluble in pure alcalis, but readily soluble in carbonated alcalis. It forms salts which have a sweetish austere taste, and which have been little examined. From indirect experiments it probably contains 25 *per cent.* oxygen; hence it may be regarded as consisting of

30	yttrium
7,5	oxygen
37,5	yttria.

Section XLII. *Thorinum.*

698. In examining some varieties of gadolinite and certain ores of cerium, Berzelius obtained a new metallic oxide, the base of which he has called *thorinum*.

Thorina differs from alumina in being insoluble in solution of potassa; from yttria, by its astringent taste without sweetness, and by its neutral solutions affording a precipitate when boiled. From Zirconia it differs in the following properties. 1. After being heated to redness it is still soluble in acids. 2. Sulphate of potassa occasions no precipitate in its solutions. 3. It is precipitated by oxalate of ammonia. 4. Sulphate of thorina crystallizes, while sulphate of zirconia does not. (Thomson, Vol. i. p. 567)

CHAPTER VI.

Of Vegetable Substances.

699. HAVING in the preceding chapters considered the properties of the elementary substances, and such of their compounds as can be artificially formed, or are found in the mineral world, we proceed in this and in the succeeding chapter to examine the states of combination in which they occur in organic substances.

The several sections of the present chapter will relate to the formation of vegetable substances and their chemical physiology; to the analysis of vegetable products, and the properties of their proximate component parts; and to the phenomena and products of fermentation.

SECTION I. *Of the Structure and Growth of Plants, and of the chemical Phenomena of Vegetation.*

700. IN examining the external structure of a perfect and full-grown vegetable, or plant, the essential organs of which it is observed to consist are the root, the stem, the leaves, the flowers, and the seeds.

The *root* serves to attach the plant to the soil, and is one of its organs of nutriment; in its structure it closely resembles the stem, of which it may be regarded as a continuation, terminating in more or less minute ramifications, analogous to the branches deprived of leaves. The *stem* is usually erect and subdivided into *branches* which bear the *leaves* and *flowers*, and upon which the *seeds* are ultimately produced.

701. When a branch of a tree is cut transversely it exhi-

bits a *cortical portion,* or *bark; wood;* and *pith,* or *central medullary substance.*

The bark is subdivisible into an external layer or *cuticle,* under which is a *cellular substance* lying upon the innermost part, or *cortical layers.*

The *cuticle* extends over every part of the plant; it admits of absorption and transpiration, and being generally transparent, at least upon the leaves and flowers, it admits the influence of light. The cuticle varies in texture and appearance in different plants. On the currant and elder tree it is smooth and scales off: on the fruit of the peach, and on the leaf of the mullein, it is covered with wool; on the leaf of the white willow, it is silky; in several plants, it is covered with hair and bristles, which in the nettle are perforated and contain a venomous fluid: on the plum and upon many leaves, it is varnished with a resinous exudation, which prevents injury from rain: it is fungous on the bark of the cork tree: and on grasses, on the equisetum, and especially on different species of the rattan, it is covered with a glassy network of siliceous earth.

Under the cuticle, or epidermis, is the *parenchyma;* a soft substance, appearing under the microscope of a honeycombed or hexagonal cellular structure.

The *cortical layers* appear of a tubular and fibrous texture, and with the cellular substance receive and elaborate the sap.

The *wood* consists of an outer stratum of living wood called the *alburnum* or *sap-wood;* and an inner dead part, or *heart-wood.* In the alburnum, which is tubular, the sap appears to rise from the roots; it passes into the leaves, where it undergoes changes, and thence enters the vessels of the inner bark, in which new parts are produced, and which is thus enabled annually to generate a layer of new wood.

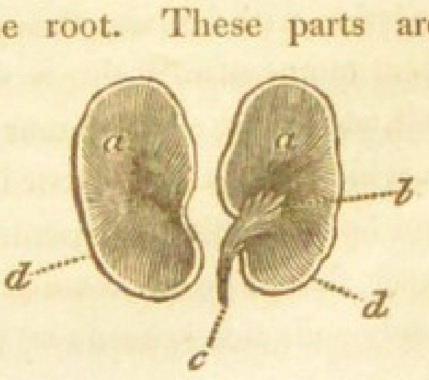
When the tubular structure is examined by a magnifier, it appears composed of vessels, some of which are simple, others perforated in various ways, and others spiral. The fibres of the wood consist of concentric and diverging layers, which have been called the *spurious* and the *silver grains.*

The *pith* occupies the centre of the wood; it is very variable in quantity in plants of different ages, and appears not to be of essential importance. It probably sometimes serves as a reservoir of moisture.

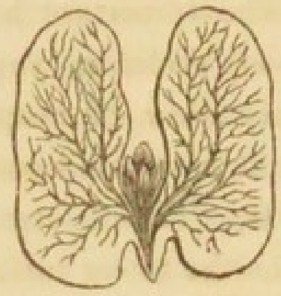
The *leaves* are highly vascular, and appear composed of a woody skeleton, supporting a tubular and cellular structure. They allow of evaporation and absorption, and in them the sap is concocted and rendered fit for the production of new parts. The absorption and evaporation principally take place upon the lower surface of the leaf. In most plants the leaves are annually re-produced.

The *flower* consists of the *calyx,* or green support of the *corolla,* or *floral leaves;* and of the *pistil* and *stamens.* The pistil is surmounted by the *style,* and is connected with a vessel containing the rudiments of the seeds. The stamens are surmounted by *anthers,* covered with a fine powder called the *pollen,* and which, being deposited upon the style, renders the seeds productive.

The seed is extremely various in form. It consists essentially of the *cotyledon,* the *plume,* and the *radicle.* The cotyledon contains the matter necessary for the early nutrition of the young plant. Sometimes it is single, sometimes double, and sometimes di isible into several lobes. The plume afterwards produces the stem and leaves, and is enveloped by the cotyledons; the adicle generally projects a little, and when the seed vegetates, it becomes the root. These parts are usually enveloped in a common membrane, and are well seen in the garden bean, represented in the annexed cut. *a a* are the cotyledons; *b* the plumula; *c* the radicle; *d d* the external membrane.



702. When a seed is placed under favourable circumstances the different parts begin to grow; the membranes burst, the plumula gradually expands and rises to the surface of the soil, and the radicle puts forth ramifications and becomes a root. These changes constitute *germination*. The cotyledons, originally insipid and farinaceous, become sweet and mucilaginous, and furnish materials for the early nutriment of the young plant, before its root and leaves are adequate to their full functions;. and vessels are observed ramifying throughout the cotyledons for this purpose as here represented.



When the root and stem have acquired a certain degree of vigour, the cotyledons either rot away, or become leaves; and the plant then derives its nourishment by the absorbing powers of the root and leaves, the former collecting materials from the soil, the latter from the atmosphere. The circumstances requisite for the healthy germination or growth of a seed are principally the following. 1. A due temperature, which is always above the freezing point, and below 100°. 2. Moisture in due proportion. 3. A proper access of air, the oxygen of which is slowly converted into carbonic acid. The joint operation of these agents also is required; for seeds exposed to air and moisture, but kept below 32° will not grow, though they are not injured by the low temperature: nor will a seed vegetate without air, though moisture be present and a sufficient temperature; this is shewn by burying seeds deep in the soil, and by the spontaneous vegetation upon newly-turned earth, in which seeds had existed, but through absence of oxygen had been unable to vegetate. Hence in all cases of tillage the seeds should be so sown as that the air may have access; in sandy soils this is easily attained, but in clayey soils the adhesiveness of the materials is often the cause of their unproductiveness.

703. As the plant advances to perfection, it becomes dependant upon the air and soil for its nutriment: the roots absorb moisture and other materials; and the leaves, while they exhale moisture, frequently absorb carbon from the carbonic acid present in the atmosphere, and evolve oxygen. This evolution of oxygen takes place while plants are exposed to the solar rays, and appears one of the most efficient causes hitherto suggested of the purification and renovation of the air. In the night-time, the leaves of plants always exhale carbonic acid, and at all times if the leaves be dying or unhealthy. There are also certain plants which appear at all times rather to deteriorate than renovate the air; on the whole, however, the balance is in favour of amelioration, (Davy's *Agricultural Chemistry*, 4to. p. 195.) though the disappearance of the enormous quantities of carbonic acid gas continually pouring into our atmosphere, can, I think, scarcely be referred to the purifying action of vegetables alone.

704. The fluid found in the vessels of plants is called their *sap*; it has a motion in the vessels, and appears to rise from the roots in a series of tubes in the alburnum; it then circulates in the leaves; becomes changed considerably in composition, and enters the vessels of the inner bark, enabling it to produce a new layer of wood, and to form the peculiar secretions which belong to it, and which, in smaller quantity, are also found in other parts of the vegetable.

The cause of the motion of the sap has never been satisfactorily accounted for, though it is, perhaps, principally referable to the contraction and expansion produced by changes of temperature.

That the sap ascends in the *alburnum*, and descends in the *liber*, or inner bark, is shewn by making an incision into the former and latter. The wound of the one will exude upon its lower surface, and of the other upon its upper surface; and if a circular strip of bark be removed from a small branch of a tree near the stem, there will, of course, be an accumulation of sap in that branch, and its produce of leaves, flowers, and fruit, is often remarkably increased by such an operation.

If the alburnum, on the contrary, of a branch be completely divided, it dies, as nourishment is then excluded; a fact pointed out by Mr. Knight; who has also shewn, in proof of the situation of the vessels carrying the ascending sap, that coloured fluids applied to the root always pass upwards in the alburnum only. (*Philos. Trans.* 1801.)

705. Though the presence of light, air, and moisture, aided by a due temperature, are the principal requisites for the growth of plants, these are not the only essentials, for they also derive nutriment from the soil, which becomes impoverished by their growth, and ultimately incapable of supporting healthy vegetation, unless aided by manures. It is thus that the alcaline, earthy, and saline ingredients of plants are furnished, and quick-growing vegetables require a constant supply of these substances.

Manures are of vegetable, animal, or mineral origin. The two former are capable of affording two of the essential ingredients of plants, namely, carbon and hydrogen; they may also yield some of the more immediate principles found in vegetables. The mere existence, however, of vegetable matter in the soil, is not sufficient to constitute it a manure; it must be reduced to a soluble state; to a state in which it can be absorbed by the roots of a growing vegetable; this is often effected by fermentation or putrefaction, or by applying the vegetable matter in a green state, as by plowing in a green crop. Where the vegetable matter is in an inert insoluble form, it will be of no avail unless rendered active and soluble, which is effected either by mixing it with such kinds of animal matter as undergo quick putrefaction, and are themselves pronoitious to the growth of vegetables; such, for instance, as dung, rotten fish, or decaying parts of animals; or, by the operation of alcaline bodies, such as quicklime, &c.

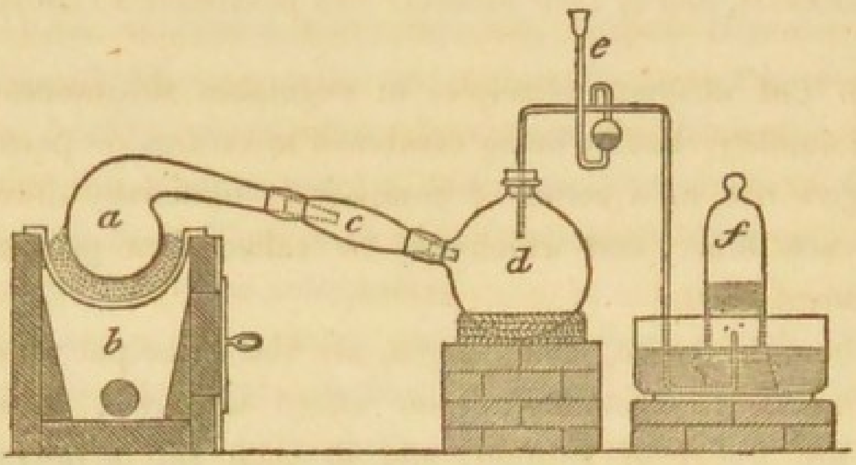
When newly burned lime is strewed over a soil containing inert vegetable matter, it acts upon it, and renders it more or less soluble; while the lime, by absorbing moisture and carbonic acid, is slaked, and passes into the state of chalk, which is not hurtful to vegetables, and often a very useful addition to the soil; but when limestone contains magnesia, that earth remains caustic, and sometimes proves highly injurious.

Section II. *Of the Composition and Analysis of vegetable Substances, and of their ultimate and proximate Principles.*

706. The *ultimate* principles of vegetable substances are few in number; but by being combined in various proportions, they give rise to a series of compounds materially differing from each other, and which may be called their proximate component parts.

Carbon, hydrogen, and oxygen, are the principal ultimate components of vegetables; some afford nitrogen; in some there are traces of sulphur, and in their sap or juices we find small proportions of potassa and of lime, sometimes of soda and of magnesia; these bodies are combined with acids, and chiefly obtained by burning or incineration. It has already been said, that some plants contain silica; sulphate of lime is found in clover; nitrate of potassa in the sap of the sun-flower, and nitrate of soda in barley. Common salt is a very frequent ingredient in marine plants; phosphate of lime is found in oats and some other seeds; and nearly all vegetables yield traces of oxide of iron, and many of oxide of manganese. In Saussure's *Chemical Researches on Vegetation*, and in the fourth volume of Dr. Thomson's *System of Chemistry*, are copious tables, shewing the earthy and saline constituents of vegetables.

707. When vegetable substances are submitted to destructive distillation, the carbon, hydrogen, and oxygen which they contain enter into new arrangements, and a variety of *products* are obtained, differing in quantity and quality according to the nature of the vegetable substance, and varying with the mode of distillation. Water, empyreumatic oil, acids, carbonic oxide and acid, and carburetted hydrogen, are in this way formed; and, if the vegetable contain nitrogen, ammonia may be obtained. A portion of charcoal, with the saline and earthy ingredients, remain in the retort. By a careful analysis of these products, the relative proportions of carbon, hydrogen, and oxygen, and of nitrogen, if present, may be judged of. The following form of apparatus may be used in these researches.

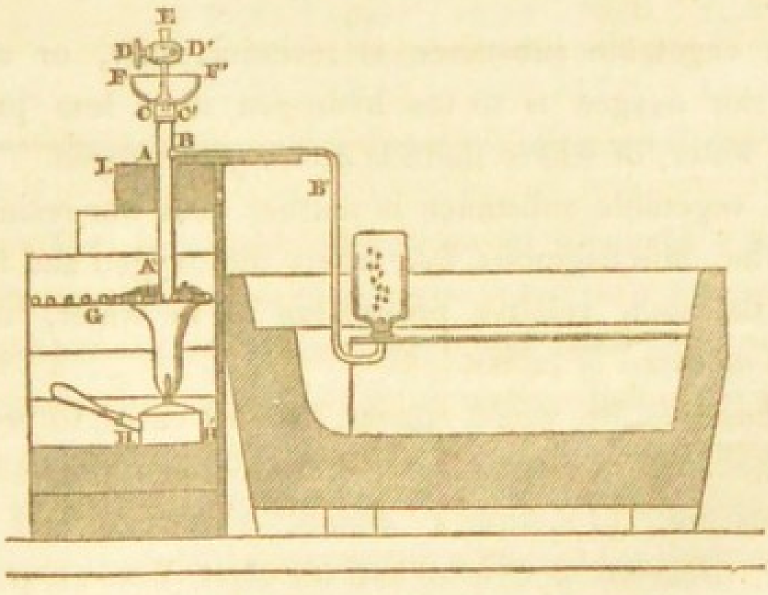


a is a glass or earthen retort, containing the vegetable substance to be decomposed, and placed in a sand heat upon the furnace *b*, which is gradually raised to a red heat. It is connected by the adopter *c* with the receiver *d*, which is kept cool for the condensation of the liquid products; the gases pass into the receiver *f* standing over mercury. *e* is a tube of safety, to allow for sudden expansion or contraction; there being in its lower part a small quantity of mercury which is occasionally elevated or depressed. The joints are secured by lute.

708. An improved mode of ascertaining the relative proportions of the ultimate component parts of vegetable products

has been devised by M. M. Gay-Lussac and Thenard, (*Recherches Physico-Chimiques*, Tom. II.) It consists in burning the vegetable substance with chlorate of potassa. (286) The requisite proportion of the chlorate, ascertained by previous experiment, is mixed with a given weight of the vegetable matter, and made into a small ball, which is dried, and burned in the apparatus described below. The gases are collected over mercury. The carbonic acid is absorbed by solution of potassa: if nitrogen be present, it will be found in the residuary gas; if carburetted hydrogen has been disengaged, its quantity and composition may be ascertained by detonation with oxygen. There should, however, always be allowance made for the production of excess of oxygen: thus the quantity of carbon is estimated from that of the carbonic acid formed, the quantity of hydrogen is deduced from that of the oxygen which has disappeared for the production of water, and the quantity of oxygen is learned by the remaining excess.

The details of the process will be found in the fourth volume of M. Thenard's *Traité de Chimie*, with the following arrangement and description of the apparatus.



A hole is made through a brick L, and the glass tube AA is passed through it as far as to the small lateral tube BB, which passes into the mercurial trough. The lower extremity of the tube rests upon the grate G, where it is to be heated red-hot by charcoal, inflamed by the lamp H. A brass cock is fitted by grinding, to the tube CC. It has a solid plug DD, in which is a cavity large enough to contain one of the balls to be analysed, and which is introduced at the opening E. The plug is then turned round, and the ball falls into the red-hot part of the tube, where it burns, the gases passing into the mercurial apparatus. F. F. is a basin, into which ice may be introduced to keep the metallic parts of the apparatus cool. It is convenient to case the lower part of the tube A in iron, as it is sometimes blown out at that part by the expansion within.

709. By thus subjecting different vegetable substances to analysis, M. M. Gay-Lussac and Thenard have arrived at the following results.

a. A vegetable substance is always acid, when the oxygen which it contains is to the hydrogen, in a proportion greater than is necessary to form water, or where there is *excess of oxygen*.

b. A vegetable substance is resinous, oily, or alcoholic, where the oxygen is to the hydrogen in a less proportion than in water, or where there is *excess of hydrogen*.

c. A vegetable substance is neither acid nor resinous, but saccharine, mucilaginous, *&c*., where the oxygen and hydrogen are in the same relative proportion as in water, or where there is *no excess of either*.

To these results, which appear, in most cases, to be correct, there are some exceptions which have been pointed out by M. Saussure, (Thomson's *Annals*, Vol. VI.,) and by Mr. Daniell, (*Journal of Science and the Arts*, Vol. VI. p. 326.)

The following Table exhibits the results of the analysis of several substances, by the mode above described. (Thenard's *Treatise on Chemical Analysis, translated by A. Merrick.*)

SUBSTANCES ANALYSED.	Carbon contained in that body.	Oxygen contained in that body.	Hydrogen contained in that body.	Or supposing the oxygen and hydrogen to be in the state of water in the vegetable substance.		
				Carbon.	Water.	Excess of Oxygen.
Sugar	42,47	50,63	6,90	42,47	57,53	0
Gum arabic . . .	42,23	50,84	6,93	42,23	57,77	0
Starch	43,55	49,68	6,77	43,55	56,45	0
Sugar of milk . .	38,825	53,834	7,341	38,825	61,175	0
Oak	52,53	41,78	5,69	52,53	47,47	0
Beech	51,45	42,73	5,82	51,45	48,55	0
Mucous acid. . .	33,69	62,67	3,62	36,69	30,16	36,15
Oxalic acid . . .	26,57	70,69	2,74	33,57	22,87	50,56
Tartaric acid . .	24,05	69,32	6,63	24,05	55,24	20,71
Citric acid. . . .	33,81	59,86	6,33	33,81	52,75	13,44
Acetic acid . . .	50,22	44,15	5,63	50,22	46,91	2,87
						hydrog. in exc.
Resin of turpentine	75,94	13,34	10,72	75,94	15,16	8,90
Copal	76,81	10,61	12,58	76,81	12,05	11,14
Wax.	81,79	5,54	12,67	81,79	6,30	11,91
Olive oil	77,21	9,43	13,36	77,21	10,71	12,08

710. The *proximate* principles of vegetables are chiefly separable by the action of solvents, of which the principal are cold and hot water, alcohol, ether, and a few of the acids. The manner of applying these will be made obvious by the details in the following sections. The number of proximate principles which are thus capable of being distinguished and separated from each other, is considerable; those which have been

most accurately examined are enumerated in the following table, and will each form the subject of a separate section.

1 Gum.
2 Sugar.
3 Starch.
4 Gluten.
5 Extractive matter.
6 Tannin.
7 Colouring matter.
8 Wax.
9 Fixed oil.
10 Volatile oil.
11 Camphor.
12 Resins.
13 Narcotic principle.
14 Bituminous substances.
15 Vegetable acids.
Tartaric acid.
Oxalic acid.
Benzoic acid.
Citric acid.
Malic acid.
Gallic acid.

Section III. *Gum.*

711. Gum is contained in considerable quantities in the sap of many vegetables, and frequently appears as a spontaneous exudation. *Gum arabic* may be taken as a specimen of pure gum. Its specific gravity is about 1,4. It has a slightly yellow tint, and is translucent, inodorous, and insipid. It dissolves in water, forming a viscid solution, from which it may be obtained

in its original state by evaporation. It is insoluble in alcohol, which, therefore, causes a white precipitate in its aqueous solutions. It is also insoluble in ether and oils; it undergoes no change by exposure to air, and its aqueous solution does not ferment, but only becomes slightly sour when kept for a long time.

712. Gum is decomposed by sulphuric and nitric acids: the former produces water, acetous acid, and charcoal; the latter, among other products, converts a portion of the gum into a white acid substance, called the *mucous acid*, and which is analogous to that obtained from sugar of milk, or *saccholactic acid*.

Dilute sulphuric, and muriatic acids, dissolve gum without change.

713. The alcalies, and solutions of the alcaline earths, also dissolve gum, and the addition of acids occasions its partial precipitation without having undergone any apparent alteration.

There are several varieties of gum differing a little from each other. *Cherry-tree gum* and *gum tragacanth* do not dissolve in cold water, but in other respects their properties resemble those of gum arabic.

SECTION IV. *Sugar.*

714. SUGAR may be extracted from the juice of a number of vegetables, and is contained in all those having a sweet taste; that which is commonly employed is the produce of the *arundo saccharifera*, or *sugar cane*, a plant which thrives in hot climates. Its juice is expressed and evaporated with the addition of a small quantity of lime, until it acquires a thick consistency; it is then transferred into wooden coolers, where a portion concretes into a crystalline mass, which is

drained and exported to this country under the name of *muscovado*, or *raw sugar*. The remaining liquid portion is *molasses*, or *treacle*.

715. The following is a sketch of the process by which raw sugar is purified in this country.

Raw sugar is chosen by the refiner by the sharpness and brightness of the grain, and those kinds are preferred which have a peculiar grey hue. Soft grained yellow sugars, although they may be originally whiter, are not so fit for the purposes of the manufactory, and it is for this reason that sugars from particular countries are never used: such are those from the East Indies, Barbadoes, *&c.* They do not possess the property of crystallizing so perfectly, and approach in this respect to the nature of grape sugar.

There appear to be two perfectly distinct kinds of saccharine matter; one, when pure, is transparent and colourless, and crystallizes under proper management in a regular form, generally in flattened six-sided prisms; the other is uncrystallizable, and generally highly charged with colouring matter. This colouring matter is not, perhaps, essential to it, but may arise in the present case from the effect of fire, by the agency of which it is peculiarly prone to decomposition. We may mention, as familiar instances of these two, *white-sugar-candy* and *treacle*. The juice of the cane is composed of these ingredients, and though they are in some degree separated in our Indian colonies by the process of evaporation and filtration, yet the raw sugar which we receive contains still much of the latter combined with the former. The process of refining consists in further separating the two.

The proper sugar being selected, the *pans*, which resemble in some measure those used in the West Indies, are charged with a certain portion of lime-water, with which bullock's blood is well mixed by agitation. They are then filled with the sugar, which is suffered to stand a night to dissolve. The use of the lime-water is not, as is generally supposed, to neutralize any free acid in the raw material; but, by combining with the molasses, to render it more soluble, and thus to facilitate its separation from the pure solid sugar. In the purer kinds, and more especially when the refined is again melted over for the purpose of bringing it to its utmost degree of purity, lime is not used, the quantity of molasses being so small as to be easily removed by the agency of water alone.

Fires are lighted under the pans early in the morning; and when the liquid begins to boil, the albumen of the blood coagulates and rises to the top, bringing all the impurities of the sugar with it. These are taken off with a skimmer. The liquid is kept gently simmering and continually skimmed, till a small quantity, taken in a metallic spoon, appears perfectly transparent: this generally takes from four to five hours. The whiteness of the sugar is not at all improved by this process, but is even sometimes deteriorated from the action of the fire; it only serves to remove all foreign impurities. When the solution is judged to be sufficiently clear, it is suffered to run off into a large cistern. The pans are then reduced to half their size by taking off their fronts, and a small quantity is returned into each. The fires are now increased, and the sugar made to boil as rapidly as possible, till a small quantity taken on the thumb is capable of being drawn into threads by the fore-finger. Nothing but practice can ascertain the exact point at which the boiling should be stopped: if it is carried too far, the molasses is again bound up with the sugar; and if it is not carried far enough, much of the sugar runs off with the molasses in the after process. When this point is ascertained, the fire is instantly damped, and the boiling sugar carried off in basins to the *coolers*. A fresh quantity is pumped into the pans, which is evaporated in the like manner.

When the sugar is in the coolers, it is violently agitated with wooden oars till it appears thick and granulated, and a portion taken on the finger is no longer capable of being drawn into threads. It is upon this agitation in the cooler that the whiteness and fineness of grain in the refined sugar depends. The crystals are thus broken whilst forming, and by this means the whole is converted into a granular mass, which permits the coloured liquid saccharine matter to run off, and which would be combined with the solid if suffered to form in larger crystals. This granular texture, likewise, facilitates the percolation of water through the loaves in the after process, which washes the minutely divided crystals from all remaining tinge of the molasses. That this is the true theory of the whitening of sugar by the process of refining, appears from a comparison with the process for making candy. In this latter, the raw material is cleared and boiled exactly in the same manner; but instead of being put into coolers and agitated, it is poured into pots, across which threads are strung, to which the crystals attach themselves: these are set in a stove, and great care is taken not to disturb the liquid, as upon this depends the largeness and beauty of the candy. In this state it is left for five or six days, exposed to a heat of about 95°, when it is taken out and washed with lime-water: this takes off the molasses from the outside, but a great quantity is combined in the crystals, and the consequence is, that candy is never whiter than the sugar from which it is made.

When the sugar has arrived at that granular state in the coolers above described, it is poured into conical earthen moulds, which have previously been soaked a night in water. In these it is again agitated with sticks, for the purpose of extricating the air bubbles which would otherwise adhere to the sugar and the moulds, and leave the coat of the loaf rough and uneven. When sufficiently cold, the loaves are raised up to some of the upper floors of the manufactory, and the paper stops being removed from their points, they are set, with their broad ends upward, upon earthen pots. The first portions of the liquid molasses soon run down, and leave the sugar much whitened by the separation. This self-clearance is much assisted by a high temperature; and when it is perfected, pipe-clay, carefully mixed up with water to the consistence of thick cream, is put upon the loaves to the thickness of about an inch: the water from this slowly percolates the loaves; and, washing the solid sugar from all remains and tinge of the molasses, runs into the pots. The clay is of no other use than to retain the water, and prevent its running too rapidly through the mass, whereby too much of the sugar would be dissolved: a sponge, dipped in water, acts in the same manner. The process of *claying* is repeated four or five times, according to the nature of the sugar and the degree to which it has been boiled. When the loaves are perfectly cleansed from all remains of the coloured fluid, they are suffered to remain some time for the water to drain off; when this is completed, they are set, with their faces down, when all remains of it return from their points, and it is equally diffused throughout: they are then set in a stove, heated to about 95°, and thoroughly dried.

The syrup, or the mixed solution of sugar and molasses which runs into the pots, is mingled in the next boilings with the solution of raw sugar in the pans, and again evaporated. It is divided according its fineness; the first running containing, of course, more molasses, is reserved for the coarser loaves; whilst the last, being little else than a solution of sugar, is boiled into loaves, of the same degree of fineness as those from which it ran. The lowest syrups are boiled into what is called bastard sugar, from which the molasses runs with very little mixture of the solid sugar. This is called *treacle,* and is totally incapable of further crystallization.

The produce of 1 cwt. of raw sugar worked in this manner is upon an average

lbs.	
63	refined
18	bastard
27	molasses
4	lost weight, dirt, *&c.*
112	

The process above described may almost be considered as mechanical. The only truly chemical parts of it are the clearing with blood, and the use of lime-water, which, leaving the solid sugar untouched, combines with the molasses, and rendering it in some measure saponaceous, facilitates its solution during the percolation of the water.

Attempts have lately been made to whiten the sugar during its boiling, by the addition of prepared charcoal. This destroys some of the colouring matter of the molasses, and tends materially to whiten the sugar.

Another attempt has been made to improve the process of claying, by the substitution of a strong solution of very white sugar for the clay. The idea was, that the water having a stronger affinity for the molasses than for the solid sugar, would in its passage through the loaves wash away the former, and leave the latter in its place, whereby more weight and a closer grain would be obtained. The idea was ingenious but the advantages scarcely counterbalance the additional expense of preparing the solution of fine sugar in the first instance.

716. Sugar may be obtained from the sap of many other plants. It exists in large quantity in the sugar maple, (*acer saccharinum*) in the manna ash (*fraxinus ornus*), and in the root of the common beet (*beta vulgaris*). In many ripe fruits sugar is a predominating ingredient; and in dried grapes, figs, *&c.*, it is often seen as a superficial incrustation. Though these

kinds of sugar differ a little from each other, they can scarcely be regarded as distinct species. Honey is also a variety of sugar.

717. Sugar is a white brittle substance of a pure sweet taste, soluble in its own weight of water at 60°. Boiling water dissolves a considerably larger quantity. This solution is called *syrup*; it is viscid, and furnishes crystals in the form of four and six-sided prisms, irregularly terminated. Sugar is readily soluble in alcohol.

718. Nitric and sulphuric acids decompose sugar; the former converts it into oxalic acid; the latter evolves charcoal and produces water and acetous acid.

719. The alcalis dissolve sugar, and destroy its sweet taste, which re-appears if an acid be added. When, however, the alcalis are left for a long time in the contact of sugar they effect a more important change, becoming carbonated and converting the sugar into gum. From a solution of sugar in lime water, Mr. Daniell obtained crystals of carbonate of lime and a portion of gum. The addition of phosphuret of lime to syrup produces an analagous change. (*Journal of Science and the Arts*, Vol. VI. p. 32.)

720. Both sugar and gum have the property of decomposing several of the metallic salts, and forming with some of them insoluble compounds. This is especially the case with solution of acetate of lead, and Berzelius has called these compounds of *saccharate* and *gummate* of lead.

721. When sugar is exposed to heat it fuses, becomes brown, evolves a little water, and is resolved into new arrangements of its component elements. The relative proportions of elements in gum and sugar appear from the experiments of Gay Lussac (709.) to be nearly the same. The analyses of these two substances by Berzelius afforded light differences only; according to him they contain

$$\left.\begin{array}{l}\text{Carbon}\ldots\ldots 41{,}906\\\text{Oxygen}\ldots\ldots 51{,}306\\\text{Hydrogen}\ldots\ 6{,}788\end{array}\right\}\begin{array}{c}\text{Gum}\\=100\\ \ \end{array}\left.\begin{array}{r}\ldots\ldots 44{,}200\\\ldots\ldots 49{,}015\\\ldots\ldots\ 6{,}785\end{array}\right\}\begin{array}{c}\text{Sugar}\\=100\\ \ \end{array}$$

SECTION V. *Starch.*

722. *Starch*, or *Fecula*, may be separated from a variety of vegetable substances; it is contained in the esculent grains, and in many roots. The process for obtaining it consists in diffusing the powdered grain or the rasped root in cold water, which becomes white and turbid; the grosser parts may be separated by a strainer, and the liquor which passes deposits the starch, which is to be washed in cold water and dried in a gentle heat.

The common process for obtaining the starch of wheat consists in steeping the grain in water till it becomes soft; it is then put into coarse linen bags, which are pressed in vats of water; a milky juice exudes, and the starch falls to the bottom of the vat. The supernatant liquor undergoes a slight fermentation, and a little vinegar is formed, which dissolves some impurities in the deposited starch; it is then collected, washed, and dried in a moderate heat, during which it splits into the columnar fragments which we meet with in commerce, and which are generally rendered slightly blue by a little smalt.

723. Pure starch is a white substance, insoluble in cold water, but readily soluble at a temperature between 160° and 180°. Its solution is gelatinous, and by careful evaporation yields a substance resembling gum in appearance, which is a compound of starch and water. Starch is insoluble in alcohol and in ether. The most characteristic property of starch is that of forming a blue compound with iodine; it may be obtained by adding an aqueous solution of iodine to a dilute solution of starch.

Sulphuric and nitric acids dissolve starch, and slowly decompose it, or resolve it into new compounds. Dilute nitric acid dissolves it without decomposition.

It appears by a reference to the ultimate elements of starch and sugar, that they differ little in composition, and it is therefore not surprising that the former is easily convertible into the latter.

724. The change of starch into sugar is always observed during the germination of seeds, and in the process of *malting* a similar conversion is effected.

Malt is barley which has been made to germinate to a certain extent, after which the process is stopped by heat. The barley is steeped in cold water, and is then made into a heap or *couch* upon the malt-floor: here it absorbs oxygen and evolves carbonic acid, its temperature augments, and then it is occasionally turned, to prevent its becoming too warm. In this process the radicle lengthens, and the plume, called by the maltsters the *acrospire*, elongates; and when it has nearly reached the opposite extremity of the seed, its further growth is arrested by drying at a temperature slowly elevated to 150° or more. The malt is then cleansed of the rootlets.

According to Dr. Thomson, barley loses about 8 *per cent.* by converting it into malt, of which

1,5	is carried off by the steep-water
3,0	dissipated in the floor
3,0	roots separated by cleansing
0,5	waste
8,0	

The following comparative analysis of unmalted and malted barley shews the change which has taken place in the operation.

Gum	5	14
Sugar	4	16
Gluten	3	1
Starch	88	69
	100 barley.	100 malt.

Proust has described a principle in barley, to which he has given the name of *Hordein;* it appears, however, to be a variety of starch, and can scarcely be admitted as a distinct vegetable principle. (*Annales de Chimie & Phys.* T. V.)

725. Another mode of converting starch into sugar was discovered by M. Kirchoff; it consists in boiling it with very dilute sulphuric acid. A pound of starch may be digested in six or eight pints of distilled water, rendered slightly acid by two or three drachms of sulphuric acid. The mixture should be simmered for a few days, fresh portions of water being occasionally added to compensate for the loss by evaporation. After this process the acid is saturated by a proper proportion of chalk, and the mixture filtered and evaporated to the consistence of syrup; its taste is sweet, and, by purification in the usual way, it affords crystallized sugar. M. M. de la Rive and Saussure have shewn that the contact of air is unnecessary in the above process; that no part of the acid is decomposed, no gas evolved, and that the sugar obtained exceeds by about one-tenth, the original weight of the starch. M. de Saussure, therefore, concludes that the conversion of starch into sugar depends upon the solidification of water, a conclusion strengthened by the following comparative analysis. (Thomson's *Annals*, Vol. II.)

	100 parts of Starch contain	100 parts of Starch sugar contain
Carbon	45,39	37,29
Oxygen	48,31	55,87
Hydrogen	5,90	6,84
Nitrogen	0,40	0,00
	100,00	100,00

This analysis of starch is somewhat at variance with that given by Gay Lussac; (709.) indeed the small portion of nitrogen cannot be considered as an essential component.

Berzelius has given the following as the component parts of starch. (Thomson's *Annals*, Vol. v.)

Carbon........ ...	43,481
Oxygen............	48,455
Hydrogen	7,064
	100,000

726. When starch is exposed to a temperature between 600° and 700° it swells, and exhales a peculiar smell; it becomes of a brown colour, and in that state is employed by calico printers under the name of *British gum*. It is soluble in cold water, and does not form a blue compound with iodine. Vauquelin found it to differ from gum in affording oxalic instead of mucous acid when treated with nitric acid.

Section VI. *Gluten.*

727. Gluten may be obtained from wheat-flour by forming it into a paste and washing it under a small stream of water. The starch is thus washed away, and a tough elastic substance remains, which is gluten.

Its colour is gray, and, when dried, it becomes brown and brittle. It is nearly insoluble in water, in alcohol, and in ether. When allowed to putrefy, it exhales an offensive odour; and when submitted to destructive distillation, it furnishes ammonia, a circumstance in which it resembles animal products. Most of the acids and the alcalis dissolve it.

Gluten is an essential ingredient in wheat-flour, and contributes much to its nutritive quality; it gives considerable tenacity to its paste, and renders it peculiarly fit for making bread.

728. A substance much resembling gluten, has been found in the juices of certain vegetables, especially in those which

are milky and coagulable by acids. It is contained in the sap of the houseleek, of the cabbage, and of most of the cruciform plants. Submitted to destructive distillation, it affords ammonia, and is in other respects similar to the animal principle, called albumen; hence it has been termed *vegetable albumen.*

729. *Caoutchouc* and *Birdlime* may also be considered as closely allied to gluten. These substances are insoluble in water and in alcohol, but they are soluble in sulphuric ether. Caoutchouc is highly inflammable, burning with a bright flame, which throws off charcoal. When heated it softens, and is in that state soluble in some of the fixed oils. It is said to dissolve easily in oil of cajeput. These solutions are sometimes used as varnishes, but with the exception of that in ether, they remain clammy.

730. The principles which have now been adverted to, *viz.*, sugar, starch, gum or mucilage, and gluten, constitute the principal nutritive ingredients in most of the esculent vegetables. Wheat grown in this country contains from 18 to 24 *per cent.* of gluten, the remainder being principally starch. The wheat of the south of Europe generally contains a larger quantity of gluten, and is therefore more excellent for the manufacture of macaroni, vermicelli, and other preparations requiring a glutinous paste. The excess of gluten in wheat-flour compared with other grain, renders it peculiarly fit for making bread; for the carbonic acid, extricated during the fermentation of the paste, is retained in consequence of its adhesiveness, and forms a spongy and light loaf.

A hundred parts of barley contain upon an average 80 parts of starch, 6 of gluten, and 7 of sugar, the remaining 7 parts being husk.

From 100 parts of rye Sir Humphry Davy obtained 61 parts of starch and 5 of gluten.

From 100 parts of oats he procured 59 of starch, 6 of gluten, and 2 of sugar.

100 parts of pease afforded about 50 of starch, 3 of sugar, 4 of gluten, and a small portion of extractive matter.

100 parts of potatoe yield upon an average 20 parts of starch; they may be considered in general as containing from one-fourth to one-fifth their weight of nutritive matter.

The turnip, carrot, and parsnep, chiefly contain sugar and mucilage: 1,000 parts of common turnips give about 34 of sugar, and 7 of mucilage; 1,000 parts of carrots furnish about 95 of sugar, and 3 of mucilage; and the same quantity of parsneps afford 90 of sugar and 9 of mucilage. The loss of weight in the above cases is referable to water, and inert vegetable matter possessed of the properties of woody fibre.

Section VII. *Extractive Matter.*

731. By the term *extract*, or *extractive principle*, we mean a substance contained in the greater number of vegetables, and generally forming the principal ingredient in the pharmaceutical preparations called *extracts.* It possesses the following properties. It is soluble in water, and the solution is of a brown colour. It is insoluble in alcohol and in ether, but it is soluble in alcohol containing a small portion of water. By repeated solutions and evaporations it may be rendered scarcely soluble in water. Solutions of chlorine, of many of the acids, and of most of the metallic oxides, occasion precipitates in the aqueous solution of extractive.

732. The following substances may be considered under this head, though many of them are obviously widely different from extractive matter.

a. Ulmin. This substance was first noticed by Klaproth, spontaneously exuding from the elm. From the observations of Berzelius, it exists in the bark of many other trees, and may be obtained by digestion in alcohol and cold water; the action of hot water afterwards dissolves the ulmin. (Thomson's *Annals*, Vol. II.)

Ulmin is of a dark brown colour, with scarcely any taste or smell. It is sparingly soluble in water and in alcohol, but readily soluble in a weak solution of carbonate of potassa. Very few of the metallic salts occasion a precipitate in its solution. The exudation from the elm is generally combined with carbonate of potassa, and is therefore readily soluble in water.

b. Polychroite. This term has been applied to the extract of saffron. (*Annales de Chimie*, Tom. LXXX.) It is of a deep yellow colour, deliquescent, readily soluble in water and in alcohol, but insoluble in pure sulphuric ether. Exposure to the solar rays soon destroys the colour of its aqueous solution. Sulphuric acid renders it blue, and nitric acid green: solutions of lime and baryta produce yellow and red precipitates: sub-acetate of lead throws down a deep yellow precipitate, and nitrate of mercury separates a red powder.

c. Hematin. This peculiar substance was first recognised by Chevreuil in the colouring matter of *logwood*. (*Annales de Chimie*, Tom. LXXXI.) It may be obtained by digesting logwood in water of the temperature of 125°. Filter, evaporate carefully to dryness, and digest the residue for 24 hours in alcohol of specific gravity of 8,37. Filter the alcohol; concentrate the solution by evaporation; add a portion of water; evaporate a little further, and set the solution aside: crystals are deposited, which, when washed with alcohol and dried, are pure hematin.

Hematin is of a reddish colour; its taste is somewhat bitter, and its aqueous solution is yellow when cold, but orange-red at the temperature of boiling water. Sulphuric acid added to this solution renders it reddish yellow. The alcalis give it a purplish tint.

d. Bitter principle.—By evaporating an infusion of quassia, a substance is obtained of an intensely bitter taste, and of a brownish yellow colour, which is readily soluble in water and in alcohol. Nitrate of silver, and acetate of lead, are the only precipitants of its aqueous solution. It is probable that the same substance exists in other bitter vegetables, and Vauquelin has discovered it in the fruit of the colocynth, and in the root of white briony. (Thomson's *System*, Vol. IV. p. 53.)

By digesting indigo, silk, and a few other substances in nitric acid, an intensely bitter matter is formed, called by Welther, the *yellow bitter principle*. (*Annales de Chimie*, Tom. XXIX.) Chevreuil has rendered it probable that this is a compound of a peculiar vegetable principle with nitric acid. It is crystallizable; burns like gunpowder; and detonates when struck with a hammer.

e. Picrotoxin.—This is a bitter poisonous substance contained in the *cocculus indicus*. It may be obtained by the following process:—Add acetate of lead to a decoction of the berries, as long as any precipitate falls; filter, evaporate, and digest the extract in highly rectified alcohol; evaporate to dryness, and agitate the remaining matter with a little water; the picrotoxin remains in the form of white prismatic crystals of a bitter taste. It is difficultly soluble in water. Alcohol, of the specific gravity of 810, dissolves one-third its weight. It is soluble in weak solutions of the pure alcalis.

f. Nicotin.—This is a principle existing in tobacco. It was obtained by Vauquelin by the following process:—(*Annales de Chimie*, LXXI.) Evaporate the expressed juice to one-fourth its bulk; and, when cold, strain it through fine linen; evaporate nearly to dryness; digest the residue in alcohol; filter and evaporate to dryness: dissolve this again in alcohol, and again reduce it to a dry state. Dissolve the residue in water, and saturate the acid which it contains with weak solution of potassa; introduce the whole into a retort, and distil to dryness; re-dissolve, and again distil three or four times successively. The nicotin will thus pass into the receiver, dissolved in water, from which solution it may be obtained by very gradual evaporation.

Nicotin is colourless, acrid, soluble in water, and, in alcohol, volatile and poisonous.

g. Asparagin.—M. M. Vauquelin and Robiquet, obtained this substance in a crystalline form by evaporating the juice of asparagus. It has a cool and slightly nauseous taste, and when burned emits acrid vapours, and leaves no traces of alcali. (*Annales de Chimie,* Tom. IV.)

h. Fungin.—This name has been given by Braconnot to a substance contained in the fleshy part of mushrooms. (*Annales de Chimie.* LXXIX.) It is insoluble in water and in alcohol, and scarcely acted upon by the elcalis, or by dilute acids. It is the substance which remains after the mushroom has been deprived of every thing soluble in alcohol and in water.

i. Inulin.—The roots of alecampane, when boiled in water, furnish a decoction, which, on cooling, deposits a white powder, in many respects resembling starch. It, however, differs in several properties from that principle, and has hence been considered a peculiar vegetable substance. (Thomson's *System,* Vol. IV. p. 75.)

k. Emetin. To obtain emetin, digest powdered ipecacuanha in alcohol, filter, evaporate carefully to dryness, and re-dissolve in cold water. To this solution add carbonate of baryta, filter, and again evaporate to dryness; digest this residuum in alcohol, and a solution is obtained, which, by careful evaporation, affords a reddish brown substance, soluble in alcohol and in water, and precipitable by sub-acetate of lead; its taste is acrid and bitter, and it is highly emetic. (M. M. Magendie and Pelletier, *Annales de Chimie et Physique,* Vol. IV.)

l. Woody fibre.—The term *lignin* has been applied to the fibrous substance which remains, after digesting wood in water and in alcohol. It is insipid, and, exposed to destructive distillation, affords a considerable quantity of vinegar tainted by empyreumatic oil, and containing a little ammonia. The charcoal which remains, is light, brittle, shining, and easily incinerated. The relative quantity yielded by different woods, has already been adverted to (216.)

m. Cork. This is a light, soft, elastic, and combustible substance, burning with a bright flame; and leaving a bulky charcoal. Its principal peculiarity is, that by digestion in nitric acid, it is converted into an orange-coloured mass, which furnishes to water a peculiar acid matter, which has been termed *suberic acid.*

n. Cotton is a downy substance found in the seed-pods of the different species of *gossypium.* It is insoluble in water and in dilute alcaline, and acid solutions. It combines with several of the metallic oxides, which are therefore used as intermedes or *mordants* in the art of dyeing. Acetate of alumina is principally used for this purpose.

SECTION VIII. *Tannin.*

733. TANNIN, or the astringent principle, is contained in many vegetables. It may be procured by digesting bruised gall-nuts, grape-seeds, oak-bark, or catechu, in a small quantity of cold water. The solution affords, when evaporated, a substance of a brownish-yellow colour, extremely astringent, and soluble in water and in alcohol.

The purest form of tannin appears to be that derived from bruised grape-seeds.

Its distinctive character is that of affording an insoluble precipitate when added to a solution of isinglass, or any other animal jelly. Upon this property the art of tanning depends, for which oak bark is generally employed; the barks, however, of many other trees may occasionally be substituted. The following table, drawn up by Sir Humphry Davy, exhibits the average quantity of tan contained in 480 lbs. of different barks.

	lbs.
Average of entire bark of middle-sized Oak, cut in spring	29
——— of Spanish Chesnut	21
——— of Leicester Willow, large size	33
——— of Elm	13
——— of Common Willow, large	11
——— of Ash	16
——— of Beech	10
——— of Horse Chesnut	9
——— of Sycamore	11
——— of Lombardy Poplar	15
——— of Birch	8
——— of Hazel	14
——— of Black Thorn	16
——— of Coppice Oak	32
——— of Oak cut in autumn	21
——— of Larch cut in autumn	8
White interior cortical layers of Oak Bark	72

Tan forms a precipitate with solution of starch, with gluten and albumen, and with many of the metallic oxides.

734. Mr. Hatchett has shewn that tan may be formed artificially by digesting charcoal in dilute nitric acid during several days; it is at length dissolved, and a reddish brown liquor is obtained, which furnishes, by careful evaporation, a brown glossy substance, amounting to about 120 parts from 100 of charcoal.

This *artificial tannin* differs in one circumstance only from natural tannin, which is, that it resists the action of nitric acid, by which all the varieties of natural tannin are decomposed, though some are more capable of resisting its action than others.

It is doubtful whether natural tan is ever obtained perfectly free from extractive and gallic acid, substances which are not contained in that artificially formed. (*Philos. Trans.* 1805, 1806.)

Section IX. *Colouring Matter.*

735. The colouring matter of vegetables appears to reside in several of their principles, and is therefore very differently acted on by solvents. Its extraction, and transfer to different substances, constitutes the *art of Dyeing*.

736. Colours have been divided by Dr. Bancroft, in his work on permanent colours, into *substantive* and *adjective*. The former communicate colour without the intervention of any other substance. They have an attraction for the fibre of cloth or linen, and are permanently retained. The latter require the intervention of some body, possessed of a joint attraction for the colouring material and stuff to be dyed. The substance capable of thus fixing the colour, has been called a *basis* or *mordant*. The mordants most frequently employed are acetate of alumina, sulphate of iron, and muriate of tin. The substance to be dyed is first impregnated with the mordant, and then passed through a solution of the colouring matter, which is thus fixed in the fibre, and its tint is either modified or exalted by the operation.

Calico-printing is a more refined and difficult branch of the art of dyeing. In this process adjective colours are almost always employed. The mordant is first applied to the calico by means of wooden blocks or copper plates, upon which the requisite patterns are engraved. The stuff is then passed through the colouring bath, and afterwards exposed on the bleaching ground, or washed. The colour flies from those parts which have not received the mordant, and is permanently retained on those parts only, to which the basis has been applied. Variety of colours is produced by employing various mordants, and different colouring materials; there are four principal colours, namely, red, yellow, blue, and black.

Reds are principally obtained from *madder, brazil wood, safflower* and *logwood,* fixed by an aluminous mordant. Scarlet is produced from the *cochineal* insect, the infusion of which is of a fine crimson colour, and may be fixed by alumine; it is rendered scarlet by the action of nitro-muriate of tin and tartar, or by tartrate of tin. (Aikin's *Dict. Art.* DYEING.)

The principal yellow dyes are *fustic wood, quercitron bark,* and *weld.* Fustic is seldom used for pure yellows: the finest yellow is obtained from weld, and quercitron bark, fixed with an aluminous mordant, to which muriate of tin and tartar are occasionally added.

Blue is chiefly derived from *indigo,* a substance produced by fermenting the leaves of the *indigofera tinctoria,* a plant abundantly cultivated in South America and in the East Indies.

Indigo is a substance of a blue colour, containing about 50 *per cent.* of pure colouring matter, which is perfectly insoluble in water, and when heated, it sublimes in the form of a blue smoke, which, upon condensation, forms acicular crystals. It is soluble in concentrated sulphuric acid. This solution is usually called *liquid blue,* and is used as a substantive colour for dyeing cloth and silk. Substances which powerfully attract oxygen render indigo green, and by exposure to air, it again acquires a blue colour. In this green state indigo is soluble in the alcalis, and the solution is commonly employed for dyeing calico. A bath for this purpose may be made by mixing one part of indigo, two parts of sulphate of iron, and two of lime, in a sufficient quantity of water: in this case the sulphate of iron is decomposed by a portion of the lime. The protoxide of iron thus produced becomes peroxidized at the expense of the indigo, which is rendered green and soluble in the alcaline liquor; cotton steeped in this solution acquires a green colour, which by exposure to air, and washing in water acidulated with sulphuric acid, becomes a permanent blue.

A little iron or zinc thrown into diluted sulphate of indigo changes or destroys the colour, in consequence of the evolution of hydrogen.

In calico-printing, *ferrocyanate of potassa* is sometimes employed to produce a blue, by applying it upon an iron mordant.

Blacks are almost always produced by the action of vegetable astringents, such as *gall-nuts, oak-bark, &c.*, upon an iron basis.

Fawn colour and buff are produced either from *sumach* or *walnut husks,* with an aluminous mordant.

Different substances are possessed of very different attractions for colouring matter. Animal substances, such as wool and silk, are, generally speaking, more easily dyed, and absorb more colouring matter than cotton, and cotton more than hemp or flax.

Section X. *Wax.*

737. This principle exists in many plants: it may be obtained by bruising and boiling them in water; the wax separates and concretes on cooling.

The berries of the *myrica cerifera,* and the leaves and stem of the *ceroxylon* afford considerable quantities of wax by this process. (Bostock. Nicholson's *Journal,* Vol. iv. Brande, *Phil. Trans.* 1811.) The glossy varnish upon the upper surface of the leaves of many trees is of a similar nature, and though there are shades of difference, these varieties of wax possess the essential properties of that formed by the bee.

738. Pure wax is colourless and insipid: its specific gravity is about, 96: it is insoluble in water, and fusible at a temperature of about 150°; at a higher temperature it is converted into vapour, and burns in the contact of air with a bright flame. It is sparingly soluble in boiling alcohol and ether,

and is deposited as the solutious cool. The fixed oils, when assisted by heat, readily dissolve it, and form a compound of variable consistency, which is the basis of *cerates* and *ointments*. It is soluble in the fixed alcalis, but the acids scarcely act upon it.

SECTION XI. *Fixed Oil.*

739. FIXED oil is generally obtained by pressure from certain seeds, such as the almond, linseed, and many others, and from the olive. The specific gravity of the fixed oils, is usually a little below that of water. They are viscid; insipid, or nearly so; and congeal at a temperature not so low as that required to freeze water. A few of them are solid at the ordinary temperature, and have been called *vegetable butters*. They are for the most part sparingly soluble in alcohol and ether, though castor-oil dissolves in any quantity in those fluids. (Brande *Phil. Trans.* 1811.)

740. If oil, which has been congealed by cold, be submitted to pressure between folds of bibulous paper, a dry, concrete, fatty matter is obtained, which Chevreuil has called *stearine:* the paper absorbs a fluid matter, which does not congeal at a much lower temperature, and which, though it does not become rancid, acquires viscidity by exposure to air. This fluid part he has called *elaine*. The relative proportions of these principles differ in the different oils. (*Annales de Chimie*, Tom. XCIII. XCIV.) See *Animal Oils*.

741. These oils cannot be volatilized without decomposition, which takes place at a temperature of about 600°; if the vapour be collected it is found acrid and empyreumatic: it was formerly employed in pharmacy, under the name of *philosophers' oil*, and as it was often obtained by steeping a brick in oil, and submitting it to distillation, it was also called *oil of bricks*. Passed through a red-hot tube, the fixed oils furnish a very

large proportion of carburetted hydrogen gas (234); and when burned in the wicks of lamps they suffer a similar decomposition, and water and carbonic acid are the products of their combustion.

742. The greater number of the fixed oils undergo little other change by exposure to air than that of becoming somewhat more viscid, and acquiring a degree of rancidity. Some few, such as linseed and nut-oil, become covered with a pellicle, and when thinly spread upon a surface, instead of remaining greasy, become hard and resinous; these are termed *drying oils*, and their drying quality is much improved by boiling them upon a small quantity of litharge.

743. The alcalis readily combine with the fixed oils, and form white compounds called *Soap*. Of these the most important is the soap of soda, which is thus made: Five parts of barilla are mixed with one of lime and a proper quantity of water. In this way a *ley*, or solution of caustic soda, is obtained, which is boiled in an iron pot with six parts of oil till the soap separates, which is accelerated by the addition of common salt; it is then suffered more perfectly to congeal, and in a few days becomes hard enough to cut into forms. (Aikin's *Dictionary*. *Art*. SOAP.) The best soaps are made with olive-oil and soda: in this country animal fat is usually employed for the common soaps, to which resin and some other substances are occasionally added. *Soft soap* is a compound of potassa with some of the common oils; even fish oil is often used.

Soap furnishes a milky solution with water. It dissolves in alcohol, and the solution, if concentrated, is of a gelatinous consistency. By carefully distilling off the alcohol, a *transparent soap* is obtained.

The acids and the greater number of salts decompose soap, forming in most cases a compound of difficult solubility; hence *hard waters* are unfit for washing, in consequence of containing sulphate of lime; hence also the alcoholic solution of soap is useful as a test for ascertaining the fitness of water for this purpose, which, if it becomes very turbid, cannot in general be used for washing.

When soaps are decomposed by the acids, the oil which they contain is found to have undergone a change, the history of which will be noticed under the head of *animal oils.*

The fixed oils readily combine with oxide of lead, when aided by heat, forming the compound usually termed *plaster.*

Section XII. *Volatile Oils.*

744. These oils are generally obtained by distilling the plants which afford them with water: they vary considerably in specific gravity, as shewn by the following table:—

Oil of Sassafras	1,094
—— Cinnamon	1,035
—— Cloves	1,034
—— Fennel	997
—— Dill	994
—— Penny-royal	978
—— Cummin	975
—— Mint	975
—— Nutmegs	948
—— Tansy	946
—— Caraway	940
—— Origanum	940
—— Spike	936
—— Rosemary	934
—— Juniper	911
—— Oranges	888
—— Turpentine	792

The volatile oils have a penetrating odour and taste; they are for the most part very soluble in alcohol, and very sparingly soluble in water; these solutions constitute *perfumed essences* and *distilled waters*. The latter are principally employed in pharmacy, and the former as perfumes.

They pass into vapour at a temperature somewhat below that of boiling water. They are very inflammable, and water and carbonic acid are the results of their perfect combustion. As many of these oils bear a very high price, they are not unfrequently adulterated with alcohol and fixed oils. The former addition is rendered evident by the action of water; the latter by the greasy spot which they leave on paper, and which does not evaporate when gently heated.

745. Nitric and sulphuric acids rapidly decompose the volatile oils: a mixture of four parts of nitric, and one of sulphuric acid, poured into a small quantity of oil of turpentine, produces instant inflammation.

Section XIII. *Camphor.*

746. This substance in many respects resembles the essential oils: like them it is volatile, inflammable, soluble in alcohol, and sparingly soluble in water.

In its ordinary state it is white, semi-transparent, and concrete. Its specific gravity ,98. It dissolves in the fixed and volatile oils. It is scarcely acted upon by the alcalis; some of the acids dissolve, others decompose it. (Hatchett, *Phil. Trans.* 1805. Chevreuil. *Ann. de Chim.* 73.)

The camphor of commerce is obtained from the *laurus camphora*; and comes chiefly from Japan. It is originally separated by distillation, and subsequently purified in Europe in a subliming vessel somewhat of the shape of a turnip, from which the cakes of camphor derive their form.

747. When camphor is repeatedly distilled with nitric acid it

is converted into *camphoric acid,* which is a crystallizable substance, soluble in about 100 parts of water at the temperature of 60°, and in its own weight of alcohol. Its combinations with the metallic oxides are called *camphorates.*

748. When a current of muriatic acid gas is passed through oil of turpentine, it deposits a concrete substance, which has been called artificial camphor, and the weight of which amounts to one half of the oil employed. When purified by sublimation with a little quicklime, it is rendered pure and white. It is lighter than water, sublimes without decomposition, burns like camphor, and in smell resembles a mixture of camphor and turpentine. (Thenard, *Mémoires d'Arcueil,* Tom. II.)

SECTION XIV. *Resins.*

749. RESINS are substances which exude from many trees, either from natural fissures or artificial wounds. Common resin is obtained by distilling the exudation of different species of fir: *oil of turpentine* passes over, and the resin remains behind. It may be taken as a perfect example of resin, and is possessed of the following properties. It is solid, brittle, a little heavier than water, and acquires negative electricity when rubbed. It has scarcely any taste or smell, is insoluble in water, readily soluble in alcohol, which takes up about one-third its weight, and becomes milky upon the addition of water. Resin is soluble in the caustic alcalis, the solution is saponaceous, and when mixed with an acid, the resin separates, scarcely altered in its properties. Nitric, muriatic, and acetic acids dissolve it without much change*.

A few of the resins derive odour from containing essential

* The properties of the resins have been very ably investigated by Mr. Hatchett, the details of whose researches will be found in his communications to the Royal Society, printed in the *Philosophical Transactions* for 1804, 1805, 1806.

oil; some afford benzoic acid when heated, and these have been termed *balsams*; copal, mastich, and a few others are very difficultly soluble in alcohol, and contain a substance somewhat analagous to caoutchouc. Guaiacum is characterized by the singular changes of colour, which its alcoholic solution suffers when exposed to the action of nitric acid. (*Phil. Trans.* 1811.)

750. *Lac* is a substance formed by an insect, and deposited on different species of trees, chiefly in the East Indies. The various kinds of lac distinguished in commerce, are *stick lac*, which is the substance in its natural state, investing the small twigs of the tree: *seed-lac*, which is the same broken off, and which, when melted, is called *shell-lac*. These substances have been examined by Mr. Hatchett *. The following table exhibits their component parts.

	Stick-Lac.	Seed-Lac.	Shell-lac.
Resin	68	88.5	90.9
Colouring matter	10	2.5	0.5
Wax	6	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5	—	—
Loss	4.0	2.5	1.8
	100	100	100

751. *Gum resins* are natural combinations of gum and resin, they are consequently only partially soluble in water and in alcohol; they readily dissolve in the alcaline solutions when assisted by heat; and the acids act upon them nearly as upon the resins. *Ammoniacum, gamboge, asafœtida, olibanum, &c.*, may be taken as examples of gum resins.

752. *Amber* is a substance which in some of its properties resembles resin; it is, however, very sparingly soluble in alcohol, and difficultly soluble in the alcalis. When sub-

* Dr. Pearson obtained a peculiar acid from a substance called *white lac*, from Madras. He has called it *laccic acid*. *Phil. Trans.* 1794.

mitted to distillation, it furnishes an acid sublimate, which has received the name of *succinic acid,* and which, when purified by repeated solutions and crystallization, possesses the following properties:—

It forms prismatic crystals soluble in 24 parts of water at 60°. It combines with the metallic oxides, and forms a class of salts termed *succinates,* of which the *succinate of ammonia* has been employed as a test for iron, the *succinate of iron* being insoluble.

753. The resins are applied to a variety of useful purposes; and dissolved in alcohol and oils they constitute the different *varnishes.*

SECTION XV. *Narcotic Principle.*

754. THE substance to which the narcotic power of certain vegetables is referable, has lately been examined with much attention by M. Serteurner; he has termed it *morphia.*

Morphia may be obtained from powdered opium by triturating it into a paste with dilute acetic acid: pour caustic ammonia into the filtered solution, and evaporate; during the evaporation a brownish substance separates, which, by digestion in a small quantity of alcohol, becomes nearly colourless, and is pure morphia.

Morphia is sparingly soluble in water, but readily soluble in alcohol and in ether, from which it may be obtained in quadrangular crystals. It is highly poisonous and narcotic, even when administered in very small doses: it is fusible and combustible.

Morphia appears in some respects to possess the properties of an alcali, and forms crystallizable compounds with the acids.

In opium morphia is said to be combined with a peculiar acid, which has been called the *meconic acid,* and this combination is decomposed by the action of ammonia in the above experiment.

SECTION XVI. *Bitumens.*

755. BITUMENS are fossile substances, bearing considerable resemblance to oily and resinous bodies. The following are the principal varieties :—

a. Naphtha is a pungent, odoriferous, oily liquid, either colourless or of a pale brown tint, found upon the borders of the Caspian Sea, and in certain springs in Italy. It is considerably lighter than water, volatile, and highly inflammable. When pure it appears to contain no oxygen, and hence is employed for the preservation of potassium, and the other highly oxydable metals. It consists according to Saussure, of

Carbon	87.21
Hydrogen	12.79
	100

b. Petroleum has most of the properties of naphtha, but is less fluid, and darker coloured. In the countries where it abounds, it is employed for burning in lamps.

c. Mineral Tar appears to be petroleum further inspissated· It is more viscid, and of a deeper colour.

d. Maltha or *Mineral Pitch* is a soft inflammable substance, heavier than water, and may be considered as derived from the exsiccation of mineral tar.

e. Asphaltum is found abundantly on the shores of the Dead Sea, in Albania, and in the island of Trinidad. Its colour is brown or black; it is heavier than water, and readily soluble in naphtha.

f. Elastic Bitumen, or *Mineral Caoutchouc* is found only in the vicinity of Castleton in Derbyshire. It is fusible and inflammable.

The above substances are insoluble in water, and difficultly soluble in alcohol, with the exception of naphtha and petroleum, which are soluble in highly-rectified alcohol.

g. *Retinasphaltum* is a substance which accompanies the Bovey Coal of Devonshire. It was first analyzed by Mr. Hatchett, who found it to consist of

55 Resin
41 Asphaltum
4 Earthy matter and loss.

h. *Pit Coal.* There are three chemical varieties of this important substance. The first, or *brown coal,* retains some remains of the vegetables from which it has originated. When heated it exhales a bituminous odour, and burns with a clear flame. It is generally of a tough consistency, and yields, according to Mr. Hatchett, a portion of unaltered vegetable extract, and resin.

The second variety, or *black coal,* is the ordinary fuel of this country. It exhibits no traces of vegetable origin, and consists principally of bitumen and charcoal, in variable proportions. When exposed to heat, it swells, softens, and burns with a bright flame, leaving a small quantity of ashes. Many varieties however abound in earthy matter, and these produce copious cinders, and burn with a less intense heat.

The products of the destructive distillation of this kind of coal have been already described (233). The residue is a hard sonorous charcoal, termed *coke,* and containing the earthy ingredients of the coal.

The third variety, or *glance coal,* consists almost entirely of charcoal, and earthy matter. It burns without flame, and when distilled produces scarcely any gaseous matter.

i. *Peat* and *Turf* consist principally of the remains of vegetables, having undergone comparatively little change. They often contain bituminous wood, and branches and trunks of trees.

k. *Mellilite* or *Honeystone* is a rare substance, found in the brown coal of Thuringia and in Switzerland. It is of a honey yellow colour, crystallized in octoëdra, and when analyzed by

Klaproth, was found to consist of alumina, combined with a peculiar body which has been called the *mellitic acid.*

Section XVII. *Vegetable Acids.*

756. The following are the principal acids, which are found ready formed in vegetable products.

1. Tartaric acid.
2. Oxalic acid.
3. Citric acid.
4. Malic acid.
5. Gallic acid.
6. Benzoic acid.

1. *Tartaric Acid.*

757. This acid may be obtained from the *supertartrate of potassa.* Mix 100 parts of this salt in fine powder with 30 of powdered chalk, and gradually throw the mixture into 10 times its weight of boiling water; when the liquor has cooled pour the whole upon a linen bag, and wash the white powder which remains with cold water: this is a *tartrate of lime;* diffuse it through a sufficient quantity of water, add sulphuric acid, equal in weight to tne chalk employed, and occasionally stir the mixture during twenty-four hours: then filter, and carefully evaporate the liquor to about one-fourth its original bulk; filter again, and evaporate with much care nearly to dryness; re-dissolve the dry mass, in about 6 times its weight of water, render it clear by filtration, evaporate slowly to the consistency of syrup, and set aside to crystallize. By two or three successive solutions and crystallizations, tartaric acid will be obtained in colourless crystals, soluble in 6 parts of water at 60°. According to Berzelius, the crystals contain 11,25 per cent of water. The aqueous solution of tartaric, in common with the

other vegetable acids, soon becomes mouldy and suffers decomposition.

When submitted to destructive distillation, it affords a brown acid liquor, which has been termed *pyrotartarous acid*.

According to Berzelius, the *tartrate of lead*, which is an insoluble salt, and easily formed by adding tartaric acid to a solution of nitrate of lead, consists of

Tartaric acid 100
Oxide of lead 167

And regarding this salt as composed of 1 proportional of acid, and 1 of oxide, we obtain the number 62,5, as the representative of tartaric acid, for

$$167 : 100 :: 104{,}5 : 62{,}5.$$

758. Tartaric acid combines with the metallic oxides, and produces a class of salts, called *tartrates*, the composition of which will be obvious from the preceding datum. Of these the following only are useful:—

759. *Tartrate of Potassa* is formed by saturating the excess of acid in *tartar*, by potassa. According to Mr. Richard Phillips *(Remarks on the Pharmacopœia)* 100 parts of tartar require 43,5 of subcarbonate of potassa. The resulting salt is soluble in less than twice its weight of water; it crystallizes in four-sided prisms, and consists of

1 proportional acid	=	62,5
1 proportional potassa	=	45
tartrate of potassa	=	107,5

This salt is used in Pharmacy as an aperient; it is the *potassæ tartras* of the *Pharmacopœia*.

760. *Bitartrate* or *Supertartrate of potassa. Tartar.* This substance exists in considerable abundance in the juice of the grape, and is deposited in wine casks, in the form of a crystallized incrustation, called *argol* or *crude tartar.* It is purified by solution and crystallization, which renders it perfectly white, and when in powder is termed *cream of tartar.*

It may also be formed, by adding excess of tartaric acid to a solution of potassa. The mixture presently deposits crystalline grains, and furnishes a striking example of the diminution of solubility by increase of acid in the salt. Upon this circumstance the use of tartaric acid as a test for potassa depends, for soda forms an easily soluble super-tartrate and consequently affords no precipitate. (312).

Bitartrate of potassa is composed of

2 proportionals of acid	=	125
1 proportional of potassa	=	45
Bitartrate of potassa	=	170

This salt requires 120 parts of water at 60° and 30 parts at 212° for its solution.

When exposed to heat, tartar fuses, blackens, and is decomposed ; and carbonate of potassa is the remaining result. (305) Provided the tartar be free from lime, which however is seldom the case, this furnishes a good process for obtaining pure carbonate of potassa.

761. *Tartrate of Potassa and Soda* is prepared by saturating the excess of acid in tartar, with carbonate of soda; it is the *soda tartarizata* of the *Pharmacopœia ;* it forms irregular prismatic crystals. It has long been used in pharmacy under the name of *Rochelle salt.*

762. The *Tartrates of Lime, Baryta* and *Strontia,* are insoluble; the former is produced by adding chalk to tartar as in the process for obtaining tartaric acid, where it is decomposed by sulphuric acid.

763. *Tartrate of Potassa and Antimony. Emetic Tartar.* This compound may be obtained by boiling protoxide of antimony, obtained by any of the processes formerly described, (512) with pure supertartrate of potassa. It is the *antimonium tartarizatum* of the *London Pharmacopœia,* where a very objectionable process is given for its preparation.

Emetic tartar may be prepared by boiling a solution of 100 parts of tartar with 100 parts of finely levigated glass of antimony, or of the protoxide described at page 255; the ebullition should be continued for half an hour, and the filtered liquor evaporated to about half its bulk and set aside to crystallize; octoedral and tetraedral crystals of the emetic salt, are thus obtained; and there is generally formed along with them a portion of tartrate of lime, which is deposited in small tufts of a radiated texture, and which may easily be separated when the mass is dried.

Mr. Phillips, in his *Experimental Examination of the London Pharmacopœia,* has stated several facts respecting the formation of this salt, which will be found useful to the manufacturer.

Emetic tartar is a white salt, slightly efflorescent, soluble in about 14 parts of cold and 2 parts of boiling water. It is decomposed by the alcalies, and when heated with ammonia, a portion of protoxide of antimony is thrown down and a very soluble compound remains in the liquor. Sulphuretted hydrogen and hydrosulphuret of ammonia produce orange-coloured precipitates in its solution. It is decomposed by bitter and astringent vegetable infusions, but they do not render it inactive as a medicine. Mr. Phillips has shewn that emetic tartar consists of 100 supertartrate of potassa, +66 protoxide of antimony. If we consider it, with Dr. Thomson, (*System,* Vol. II. p. 670) as a compound of 2 proportionals of tartaric acid, 2 of protoxide of antimony, and 1 of potassa; or as containing 1 proportional of tartrate of potassa and 1 of subtartrate of antimony, its components will stand thus:

Tartaric acid	$62{,}5 \times 2$	$= 125$
Protoxide of antimony	$52{,}5 \times 2$	$= 105$
Potassa		$= 45$
		275

2. *Oxalic Acid.*

764. This acid is found in some fruits, and in considerable quantity in the juice of the *oxalis acetosella*, or *wood-sorrel*, and in the varieties of *rhubarb*. It is most readily procured by the action of nitric acid upon sugar, and has hence been termed *acid of sugar*.

It may be obtained by introducing into a retort 4 oz. of nitric acid and 1 oz. of white sugar; nitric oxide gas is copiously evolved, and when the sugar has dissolved, about one-third of the acid may be distilled over: the contents of the retort are then emptied into a shallow vessel, and in the course of two or three days, an abundant crop of white crystals is deposited, and upon further evaporation of the mother liquor, a second portion is obtained. The whole crystalline produce is to be re-dissolved in water, and again crystallized, by which the pure acid is obtained. In this way sugar yields rather more than half its weight of oxalic acid.

765. Oxalic acid thus procured is in the form of four-sided prisms, transparent, and of a very acid taste: they dissolve in two parts of water at 60°, and in their own weights at 212°. When carefully dried they fall to powder, and lose more than one-third of their weight, being composed, according to Berzelius, (*Annales de Chimie*, LXXXI.) of

Real acid..	52
Water	48
	100

By repeated distillation with nitric acid, oxalic acid is resolved into carbonic acid and water; and the acid itself, and the salts containing it, as is the case with the other vegetable acids, are decomposed by heat. By distilling oxalate of lime, Dr. Thomson found the acid resolved into five new substances;

namely, water, carbonic acid, carbonic oxide, carburetted hydrogen, and charcoal; and by a very elaborate analysis of these gases, he determined the composition of the acid as follows :—

Oxygen....	64
Carbon....	32
Hydrogen..	4
	100

which numbers do not quite correspond with those given by Gay-Lussac and Thenard.

766. The number representing the oxalic acid, founded upon Dr. Wollaston's analysis of the bin-oxalate of potassa, (*Phil. Trans.* 1814.), and upon Berzelius' analysis of the oxalate of lead (*Annales de Chimie,* No. 243), is about 35,3. According to the latter chemist, oxalate of lead consists of 100 oxalic acid + 296,6 oxide of lead, and

$$296{,}6 : 100 :: 104{,}5 : 35{,}23.$$

The number deduced from the mean of the best analyses of oxalate of lime, is 35,7 ; and, accordingly, the mean of these which is about 35,5, may without material error be adopted as the representative number of oxalic acid, and the composition of the oxalates will be obvious accordingly.

767. *Oxalate of ammonia* is a very useful test for the presence of lime. It crystallizes in long prisms, of which 45 parts require 1,000 of water for their solution. Added to any soluble compound of lime, this salt produces an insoluble *oxalate of lime,* the composition of which is 35,5 acid + 26,5 lime.

768. *Oxalate of potassa* forms flat rhomboidal crystals soluble in 3 parts of water at 60°. It consists of 35,5 acid + 45 potassa. This salt, dissolved in oxalic acid, produces the *bin-oxalate of potassa,* which crystallizes in four-sided prisms, and consists of 2 proportionals acid $35{,}5 \times 2 = 71 + 45$ potassa. When this binoxalate is digested in dilute nitric acid, a portion of the alcali is taken up, and a salt remains consisting

of 4 proportionals of oxalic acid $35,5 \times 4 = 142 + 1$ proportional potassa $= 45$. This is the *quadroxalate of potassa*, and is the salt which exists in the wood sorrel.

769. The *oxalates* of *strontia*, *baryta*, and *magnesia*, are very nearly insoluble, and with the other metallic oxalates may be formed by double decomposition. They consist respectively of one proportional of each of their components.

770. The oxalic acid swallowed in large doses is an active poison, and fatal cases are not unfrequent in which this acid is taken by mistake for Epsom salt. The instant that the accident is discovered, a quantity of powdered chalk diffused in warm water should be taken, and vomiting excited as speedily as possible.

3. *Citric Acid.*

771. Citric acid is obtained by the following process from lemon or lime juice.

Boil the expressed juice for a few minutes, and when cold, strain it through fine linen: then add powdered chalk as long as it produces effervescence, heat the mixture, and strain as before: a quantity of citrate of lime remains upon the strainer, which, having been washed with cold water, is to be put into a mixture of sulphuric acid with 20 parts of water: the proportion of acid may be about equal to that of the chalk employed. In the course of 24 hours the citrate of lime will have suffered decomposition, and sulphate of lime is formed, which is separated by filtration. The filtered liquor, by careful evaporation, as directed for tartaric acid, furnishes crystallized citric acid.

The preparation of this acid is carried on by a few manufacturers upon an extensive scale; in different states of purity it is employed by the calico-printers, and used for domestic consumption. Many circumstances which have not here been alluded to, are requisite to ensure complete success in the operation; these have been fully described by Mr. Parkes, in the third volume of his *Chemical Essays.* The proportion of citric acid afforded by a gallon of good lemon juice, is about 8 ounces.

772. Citric acid forms crystals of a very sour taste, soluble in their own weight of water at 60°, and containing, according to Berzelius, 100 real acid + 26,5 water, a portion of which it loses by exposure to heat. The analysis of this, as well as of the other vegetable acids given by Berzelius, differs considerably from that of Gay-Lussac and Thenard, in consequence, as it would appear, of the latter chemists having neglected the exclusion of water of crystallization. Berzelius gives its constituents as follow:—

Oxygen....	54,831
Hydrogen .	3,800
Carbon	41,369
	100,000

From the analysis of citrate of lead, the representative number of citric acid appears to be 55,5; a number which closely corresponds with Berzelius' estimate of its constitution, which is

4	proportionals of oxygen . .	$7{,}5 \times 4 =$	30
3	——— hydrogen . .	$1 \times 3 =$	3
4	——— carbon . .	$5{,}7 \times 4 =$	22,8
			55,8

The number 55,5, therefore, may be adopted, and citrate of lime will consist of

1	proportional of acid =	55,5
1	——— lime =	26,5
		82

773. The *citrates* have been but little examined, and, with very few exceptions, are not important.

4. *Malic Acid.*

774. The existence of a peculiar acid in the juice of apples, was shown by Scheele, in 1785. He obtained it by adding solution of acetate of lead to the expressed juice of unripe apples, by which a *malate of lead* was formed, and afterwards decomposed by sulphuric acid. Vauquelin obtained it by a similar process, from the juice of the *houseleek.* The same acid exists, according to Braconnot, in the berries of the *mountain-ash,* from which it was first obtained by Mr. Donovan in 1815, and called by him *sorbic acid;* the apparent differences between the malic and sorbic acids, are referable to the impurities of the former. Mr. Donovan has given the following process for its preparation. *(Phil. Trans.* 1815.) Express the juice of the ripe berries, and add solution of acetate of lead, filter, and wash the precipitate with cold water, then pour boiling water upon the filter and allow it to pass through the precipitate into glass jars; after some hours crystals are deposited, which are to be boiled with 2,3 times their weight of sulphuric acid, specific gravity 1,090. The clear liquor is to be poured off, and while still hot, a stream of sulphuretted hydrogen is to be passed through it to precipitate the remaining lead; the liquid is then filtered, and when boiled so as to expel the sulphuretted hydrogen, is a solution of the pure vegetable acid.

Malic acid may also be obtained by steeping sheet-lead in the juice of apples: in a few days, crystals of malate of lead form, which may be collected and decomposed by the very careful addition of dilute sulphuric acid.

775. Malic acid when carefully prepared, is a colourless liquid, very sour, and not susceptible of crystallization. It forms crytallizable salts with many of the metallic oxides,

Titanium..............	brownish red.
Cerium	yellowish.
Tellurium.	yellow.
Arsenic...............	little change.
Molydenum............	deep brown.
Chrome	brown.
Columbium............	deep orange.
Nickel................	gray.
Mercury	deep yellow.
Osmium	purple, becoming blue.
Silver.................	yellow brown.
Platinum.............	dark green.

The omitted metals are either not precipitated, or their action has not been examined.

780. Of these compounds, the *tannogallate of iron* is of the most importance, as forming the basis of writing ink, and of black dyes.

When an infusion of galls, is dropped into a solution of sulphate of iron, it produces a deep purple precipitate, which is a very long time in subsiding; it becomes black by exposure to air. In writing ink, this precipitate is retained in suspension by mucilage, and the following proportions appear the best which can be used:

Finely bruised galls 3 ounces
Green Vitriol, (sulphate of iron)
Logwood shavings
Gum arabic, of each 1 ounce
Vinegar, 1 quart.

Put these ingredients into a bottle, and agitate them occasionally during twelve or fourteen days; then allow the coarser parts to settle, and pour off the ink for use.

The tendency of ink to become mouldy is much diminished by keeping a few cloves in the ink-bottle, or by dissolving in each pint o the ink about three grains of corrosive sublimate.

The colour of common writing-ink is apt to fade, in consequence of the decomposition of its vegetable matter; and when thus illegible, it may often be restored by washing the writing with vinegar, and subsequently with infusion of galls. Acids also destroy its colouring matter, and those inks which resist their action, contain some other colouring principle, usually finely powdered charcoal. Common writing-ink is, for this reason, much improved by dissolving in the quantity above mentioned about an ounce of *indian ink*, which is lamp-black, made into a cake with isinglass.

In dyeing black, the stuff is first impregnated with a solution of the gall-nut, and afterwards the colour is brought out by the application of sulphate, or acetate of iron.

Upon these subjects much valuable information will be found in Lewis's *Philosophical Commerce of the Arts*, and in Aikin's *Dictionary**.

6. *Benzoic Acid.*

781. Benzoic acid may be obtained by sublimation, from *Benzoin*, which is a resinous exudation from the *Styrax Benzoe* of Sumatra; it also exists in the *Balsam of Peru* and of *Tolu*. The best process for procuring this acid is that recommended by Mr. Hatchett, which consists in digesting benzoin in sulphuric acid, when it affords a copious sublimate of pure benzoic acid. It may also be obtained by boiling a pound and a half of powdered benzoin with four ounces of quicklime, in 6

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* In the *Philosophical Transactions* for 1817, I have described the properties of a species of galls from China, which furnish very pure gallic acid, and which, could they be abundantly obtained, would certainly prove a valuable substitute for common galls, in many of the processes in which they are employed.

or 8 quarts of water. When cold the clear liquor is decanted, and the residuum again boiled in half the former quantity of water. The liquors thus obtained are boiled down to half their bulk, filtered, and mixed with muriatic acid, as long as it occasions a precipitate, from which the liquor is poured off, and when dry it is put into an earthen vessel, placed in a sand heat, and sublimed into paper cones.

In the tenth volume of Nicholson's *Journal* I have detailed several experiments on benzoin, and have shewn the relative quantity of acid afforded by the several processes which have been recommended for obtaining it.

782. Benzoic acid, when it has been thus sublimed, is in the form of soft feathery crystals, of an acrid and slightly sour taste, soluble in about 30 parts of boiling water, and very sparingly soluble in cold water. It is much more soluble in alcohol, and this solution easily furnishes it in prismatic crystals.

783. The *benzoates* have not been examined with any considerable precision, except by Hisinger and Berzelius. (*Philosophical Magazine*, Vol. XL. *Annals de Chimie*. Tom. XC.) They are an unimportant class of salts.

Berzelius' analysis gives the following as the components of this acid, and of the benzoate of lead.

Hydrogen	5,16
Carbon	74,41
Oxygen	20,43
	100,00
Benzoic acid	100
Oxide of lead....................	94

Whence it appears that the representative number of benzoic acid is 112.

784. Besides the vegetable acids which have now been described, there are a few others of considerably inferior interest and importance; namely, the

Moroxylic acid, discovered by Klaproth, in the bark of the *morus alba*, or *white mulberry*. (Nicholson's *Journal*, Vol. VII.) *Boletic acid*, obtained by Braconnot, from the *boletus pseudo-ignarius*, (*Annals de Chimie*. Tom. LXXX.) *Zumic acid*, discovered by the same chemist in vegetable substances, which have undergone acetous fermentation. (Thomson's *System*, Vol. II. p. 189.) *Kinic acid*, discovered by Vauquelin, in *cinchona bark*.

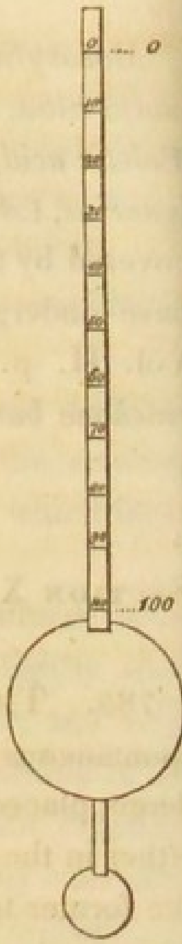
SECTION XVIII. *Phenomena and Products of Fermentation.*

785. THE term fermentation, is employed to signify the spontaneous changes, which certain vegetable solutions undergo, placed under certain circumstances, and which terminate either in the production of an intoxicating liquor, or of vinegar; the former termination constituting *vinous*, the latter *acetous* fermentation.

The principal substance concerned in vinous fermentation is sugar; and no vegetable juice can be made to undergo the process, which does not contain it in a very sensible quantity. In the production of beer, the sugar is derived from the malt, in that of wine, from the juice of the grape.

786. In the manufacture of *beer*, the malt is ground and infused in the *mash-tun*, in rather more than its bulk of water, of the temperature of 160°, or 180°. Here the mixture is stirred for a few hours; the liquor is then run off, and more water added, until the malt is exhausted. These infusions are called *wort*, and its principal contents are *saccharine matter*, *starch*, *mucilage*, and a small quantity of *gluten*. The strength of the wort is adjusted by its specific gravity, which is usually found by an instrument not quite correctly called a *saccharometer*, since it is influenced by all

the contents of the wort, and not by the sugar only. It is a brass instrument, of the shape shewn in the margin, so adjusted in weight as to sink to the point marked 0°. in distilled water, at the temperature of 70°, and when immersed in a liquor of the same temperature, and of the specific gravity of 1,100, it is buoyed up to the mark 100, just above the bulb. The intermediate space is divided into 100 equal parts, and consequently will indicate intermediate degrees of specific gravity. This is the most useful form of the instrument, though not that in common use. The specific gravity of the wort for ale is usually about 1,090, to 1,100, and for table-beer from 1,020 to 1,030.



The wort is next boiled with hops, amounting, upon the average, to $\frac{1}{20}$ the weight of the malt, their use being to cover the sweetness of the liquor by their aromatic bitter, and to diminish its tendency to acidify. The liquor is then thrown into large, but very shallow vessels, or *coolers*, where it is cooled to about 50°, as quickly as possible; it is then suffered to run into the *fermenting vat*, having been previously mixed with a proper quantity of *yeast*, which accelerates fermentation, apparently by virtue of the gluten which it contains.

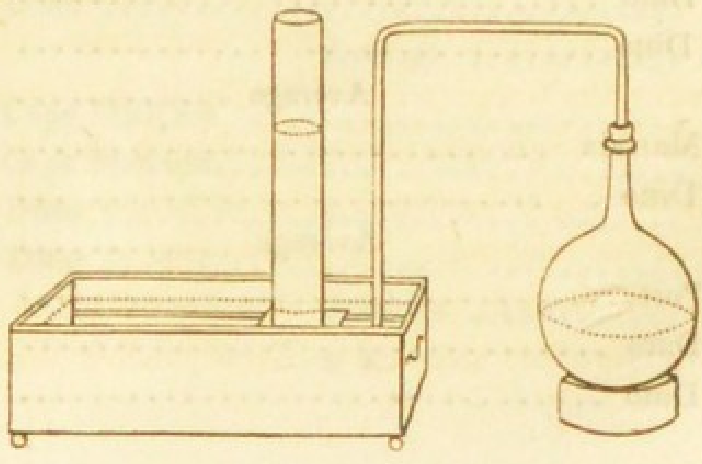
In the fermenting vessel, the different substances held in solution in the liquor, begin to act upon each other; an intestine motion ensues, the temperature of the liquor increases, carbonic acid escapes in large quantities ; at length this evolution of gas ceases, the liquor becomes quiet and clear, and it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become intoxicating.

787. The distillers prepare a liquor, called *wash*, for the

express purpose of procuring from it ardent spirits; instead of brewing this from pure malt, they chiefly employ raw grain, mixed with a small quantity only of malted grain; the water employed in the mash-tun is of a lower temperature than that requisite in brewing, and the mashing longer continued, by which it would appear that a part of the starch of the barley is rendered into a kind of saccharine matter. The wort is afterwards fermented with yeast.

788. *Wine* is principally procured from the juice of the grape, and some other saccharine and mucilaginous juices of fruits. The principal substances held in solution in grape-juice are, *sugar, gum, gluten,* and *supertartrate of potassa.* It easily ferments spontaneously at temperatures between 60° and 80°, and the phenomena it gives rise to closely resemble those of the wort with yeast. After the operation, its specific gravity is much diminished, its flavour changed, and it has acquired intoxicating powers.

789. If a mixture of one part of sugar, four or five of water, and a little yeast, be placed in a due temperature, it also soon begins to ferment, and gives rise to the same products as wort or grape-juice; and, as the free admission of air is not necessary to vinous fermentation, its results may easily be examined by suffering the process to go on in the following apparatus; consisting of a matrass containing the fermenting mixture, with a bent tube issuing from it, and passing into an inverted jar standing in water.



It will thus be found that the only gaseous product is carbonic acid; and, consequently, that carbon and oxygen are the principles which the saccharine matter loses during the process.

790. When any of the abovementioned fermented liquors are distilled, they afford a *spirituous liquor*; that from wine is termed *brandy*; from the fermented juice of the sugar-cane we obtain *rum*; and from wash, *malt spirit*; and these spirituous liquors, by re-distillation, furnish *spirit of wine, ardent spirit*, or *alcohol*.

The different fermented liquors furnish very different proportions of alcohol, and it has been sometimes supposed that it does not pre-exist to the amount in which it is obtained by distillation; but some experiments which I made upon the subject, in 1811 and 1813, and which are printed in the *Philosophical Transactions* for those years, tend to shew that it is a real educt, and not formed by the action of heat upon the elements existing in the fermented liquor. The following table exhibits the proportion of alcohol by measure, existing in 100 parts of several kinds of wine and other liquors.

		Proportion of Spirit per cent. by measure.
1.	Lissa	26,47
	Ditto	24,35
	Average	25,41
2.	Raisin wine	26,40
	Ditto	25,77
	Ditto	23,20
	Average	25,12
3.	Marsala	26,03
	Ditto	25,05
	Average	25,09
4.	Port	25,83
	Ditto	24,29
	Ditto	23,71

		Proportion of Spirit per cent. by measure.
	Port	23,39
	Ditto	22,30
	Ditto	21,40
	Ditto	19,00
	Average	22,96
5.	Madeira	24,42
	Ditto	23,93
	Ditto (Sercial)	21,40
	Ditto	19,24
	Average	22,27
6.	Currant wine	20,55
7.	Sherry	19,81
	Ditto	19,83
	Ditto	18,79
	Ditto	18,25
	Average	19,17
8.	Teneriffe	19,79
9.	Colares	19,75
10.	Lachryma Christi	19,70
11.	Constantia, white	19,75
12.	Ditto, red	18,92
13.	Lisbon	18,94
14.	Malaga	18,94
15.	Bucellas	18,49
16.	Red Madeira	22,30
	Ditto	18,40
	Average	20,35
17.	Cape Muschat	18,25
18.	Cape Madeira	22,94
	Ditto	20,50
	Ditto	18.11
	Average	20,51

		Proportion of Spirit per cent. by measure.
19.	Grape wine	18,11
20.	Calcavella	19,20
	Ditto	18,10
	Average	18,65
21.	Vidonia	19,25
22.	Alba Flora	17,26
23.	Malaga	17,26
24.	White Hermitage	17,43
25.	Rousillon	19,00
	Ditto	17,26
	Average	18,13
26.	Claret	17,11
	Ditto	16,32
	Ditto	14,08
	Ditto	12,91
	Average	15,10
27.	Zante	17,05
28.	Malmsey Madeira	16,40
29.	Lunel	15,52
30.	Sheraaz	15,52
31.	Syracuse	15,28
32.	Sauterne	14,22
33.	Burgundy	16,60
	Ditto	15,22
	Ditto	14,53
	Ditto	11,95
	Average	14,57
34.	Hock	14,37
	Ditto	13,00
	Ditto (old in cask)	8,88
	Average	12,08

		Proportion of Spirit per cent. by measure.
35.	Nice	14,63
36.	Barsac	13,86
37.	Tent	13,30
38.	Champagne (still)	13,80
	Ditto (sparkling)	12,80
	Ditto (red)	12,56
	Ditto (ditto)	11,30
	Average	12,61
39.	Red Hermitage	12,32
40.	Vin de Grave	13,94
	Ditto	12,80
	Average	13,37
41.	Frontignac	12,79
42.	Cote Rotie	12,32
43.	Gooseberry wine	11,84
44.	Orange wine,—average of six samples made by a London manufacturer	11,26
45.	Tokay	9,88
46.	Elder wine	8,79
47.	Cider, highest average	9,87
	Ditto, lowest ditto	5,21
48.	Perry, average of four samples	7,26
49.	Mead	7,32
50.	Ale (Burton)	8,88
	Ditto (Edinburgh)	6,20
	Ditto (Dorchester)	5,56
	Average	6,87
51.	Brown Stout	6,80
52.	London Porter (average)	4,20
53.	Ditto small beer (ditto)	1,28
54.	Brandy	53,39
55.	Rum	53,68

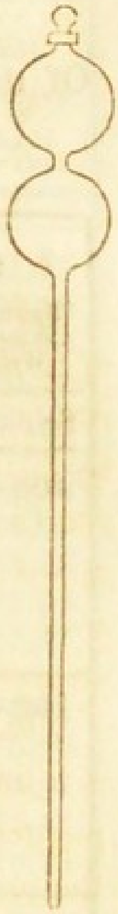
		Proportion of Spirit per cent. by measure.
56.	Gin	51,60
57.	Scotch Whiskey	54,32
58.	Irish ditto	53,90

791. The principle upon which the intoxicating properties of fermented liquors depends, and which exists in ardent spirits, is in its purest form called *alcohol*. It may be obtained by distilling the *rectified spirit of wine* of commerce, with one fourth of its weight of dry and warm subcarbonate of potassa, at a temperature of 200°; about three-fourths may be drawn over. There are other substances which may be used as substitutes for the subcarbonate, especially muriate of lime.

792. Alcohol thus obtained by slow and careful distillation, is a limpid, colourless liquid, of an agreeable smell, and a strong pungent flavour. Its specific gravity varies with its purity; the purest being ,791; as it usually occurs it is ,820 at 60°. If rendered as pure as possible by simple distillation, it can scarcely be obtained of a lower specific gravity than ,825, at 60°.

Alcohol has never been frozen, and consequently is particularly useful in the construction of thermometers intended to measure intense degrees of cold. When of a specific gravity of ,825, it boils at the temperature of 176°, the barometrical pressure being 30 inches. In the vacuum of an air-pump it boils at common temperatures. The specific gravity of the vapour of alcohol, compared with atmospheric air, is 1,613. (Gay-Lussac. *Annals de Chimie. et Physique*. Tom. I.)

793. Alcohol may be mixed in all proportions, with water, and the specific gravity of the mixture is greater than the mean of the two liquids, in consequence of a diminution of bulk that occurs on mixture, as may be shewn by the following experiment:—



The annexed wood-cut represents a tube with two bulbs, communicating with each other, the upper one being supplied with a well-ground glass stopper. Fill the tube and lower bulb with water, pour alcohol slowly into the upper bulb, and when full put in the stopper. The vessel will now be completely filled, the alcohol lying upon the water; if it be inverted, the alcohol and water will slowly mix, and the condensation that ensues will be indicated by the empty space in the tube. A considerable rise of temperature takes place in this experiment, in consequence of the condensation.

794. The strength of such spirituous liquors as consist of little else than water and alcohol, is of course ascertained by their specific gravity; and for the purpose of levying duties upon them, this is ascertained by the hydrometer*. In the *Philosophical Transactions* for 1794, Mr. Gilpin has given a copious and valuable table of the specific gravity of mixtures of alcohol and water, and of the condensation that ensues, with several other particulars. These are extremely useful, as enabling us to ascertain, without difficulty, the relative quantity of alcohol contained in any mixture of known specific gravity.

The original tables are extremely voluminous, and have been variously abridged by different persons; I have, however, thought it most useful to insert two of them, adapted to the temperature of 60°, and refer the reader to Mr. Gilpin's paper for those calculated at other temperatures.

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* An instrument constructed upon the same principle as that described at page 398. But the only correct mode of ascertaining the specific gravity of liquids, is by weighing them in a delicate balance, against an equal volume of pure water, of a similar temperature.

TABLE

Of the Specific Gravity and Composition of Mixtures of Alcohol and Water at the Temperature of 60°.

I. Spirit and Water by Weight. Sp. + W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+ 0	,82500	100	—	100,00	—	100,00
1	,82731	—	0,83	100,72	0,11	99.29
2	,82957	—	1,65	101,44	0,21	98,58
3	,83177	—	2,47	102,16	0,31	97,88
4	,83391	—	3,30	102,89	0,41	97,19
100+ 5	,83599	—	4,12	103,62	0,50	96,51
6	,83802	—	4,95	104,35	0,60	95,83
7	,84001	—	5,77	105,09	0,68	95,16
8	,84195	—	6,60	105,83	0,77	94,50
9	,84384	—	7,42	106.57	0,85	93,84
100+10	,84568	—	8,25	107,31	0,94	93,19
11	,84748	—	9,07	108,05	1,02	92,55
12	,84924	—	9,90	108,80	1,10	91,91
13	,85096	—	10,72	109,55	1,17	91,28
14	,85265	—	11,55	110,30	1,25	90,66
100+15	,85430	—	12,37	111,05	1,32	90,04
16	,85592	—	13,20	111,81	1,39	89,44
17	,85750	—	14,02	112,56	1,46	88,84
18	,85906	—	14,85	113,32	1,53	88,25
19	,86058	—	15,67	114,08	1,59	87,66
100+20	,86208	—	16,50	114,84	1,66	87,08
21	,86355	—	17,32	115,60	1,72	86,51
22	,86500	—	18,15	116,36	1,79	85,94
23	,86642	—	18,97	117,12	1,85	85,38
24	,86781	—	19,80	117,88	1,92	84,83
100+25	,86918	—	20,62	118,64	1,98	84,28
26	,87052	—	21,45	119,41	2,04	83,74
27	,87183	—	22,27	120,18	2,09	83,21
28	,87314	—	23,10	120,94	2,16	82,68
29	,87442	—	23,92	121.71	2,21	82,16

I. Spirit and Water by Weight. Sp. + W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+30	,87569	100	24,75	122,48	2,27	81,65
31	,87692	—	25,57	123,24	2,33	81,14
32	,87814	—	26,40	124,01	2,39	80,64
33	,87935	—	27,22	124,78	2,44	80,14
34	,88053	—	28,05	125,55	2,50	79,65
100+35	,88169	—	28,87	126,32	2,55	79,16
36	,88283	—	29,70	127,09	2,61	78,68
37	,88395	—	30,52	127,86	2,66	78,21
38	,88505	—	31,35	128,64	2,71	77,74
39	,88613	—	32,17	129,41	2,76	77,27
100+40	,88720	—	33,00	130,19	2,81	76,81
41	,88825	—	33,82	130,96	2,86	76,36
42	,88929	—	34,65	131,74	2,91	75,91
43	,89032	—	35,47	132,51	2,96	75,47
44	,89133	—	36,30	133,29	3,01	75,03
100+45	,89232	—	37,12	134,06	3,06	74,59
46	,89330	—	37,95	134,84	3,11	74,16
47	,89427	—	38,77	135,61	3,16	73,74
48	,89522	—	39,60	136,39	3,21	73,32
49	,89615	—	40,42	137,17	3,25	72,90
100+50	,89707	—	41,25	137,95	3,30	72,49
51	,89797	—	42,07	138,73	3,34	72,08
52	,89886	—	42,90	139,51	3,39	71,68
53	,89973	—	43,72	140,29	3.43	71,28
54	,90059	—	44,55	141,07	3,48	70,89
100+55	,90144	—	45,38	141,86	3,52	70,49
56	,90227	—	46,20	142,64	3,56	70,11
57	,90309	—	47,02	143,42	3,60	69,72
58	,90391	—	47,85	144,21	3,64	69,34
59	,90470	—	48,67	144,99	3,68	68,97
100+60	,90549	—	49,50	145,78	3,72	68,60
61	,90626	—	50,32	146,56	3,76	68,23
62	,90703	—	51,15	147,35	3,80	67,87
63	,90778	—	51,97	148,13	3,84	67,51
64	,90853	—	52,80	148,92	3,88	67,15

I. Spirit and Water by Weight. Sp. + W.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+65	,90927	100	53,62	149.71	3,91	66,80
66	,91001	—	54,45	150,50	3,95	66,45
67	,91074	—	55,27	151,28	3,99	66,10
68	,91146	—	56,10	152,07	4,03	65,76
69	,91217	—	56,92	152,85	4,07	65,42
100+70	,91287	—	57,75	153,64	4,11	65,09
71	,91356	—	58,57	154,42	4,15	64,76
72	,91424	—	59,40	155,21	4,19	64,43
73	,91491	—	60,22	156,00	4,22	64,10
74	,91557	—	61,05	156,79	4,26	63,78
100+75	,91622	—	61,87	157,58	4,29	63,46
76	,91686	—	62.70	158,37	4,33	63,14
77	,91748	—	63,52	159,16	4,36	62,83
78	,91811	—	64,35	159,95	4,40	62,52
79	,91872	—	65,17	160,74	4,43	62,21
100+80	,91933	—	66,00	161,53	4,47	61,91
81	,91993	—	66,82	162,32	4,50	61,61
82	,92052	—	67,65	163,11	4,54	61,31
83	,92110	—	68,47	163,90	4,57	61,01
84	,92168	—	69,30	164,70	4,60	60,72
100+85	,92225	—	70,12	165,49	4,63	60,43
86	,92281	—	70,95	166,29	4,66	60,14
87	,92336	—	71,77	167,08	4,69	59,85
88	,92391	—	72,60	167,87	4,73	59,57
89	,92445	—	73,42	168,66	4,76	59,29
100+90	,92499	—	74,25	169,46	4,79	59,01
91	,92552	—	75,07	170,25	4,82	58,73
92	,92604	—	75,90	171,05	4,85	58,46
93	,92656	—	76,72	171,84	4,88	58,19
94	,92707	—	77,55	172,64	4,91	57,92
100+95	,92758	—	78,37	173,43	4,94	57,66
96	,92807	—	79,20	174,23	4,97	57,40
97	,92856	—	80,02	175,02	5,00	57,14
98	,92905	—	80,85	175,82	5,03	56,88
99	,92954	—	81,68	176,62	5,06	56,62

I. Water and Spirit by Weight. W. + Sp.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+100	,93002	100	82,50	177,41	5,09	56,36
99	,93051	—	83,34	178,22	5,12	56,11
98	,93100	—	84,19	179,05	5,14	55,85
97	,93149	—	85,02	179,89	5,13	55,59
96	,93198	—	85,94	180,74	5,20	55,33
100+95	,93247	—	86,84	181,61	5,23	55,06
94	,93296	—	87,76	182,50	5,26	54,79
93	,93345	—	88,71	183,42	5,29	54,52
92	,93394	—	89,67	184,35	5,32	54,24
91	,93443	—	90,66	185,31	5,35	53,96
100+90	,93493	—	91,67	186,29	5,38	53,68
89	,93544	—	92,70	187,29	5,41	53,39
88	,93595	—	93,75	188,31	5,44	53,10
87	,93646	—	94,83	189,35	5,48	52,81
86	,93697	—	95,93	190,42	5,51	52,51
100+85	,93749	—	97,06	191,53	5,53	52,21
84	,93802	—	98,21	192,65	5,56	51,91
83	,93855	—	99,39	193,80	5,59	51,60
82	,93909	—	100,61	194,99	5,62	51,29
81	,93963	—	101,85	196,20	5,65	50,97
100+80	,94018	—	103,12	197,44	5,68	50,65
79	,94073	—	104,43	198,71	5,72	50,32
78	,94128	—	105,77	200,01	5,76	50,00
77	,94184	—	107,14	201,35	5,79	49,66
76	,94240	—	108,55	202,73	5,82	49,33
100+75	,94296	—	110,00	204,15	5,85	48,98
74	,94352	—	111,48	205,60	5,88	48,64
73	,94408	—	113,01	207,10	5,91	48,29
72	,94465	—	114,58	208,64	5,94	47,93
71	,94522	—	116,20	210,22	5,98	47,57
100+70	,94579	—	117,86	211,84	6,02	47,20
69	,94637	—	119,56	213,51	6,05	46,83
68	,94696	—	121,32	215,24	6,08	46,46
67	,94756	—	123,13	217,02	6,11	46,08
66	,94816	—	125,00	218,85	6,15	45,69

I. Water and Spirit by Weight. W. + Sp.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+65	,94876	100	126,92	220,74	6,18	45,30
64	,94936	—	128,90	222,69	6,21	44,91
63	,94997	—	130,95	224,70	6,25	44,50
62	,95058	—	133,06	226,78	6,28	44,10
61	,95119	—	135,25	228,93	6,32	43,68
100+60	,95181	—	137,50	231,14	6,36	43,26
59	,95243	—	139,82	233,44	6,38	42,84
58	,95305	—	142,23	235,82	6,41	42,41
57	,95368	—	144,73	238,28	6,45	41,97
56	,95430	—	147,32	240,82	6,50	41,52
100+55	,95493	—	150,00	243,47	6,53	41,07
54	,95555	—	152,77	246,22	6,55	40,61
53	,95617	—	155,65	249,08	6,57	40,15
52	,95679	—	158,65	252,05	6,60	39,67
51	,95741	—	161,77	255,14	6,63	39,19
100+50	,95804	—	165,00	258,34	6,66	38,71
49	,95867	—	168,37	261,68	6,69	38,21
48	,95931	—	171,87	265,16	6,71	37,71
47	,95995	—	175,53	268,80	6,73	37,20
46	,96058	—	179,35	272,59	6,76	36,68
100+45	,96122	—	183,34	276,56	6,78	36,16
44	,96185	—	187,50	280,70	6,80	35,63
43	,96248	—	191,86	285,05	6,81	35,08
42	,96311	—	196,43	289,60	6,83	34,53
41	,96374	—	201,21	294,38	6,83	33,97
100+40	,96437	—	206,25	299,42	6,83	33,40
39	,96500	—	211,54	304,71	6,83	32,82
38	,96563	—	217,10	310,28	6,82	32,23
37	,96626	—	222,97	316,15	6,82	31,63
36	,96689	—	229,17	322,36	6,81	31,02
100+35	,96752	—	235,71	328,90	6,81	30,40
34	,96816	—	242,65	335,84	6,81	29,78
33	,96880	—	250,00	343,21	6,79	29,14
32	,96944	—	257,81	351,04	6,77	28,49
31	,97009	—	266,13	359,38	6,75	27,83

I. Water and Spirit by Weight. W. + Sp.	II. Specific Gravity.	III. Spirit by Measure.	IV. Water by Measure.	V. Bulk of Mixture.	VI. Diminution of Bulk.	VII. Quantity of Spirit *per Cent.* by measure.
100+30	,97074	100	275,00	368,28	6,72	27,15
29	,97139	—	284,48	377,79	6,69	26,47
28	,97206	—	294,64	387,99	6,65	25,77
27	,97273	—	305,56	398,95	6,61	25,07
26	,97340	—	317,31	410,74	6,57	24,35
100+25	,97410	—	330,00	423,48	6,52	23,61
24	,97479	—	343,75	437,29	6,46	22,87
23	,97550	—	358,70	452,31	6,39	22,11
22	,97622	—	375,00	468,64	6,36	21,34
21	,97696	—	392,86	486,58	6,28	20,55
100+20	,97771	—	412,50	506,29	6,21	19,75
19	,97848	—	434,21	528,08	6,13	18,94
18	,97926	—	458,33	552,29	6,04	18,11
17	,98006	—	485,29	579,34	5,95	17,26
16	,98090	—	515,62	609,76	5,86	16,40
100+15	,98176	—	550,00	644,25	5,75	15,52
14	,98264	—	589,29	683,66	5,63	14,63
13	,98356	—	634,61	729,10	5,51	13,72
12	,98452	—	687,50	782,11	5,39	12,79
11	,98551	—	750,00	844,74	5,26	11,84
100+10	,98654	—	825,00	919,87	5,13	10,87
9	,98761	—	916,67	1011,70	4,97	9,88
8	,98873	—	1031,25	1126,44	4,81	8,88
7	,98991	—	1178,57	1273,92	4,65	7,85
6	,99115	—	1375,00	1470,52	4,48	6,80
100+ 5	,99244	—	1650,00	1745,70	4,30	5,73
4	,99380	—	2062,50	2158,37	4,13	4,63
3	,99524	—	2750,00	2846,04	3,96	3,51
2	,99675	—	4125,00	4221,21	3,79	2,37
1	,99834	—	8250,00	8346,38	3,62	1,20

795. Alcohol is extremely inflammable, and burns with a pale blue flame, scarcely visible in bright daylight. It occasions no fuliginous deposition upon substances held over it, and the products of its combustion are carbonic acid and water, the weight of the water considerably exceeding that of the alcohol consumed. According to Saussure, jun., 100 parts of alcohol afford, when burned, 136 parts of water.

796. When the vapour of alcohol is passed through a red-hot copper tube, it is decomposed, a portion of charcoal is deposited, and a large quantity of carburetted hydrogen gas is evolved.

The most satisfactory experiments on the composition of alcohol are those of Saussure, as quoted by Dr. Thomson, (*System*, Vol. II. p. 327.) He passed the alcohol through a red-hot porcelain tube, terminating in a glass tube six feet long, and surrounded by ice; all the products were carefully collected and weighed. The result of this analysis was, that 100 parts of pure alcohol consist of

Hydrogen	13,70
Carbon	51,98
Oxygen	34,32
	100,00

These numbers approach to 3 proportionals of hydrogen, = 3; 2 of carbon, = 11,4; and 1 of oxygen, = 7,5.

Or it may be regarded as composed of

Olefiant gas	61,63
Water......	38,37
	100,00

If we consider it as composed of one volume of olefiant gas, and one volume of the vapour of water, the two volumes being condensed into one, the specific gravity of the vapour of alcohol, compared with common air, will be 1,599, or, according to Gay-Lussac, 1,613.

797. Alcohol is a powerful solvent of many saline substances; it dissolves many of the muriates and nitrates, but very few of the sulphates. The resins, soaps, extractive matter, and tannin, nearly all the volatile oils, and a few of the fixed oils, are copiously dissolved by it; so also are the acids, with the exception of the phosphoric, and those with metallic bases. Ammonia, potassa, and soda are very soluble in it.

798. When alcohol is submitted to distillation, with certain acids, a peculiar compound is formed, called *ether*, the different ethers being distinguished by the name of the acid employed in their preparation.

a. Sulphuric Ether.

799. *Sulphuric Ether* is the most important of these compounds. It is prepared as follows. Equal weights of alcohol and sulphuric acid, are carefully mixed and introduced into a glass retort placed in a sand bath, to which is adapted a capacious tubulated glass globe, connected with a receiver, as represented in the wood-cut at page 103. Raise the mixture in the retort to its boiling point as rapidly as possible, and keeping the receiver cool by water or ice, continue the distillation, till opaque vapours appear in the retort; then remove the receiver, and agitate its contents with a little quick-lime; after which pour off the clear liquor, and re-distil to the amount of three-fourths its original quantity with the same precautions as before. The ether may be further purified, by distilling it off muriate of lime. The *London Pharmacopœia* directs the distillation of ether with potassa, for its purification from sulphurous acid; and Mr. Richard Phillips, in his "*Experimental Examination*," has given the following directions for procuring ether for pharmaceutical purposes, which answer extremely

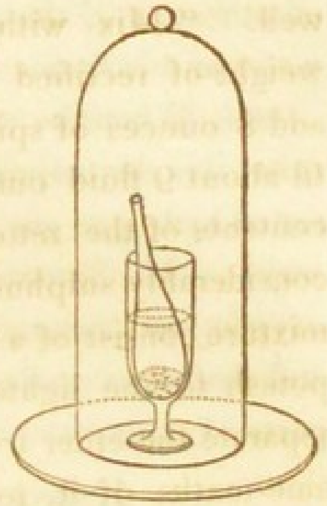
well. "Mix with 16 ounces of sulphuric acid, an equal weight of rectified spirit, and distil about 10 fluid ounces; add 8 ounces of spirit to the residuum in the retort, and distil about 9 fluid ounces; or continue the operation until the contents of the retort begin to rise, or the product becomes considerably sulphurous; mix the two products, and if the mixture consist of a light and heavy fluid, separate them: add potash to the lighter, as long as it appears to be dissolved; separate the ether from the solution of potash, and distil about nine-tenths of it, to be preserved as *ether sulphuricus,* the specific gravity of which ought to be at most ,750.

800. Sulphuric ether, is a transparent, colourless liquid, of a pleasant smell, and a pungent taste; it is highly exhilarating, and produces a degree of intoxication, when its vapour is inhaled by the nostrils. Its specific gravity varies extremely with its purity. Lowitz is said to have procured it as light as ,632. I have never obtained it lower than 700; and as ordinarily prepared, its specific gravity varies between ,730, and ,760.

It is extremely volatile, and when poured from one vessel into another, a considerable portion evaporates; during its evaporation from surfaces, it produces intense cold, as may be felt by pouring it upon the hand; and seen, by dropping it upon the bulb of a thermometer, which sinks to many degrees below the freezing point. (54) The specific gravity of the vapour of sulphuric ether, compared with atmospheric air, is, according to Gay-Lussac, as 2,586, to 1,000.

At mean pressure, sulphuric ether, when of a specific gravity of ,720 boils at 98°, and under the exhausted receiver of the air-pump, at all temperatures above — 20°; hence were it not for atmospheric pressure, ether would only be known in the state of vapour.

In consequence of the cold produced during the vaporization of sulphuric ether, the phenomena of boiling and freezing may be exhibited in the same vessel. For this purpose procure a very thin flask which fits loosely into a wine-glass, as shewn in the margin. Pour a small quantity of ether into the flask, and of water into the glass, and place the whole under a receiver of the air-pump; during exhaustion, the ether will boil, and a crust of ice will gradually form upon the exterior of the flask.



When subjected to a degree of cold equal to -46°, sulphuric ether freezes.

801. Ether dissolves the resins, several of the fixed oils, and nearly all the volatile oils; it also dissolves a portion of sulphur, and of phosphorus; the latter solution is beautifully luminous when poured upon warm water, in a dark room. The fixed alcalies are not soluble in ether, but it combines with ammonia.

802. Ether is sparingly soluble in water, and in alcohol it dissolves in all proportions. The *spiritus etheris sulphurici* of the *Pharmacopœia*, is an alcoholic solution of ether.

803. Ether is highly inflammable, and in consequence of its volatility it is often kindled by the mere approach of a burning body; a circumstance which renders it highly dangerous to decant, or open vessels of ether near a candle.

The inflammability of ethereal vapour, may be shewn by passing a small quantity into a receiver, furnished with a brass stop-cock and pipe, inverted over water at the temperature of 100°. The receiver becomes filled with the vapour, which may be propelled and inflamed; it burns with a bright bluish white flame.

804. When ether is admitted to any gaseous body, it increases its bulk. Oxygen thus expanded, produces a highly inflammable mixture; if the quantity of oxygen be large, and

of ether small, the mixture is highly explosive, and produces water and carbonic acid.

805. When the vapour of ether is passed through a red-hot tube, it is decomposed, and furnishes a large quantity of carburetted hydrogen gas. Its analysis has been performed in various ways. M. Saussure, by detonating ethereal vapour with oxygen, and ascertaining the quantity of carbonic acid formed, and that of oxygen consumed, is led to consider the component parts of ether, as

Hydrogen................	14,40
Carbon..................	67,98
Oxygen..................	17,62

which proportions are equivalent to

Olefiant gas	100
Water.....................	25

Or, it may be stated as consisting of

5 proportionals of olefiant gas,		$6{,}7\times5=33{,}5$
1 ———————— water		——— $= 8{,}5$
		42,0

which numbers, reduced to ultimate components, give

6 proportionals of hydrogen		$1\times6= 6.$
5 ————————	carbon	$5{,}7\times5=28{,}5$
1 ————————	oxygen	——— $= 7{,}5$
		42,0

806. By reverting to the composition of alcohol, the change effected upon it by the sulphuric acid in the process of etherification will be evident, as also the rationale of the production of olefiant gas (796). Alcohol consists of

Olefiant gas	100
Water	50

If we now subtract the whole of the water, which may be effected by a due proportion of sulphuric acid, we obtain olefiant gas only, but, if we only abstract half the water, we convert the alcohol into ether; not that either of these conversions are ever perfectly performed in any of our processes.

807. When a little ether is introduced into chlorine, the gas is absorbed, and a peculiar compound results, in which muriatic acid is very perceptible; if the ether be inflamed, a large quantity of charcoal is deposited, and muriatic acid gas is abundantly evolved.

808. If ether be mixed with its bulk of sulphuric acid, and submitted to distillation, a portion of it is converted into a peculiar fluid, which has been termed *oil of wine;* it is the *oleum ethereum* of the *Pharmacopœia*, though the directions given in that work for its preparation, are very inadequate. It has a sweetish taste, and a rich agreeable odour. It does not mix with water, but readily dissolves in ether and in alcohol. It is very inflammable, and deposits a large quantity of carbon during its combustion. Its composition has not been inquired into.

809. When ether is passed over red hot platinum wire, or consumed in the lamp, without flame, described in the Chapter on Radiant Matter, a peculiar acid substance is produced, which has lately been subjected to an interesting series of experiments, by Mr. J. F. Daniell, (*Journal of Science*, Vol. VI., p. 318.) He obtained it by placing the lamp filled with ether, and properly trimmed with a coil of glowing platinum wire, under the head of an alembic, in which the vapour was condensed, and collected in a phial applied to its beak.

Lampic acid, for so Mr. Daniell has termed this product, is colourless, sour, and pungent; its vapour is very irritating, and its specific gravity, when purified, by carefully driving off a portion of alcohol which it contains, is about 1015. It reddens vegetable blues, and decomposes the alcaline carbonates with effervescence.

Mr. Daniell has described many of the combinations of this acid, which he terms *lampates*, and has given some experiments upon its composition, whence he deduces its ultimate components, as follow:

1	proportional carbon	....	5,7
1	——— hydrogen	....	1
1	——— water	....	8,5
			15,2

When lampic acid is added to the solutions of silver, gold, platinum, mercury, and copper, and the mixture heated, the metals are thrown down in the metallic state.

On distilling the *lampate of mercury*, made by digesting the peroxide of mercury in the acid, Mr. Daniell obtained the concentrated or pure lampic acid, in the form of a very dense liquid, with an intensely suffocating odour.

b. Nitric Ether.

810. When strong nitric acid and alcohol are mixed in equal proportions, a violent action presently ensues; there is a very copious evolution of an inflammable aëriform body, which has been called *nitrous etherised gas*, and which appears to be a compound of nitrous ether, and nitric oxide. If we endeavour to condense the volatile products, we find that the receiver contains alcohol, water, nitrous ether, nitrous acid, and acetic acid, and that the greater portion of the true ether has made its escape with the gaseous products. Thenard has paid much attention to this subject, and has given the following process for obtaining nitric ether. (*Mémoires d'Arcueil,* Tom. I. and *Traité de Chimie,* Tom. III. p. 278.)

Introduce into a sufficiently capacious retort equal weights of alcohol, (sp. gr. 820) and of nitric acid of commerce (sp. gr. 1,30) and connect it with five Wolfe's bottles, the first of which is empty, and the remaining four half filled with a saturated solution of salt in water. Apply a gentle heat to the retort, till the liquor begins to effervesce; then withdraw the fire, and the gaseous matter passing through the bottles, which should be kept cold by ice, deposits the ether upon the saline solution, from which it is to be decanted, shaken with chalk, and redistilled at a very gentle heat.

811. Nitric ether thus prepared, has the following properties. It has a very powerful etherial odour; its colour is pale yellow; its taste very pungent; its specific gravity above that of alcohol, but less than that of water. It is more volatile than sulphuric ether, and the heat of the hand is sufficient to produce its ebullition. It is soluble in 48 parts of water; and in all proportions in alcohol; this last solution is the *spiritus ætheris nitrici*, or *sweet spirit of nitre*, of the *Pharmacopœia.* It is decomposed by keeping, and nitric and acetic acids are formed in it. According to Thenard, nitric ether consists of

Oxygen	48,52
Carbon	28,45
Nitrogen	14,49
Hydrogen	8,54
	100,00

Dr. Thomson, (*System*, Vol. II. p. 341.) concludes from analogy, that nitric ether consists of four proportionals of olefiant gas = 26,8 and one of nitric acid, = 50,5, or of

4	Proportionals of hydrogen	1 × 4 =	4,
4	———— carbon	5,7 × 4 =	22,8
1	———— nitrogen	————	13,
5	———— oxygen	7,5 × 5 =	37,5
			77,3

812. When nitric acid, holding mercury or silver in solution, is added to alcohol, a white precipitate is formed during the effervescence that ensues, which is possessed of powerful detonating properties.

Fulminating Mercury was discovered by Mr. Howard, who has given the following directions for its preparation. Dissolve 100 grains of mercury, in a measured ounce and a half of nitric acid, by the assistance of a gentle heat; pour this solution into two measured ounces of alcohol, previously put into an evaporating basin, and apply a gentle heat till an effervescence ensues; when this has ceased, pour the liquid off the precipitate which had formed, collect it upon a filter, wash it with a small quantity of water, and dry it at a heat not exceeding 212°.

Fulminating mercury thus prepared is in the form of small crystalline grains, of a whitish yellow or pale grey colour. A few grains placed on a smooth anvil and struck with a hammer, detonate with a sharp, stunning report; it also explodes by friction, heat, and electricity; and by the action of concentrated sulphuric acid, though with less noise.

Mr. Howard considers this powder as a compound of oxalate of mercury, and nitrous etherised gas; Fourcroy, however, has shewn that its composition varies a little, under different circumstances of preparing it. (Howard, *Phil. Trans.* 1800.)

813. By a similar process nearly, a species of *fulminating silver*, may be prepared. (Descotils, Nicholson's *Journal*, Vol. XVIII.) Upon three drachms of powdered nitrate of silver, pour two ounces and a half of alcohol, and add seven drachms by measure of nitric acid. When the effervescence has nearly ceased add a little water, wash the precipitate, and dry it in the open air, secluded from light. (Accum's *Chemical Amusement*, 3d edit. p. 102.)

This very dangerous compound explodes upon slight friction, or when gently heated, or touched with sulphuric acid; and, upon the contact of a sharp piece of glass, or rock crystal, it detonates even under water: an electric spark also occasions its explosion.

When exploded under slight pressure in contact of gunpowder, it inflames it.

The composition of this species of fulminating silver has not been ascertained with precision; indeed, the subject is one of extreme difficulty, in consequence of the new products that are formed by its sudden decomposition.

c. Muriatic Ether.

814. Muriatic ether was thus obtained by Thenard, (*Mémoires d'Arcueil*, Tom. I.) Equal measures of strong liquid muriatic acid, and highly rectified alcohol, are put into a retort communicating with a receiver, from which a tube passes into a Wolfe's bottle containing warm water, and having a tube of safety: from this there issues a bent tube passing into a bottle surrounded by ice. On applying heat to the retort, a portion of alcohol and acid pass into the first receiver, and the ether in a gaseous state escapes through the warm water and the bent tube, and is condensed in the cold vessel.

At a temperature somewhat below 70° muriatic ether passes into the state of vapour, of which the specific gravity is about 2,220, that of air being 1,000; it is highly inflammable, its taste sweetish and ethereal, and soluble in its own bulk of water, at 64°. Its specific gravity in a liquid state, at 40°, is 870. It is remarkable that this ether does not affect vegetable blues, nor does it afford traces of chlorine to the usual tests; but, when burned, muriatic acid is immediately perceptible. According to Thenard, this ether contains

Muriatic acid..........	29,44
Carbon	36,61
Oxygen	23,31
Hydrogen	10,64
	100,00

Dr. Thomson considers muriatic ether as a compound of four proportionals of olefiant gas, and one of muriatic acid; hence it would contain

5 proportionals of hydrogen	$1 \times 5 =$	5,
4 ——— carbon	$5,7 \times 4 =$	22,8
1 ——— chlorine	———	33,5
		61,3

d. Hydriodic Ether.

815. By distilling two measures of alcohol, with one of concentrated liquid hydriodic acid, Gay-Lussac obtained an ethereal liquid, of a specific gravity of 1,920 at 72°, and requiring a temperature of 148° for its ebullition. Its properties have not been very satisfactorily investigated, nor have any accurate experiments demonstrated its composition. (*Annales de Chimie*, XCI.)

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816. When any of the vinous liquors are exposed to the free access of atmospheric air, at a temperature of 80° or 85° they undergo a second fermentation, terminating in the production of a sour liquid, called *vinegar*. During this process a portion of the oxygen of the air is converted into carbonic acid; hence, unlike vinous fermentation, the contact of the atmosphere is necessary, and the most obvious phenomenon is the removal of carbon from the beer or wine; the vinegar of this country is usually obtained from malt liquor, while wine is

employed as its source in those countries where the grape is abundantly cultivated.

The colour of vinegar varies according to the materials from which it has been obtained; that manufactured in England, is generally artificially coloured with burnt sugar; its taste and smell are agreeably acid. Its specific gravity is liable to much variation; it seldom exceeds 1,0250. When exposed to the air it becomes mouldy and putrid, chiefly in consequence of the mucilage which it contains, and from which it may be in some measure purified by careful distillation. According to Mr. R. Phillips, (*Remarks on the London Pharmacopœia,*) when good malt vinegar of the specific gravity of 1,020 is distilled, the first eighth that passes over, is of the specific gravity 0,997; the next six-eights are of specific gravity 1,0023, and a fluid ounce decomposes 8,12 grains of precipitated carbonate of lime. The lightness of the first portion, is owing to its containing alcohol; consequently, in the *Pharmacopœia* process it is ordered to be rejected. The term *distilled vinegar* is properly applied to the second portion; it is erroneously called *acetic acid,* in the *Pharmacopœia.* The matter which remains in the still is empyreumatic, and frequently contains some other vegetable acids: when the vinegar has been adulterated, which is not unfrequently the case, we sometimes find in it muriatic and sulphuric acids.

817. Distilled vinegar is colourless, and of a flat acid taste; it consists essentially of the real acid, diluted with water. To obtain *acetic acid,* or as it has been sometimes called, *radical vinegar,* distilled vinegar may be saturated with some metallic oxide, and the acetate thus obtained, subsequently decomposed.

Acetic acid is thus procured by distilling *acetate of copper,* or *crystallized verdigris,* in a glass retort heated gradually, nearly to redness: it requires re-distillation to free it from a little oxide of copper, which passes over in the first instance.

Acetic acid may also be obtained by distilling *acetate of lead* with half its weight of sulphuric acid.

The acid obtained by these processes is transparent and colourless, its odour highly pungent, and it blisters and excoriates when applied to the skin. Its specific gravity is 1,080. It is extremely volatile, and its vapour readily burns; it combines in all proportions with water, and when considerably diluted, resembles distilled vinegar. When highly concentrated it crystallizes at the temperature of 40°, but liquefies when its heat is a little above that point.

818. According to Berzelius, whose analysis of acetic acid was very carefully conducted, (Thomson's *Annals*, Vol. IV.) its ultimate components are,

Carbon	46,83
Oxygen..................	46,82
Hydrogen	6,35
	100,00

These numbers reduced to definite proportionals, give

3	Proportionals of	hydrogen	$1 \times 3 = 3$
4	————	carbon	$5,7 \times 4 = 22,8$
3	————	oxygen	$7,5 \times 3 = 22,5$
			48,3

hence we see that there is no excess of oxygen in acetic acid, but that it consists of

3	Proportionals of water	$8,5 \times 3 = 25,5$
4	———— carbon	$5,7 \times 4 = 22,8$
		48,3

The chemist above quoted has given the composition of acetate of lead, at 100 acid + 217,5 oxide of lead, and

$$217,5 : 100 :: 104,5 : 48.$$

so that the number 48 may safely be adopted as the representative of acetic acid.

819. The acetates are mostly very soluble, deliquescent, and difficultly crystallizable; they are decomposed by sulphuric acid, and when submitted to destructive distillation furnish a modified vinegar, which has been termed *pyroacetic acid,* or *spirit*. The following are among the most important of the acetates.

820. *Acetate of Ammonia,* is a very deliquescent, soluble salt, and extremely difficultly crystallizable. In solution, obtained by saturating distilled vinegar with carbonate of ammonia, it constitutes the *liquor ammoniæ acetatis* of the *Pharmacopœia,* which has long been used in medicine as a diaphoretic, under the name of *spirit of Mindererus*.

821. *Acetate of Potassa* is usually formed by saturating distilled vinegar with carbonate of potassa, and evaporating to dryness. If this salt be carefully fused, it concretes into a lamellar deliquescent mass on cooling. It is the *terra foliata tartari,* and *digestive salt of Sylvius* of old pharmacy. It dissolves in its own weight of water, at 60°, and the solution has an acrid saline taste. It consists of one proportional of each of its components, or 45 potassa + 48 acetic acid = 93 acetate of p tassa.

822. *Acetate of Lime,* is a difficultly crystallizable salt, readily soluble in water, and of a bitter saline taste; consisting of 26,5 lime + 48 acid. It is sometimes obtained by saturating the vinegar formed during the distillation of wood, and employed in the preparation of *acetate of alumina,* which is used by the calico-printers as a mordant.

823. *Acetate of Lead,* is the *sugar of lead,* and *salt of Saturn* of the old chemists: it may be regarded as the most important of the acetates; it is used in pharmacy, and by dyers and calico-printers, for the preparation of acetate of alumina and of iron, which are formed by mixing its solution with that of the sulphates of those metals, an insoluble sulphate of lead being at the same time produced. Acetate of lead is formed

by digesting the carbonate in distilled vinegar, or in the acetic acid obtained by the destructive distillation of wood; it usually occurs in masses composed of acicular crystals; but by careful crystallization it may be obtained in quadrangular prisms. Its taste is sweet and astringent, and it is soluble in about four parts of water, at 60°. It is sometimes improperly termed a superacetate, but the salt is neutral, though when dissolved in water containing the smallest portion of carbonic acid a white insoluble compound of lead falls, and a little acetic acid being liberated, the solution is rendered sour. According to the experiments of Berzelius, acetate of lead consists of

Acetic acid	26,97
Protoxide of lead..............	58,71
Water	14,32
	100

hence the dry acetate is composed of

1	Proportional of acetic acid.	48
1	————— yellow oxide of lead	104,5

When acetate of lead is submitted to destructive distillation it furnishes a considerable quantity of a peculiar fluid, smelling and burning like alcohol. (Proust, *Journal de Physique*, Tom. LVI.

824. When 100 parts of sugar of lead are boiled in water, with about 150 of yellow oxide, or of finely powdered litharge, a salt is obtained which crystallizes in plates, and is less sweet and soluble than the acetate; it has been termed *sub-acetate of lead*, and consists, according to Berzelius, of 1 proportional of acid = 48 + 3 proportionals of oxide of lead, 313,5. This compound has long been used in pharmacy, under the name of *Goulard's extract of lead.* It is very rapidly precipitated by carbonic acid, of which it is a most delicate test; it also has a strong attraction for vegetable colouring matter, upon which

principle I employed it in my analysis of wines. (*Phil. Trans.* 1813.)

825. *Acetate of Copper.* By exposing copper to the fume of vinegar, it becomes gradually encrusted with a green powder called *verdegris,* which is separable by the action of water, into an insoluble *subacetate of copper,* and a soluble *acetate.*

Acetate of copper may be obtained by digesting verdegris, or oxide of copper, in acetic acid; by evaporating this solution it is obtained in prismatic crystals of a fine green tint. It dissolves sparingly in water and alcohol, and communicates a beautiful blue-green colour to the flame of the latter; by distillation it affords a very pure acetic acid. According to Dr. Thomson, acetate of copper in its crystallized state, consists of

1	Proportional of acid	48
1	——————— oxide of copper	67,5
8	——————— water	66
		181,5

CHAPTER VII.

Of Animal Substances.

826. THE different sections of this chapter will contain an account of the ultimate and proximate principles of the substances belonging to the animal creation, of the different methods of analysis by which these principles are obtained, and of such of the animal functions as are concerned in their production, where these are susceptible of chemical elucidation.

SECTION I. *Of the ultimate principles of Animal Matter, and of the products of its destructive distillation.*

827. THE proximate principles of the animal creation, consist, like those of vegetables, of a few elementary substances, which by combination in various proportions, give rise to their numerous varieties. Carbon, hydrogen, oxygen, and nitrogen, are the principal ultimate elements of animal matter; and phosphorus and sulphur are also often contained in it. The presence of nitrogen constitutes the most striking peculiarity of animal, compared with vegetable bodies; but as some vegetables contain nitrogen, so there are also certain animal principles, into the composition of which it does not enter.

828. The presence of nitrogen stamps a peculiarity upon the products obtained by the destructive distillation of animal matter, and which are characterised by the presence of ammonia, formed by the union of the hydrogen with the nitrogen. It is sometimes so abundantly generated as to be the leading

product; thus, when horn, hoofs, or bones, are distilled *per se,* a quantity of solid carbonate of ammonia, and of the same substance combined with empyreumatic oil, and dissolved in water, are obtained; hence the pharmaceutical preparations called *spirit* and *salt of hartshorn,* and Dippel's *animal oil.* Occasionally the acetous, benzoic, and some other acids are formed by the operation of heat on animal bodies, and these are found united to the ammonia; cyanogen and prussic acid also frequently occur.

If the gas evolved during the decomposition of animal bodies be examined, it is generally inflammable, and consists of carburetted hydrogen, often with a little sulphuretted and phosphuretted hydrogen; carbonic oxide, carbonic acid, and nitrogen, are also sometimes detected in it.

The coal remaining in the retort is commonly very difficult of incineration, a circumstance depending upon the common salt and phosphate of lime, which it usually contains, forming a glaze upon its surface, which defends the carbon from the action of the air. Animal charcoal is also found to be more effectual in destroying colour and smell, than that obtained from vegetables.

829. By the term *putrefaction* we mean the changes which dead animal matter undergoes, and by which it is slowly resolved into new products. These changes require a due temperature, and the presence of moisture; for below the freezing point of water, or when perfectly dry, it undergoes no alteration.

During putrefaction the parts become soft and flabby, they change in colour, exhale a nauseous and disgusting odour, diminish considerably in weight, and afford several new products, some of which escape in a gaseous form, others run off in a liquid state, and others are contained in the fatty, or earthy residuum.

The presence of air, though not necessary to putrefaction, materially accelerates it, and those gases which contain no oxygen, are very efficient in checking or altogether preventing the process. Carbonic acid also remarkably retards putrefaction; and if boiled meat be carefully confined in vessels containing that gas, it remains for a very long time unchanged, as seen in M. Appert's method of preserving meat.

There are several substances which, by forming new combinations with animal matter, retard or prevent putrefaction, such as many of the saline and metallic compounds; sugar, alcohol, volatile oils, and many other substances also stand in the list of anti-putrifactives, though their mode of operating is by no means understood.

830. The effluvia which arise from putrescent substances, and more especially those generated in certain putrid disorders, have a tendency to create peculiar diseases, or to give the living body a tendency to produce poisons analogous to themselves. An atmosphere thus tainted by infectious matter, may be rendered harmless by fumigation with the volatile acids, more especially the nitrous and the muriatic; chlorine is also very effectual: the vapour of vinegar, though sometimes useful in covering a bad smell, is not to be relied on. It appears evident that the acid and chlorine act chemically upon the pernicious matter, and resolve it into innocuous principles.

831. When muscular flesh is immersed in a stream of running water, it is partially converted into a substance, having many of the properties of fat, combined with a portion of ammonia. The same changes have been observed where large masses of putrefying animal matter have been heaped together, or where water has had occasional access to it. Nitrate of ammonia is also sometimes formed under the same circumstances.

832. Instead of considering the proximate principles of animals under separate sections, as has been done in regard to vegetable bodies, I shall make them known under the heads of those subtances in which they occur, the principal of which are the following:

1. Blood. Albumen, Colouring Matter.
2. Milk. Sugar of Milk.
3. Bile. Resin of Bile.
4. Lymph. Mucus. Sinovia, *&c.*
5. Urine. Urea. Urinary Calculi.
6. Skin. Membrane.
7. Muscle. Ligament. Horn. Hair.
8. Fat. Spermaceti, *&c.*
9. Cerebral substance.
10. Shell and Bone.

Section II. *Of the Blood.*

833. In the higher orders of animals the blood is of a red colour, florid in the arteries, and dingy in the veins. The specific gravity of human blood is liable to some variation. I have found it as low as 1,050 and as high as 1,070, but am unable to refer to any circumstances which might be considered as the cause of this difference.

When blood is drawn from its vessels in the living animal, it soon concretes into a jelly-like mass, which afterwards gradually separates into a fluid *serum,* of a pale straw colour, and a coagulated *crassamentum,* or *cruor,* which is red. The cause of this coagulation is quite unknown.

834. The specific gravity of the serum of the blood, is upon an average 1,030. It reddens the yellow of turmeric, and changes the blue of violets to green, a property derived from a portion of soda. At a temperature of 160°, it becomes a firm yellowish white coagulum, resembling in appearance and properties the coagulated white of egg, and, as the principle to which this property is owing is the same in both substances, it has been called *albumen.* Alcohol, and many of the acids also, occasion the coagulation of the serum of blood.

100 parts of human serum contain between eight and nine parts of albumen, rather less than one part of subcarbonate of soda, and about the same quantity of common salt, the remaining 90 parts being water. These at least are the proportions which my own experiments lead me to believe correct; but the analysis is involved in so much difficulty that the results can only be considered as approximating to the truth; indeed it is probable that the composition of the serum is liable to much variation.

Dr. Marcet and Berzelius have each given an analysis of the serum of human blood; the following are their results. (*Medico-Chirurgical Transactions*, Vol. II. *Annals of Philosophy*, Vol. II.)

Marcet.

Water	900
Albumen	86,8
Muriates of potash and soda	6,6
Muco-extractive matter	4,0
Subcarbonate of soda	1,65
Sulphate of potash	0,35
Earthy phosphates	0,60
	1000,00

Berzelius.

Water	905,0
Albumen	80,0
Muriates of potash and soda	6,0
Lactate of soda, with animal matter	4,0
Soda and phosphate of soda with ditto	4,1
Loss	0,9
	1000,0

835. *Albumen*, which constitutes a leading ingredient in the serum, and which we shall presently find also in the cruor,

is a very important animal principle, and is found in the greater number of animal fluids and solids.

Liquid Albumen is soluble in water, and always contains a notable portion of soda, indicated by its action on vegetable colours. It is coagulated by heat, acids, and alcohol, unless it be considerably diluted with water, in which case a portion separates in the form of white flakes after some hours' standing. Solution of corrosive sublimate, added to albumen very much diluted, produces a cloudiness, and hence it is a useful test of albumen. (Bostock, Nicholson's *Journal*, XIV.) It is also instantly coagulated by Voltaic electricity; and if two platinum wires connected with a small battery be immersed into a diluted albumen, it will cause a very rapid coagulation at the negative pole, and scarcely any effect at the positive pole. This circumstance induced me to attribute the coagulation to the removal of the alcali, by alcohol, and by acids; but how heat operates is not very obvious, unless we be allowed to consider it as effecting a kind of decomposition of the liquid albumen. We might thus consider liquid albumen as a compound of albumen and soda dissolved in water: the effect of heat would then be to transfer the soda to the water, and thus occasion a coagulation; and a solution of soda is always found oozing from coagulated serum, and has sometimes been called *serosity;* in time it re-acts upon the coagulum, and dissolves a portion of it.

836. When albumen is dried in a moderate heat, it shrinks and becomes brown, and semi-transparent, and resembles horn in appearance and properties. In this state it scarcely dissolves in boiling water, though it gradually softens; it is not prone to decomposition; it dissolves in the alcalis, a portion of ammonia being evolved, and a saponaceous compound is formed. Dilute nitric acid converts it into a substance having the properties of gelatine. (Hatchett,

Phil. Trans. 1800.) By destructive distillation albumen furnishes a variety of products characterized by the presence of a large proportion of ammonia. According to Gay-Lussac and Thenard, (*Recherches Physico-chymiques*) its ultimate constituents are

Carbon	52,883
Oxygen	23,872
Hydrogen	7,540
Nitrogen	15,705
	100,000

837. When the coagulum of the blood is carefully washed under a small stream of water, the colouring matter is gradually dissolved, and washed out of it, and a white fibrous substance remains, which has been termed *fibrina* or *coagulable lymph*, but of which the chemical properties are those of albumen.

It sometimes happens, when the blood is long in coagulating, as in certain inflammatory diseases, that a portion of this albumen is left without the colouring matter, forming what has been called the *buffy coat of blood*; in this case it is so tough as to admit of being removed from the coloured portion, and when dried, shrinks up, and appears exactly like horn.

Although the cause of the spontaneous coagulation of blood be unknown, the process consists in a portion of the albumen separating in a solid form along with the colouring matter, while another portion remains dissolved in the serum; this effect is somewhat analogous to the crystallization of a saline solution, in which one portion of the salt separates, while another remains dissolved.

838. The colour of the blood has generally been referred to small globules of a red colour, which by the aid of the microscope may be discerned in it; and it was supposed that these globules are soluble in water. But it has been

hewn by Dr. Young, that this is not the case, and that the ffect of water is to dissolve the colouring matter only, leaving ne globule perfectly colourless; in this state the globular par-cles have the properties of albumen. The diameter of the lobules in human blood varies from $\frac{1}{6000}$ to $\frac{1}{4000}$ of an nch. (*Remarks on Blood and Pus, in* Dr. Young's *Medical Literature.*)

The colouring matter of the blood can scarcely be obtained ree from other substances. By stirring it during coagulation, considerable portion is diffused through the serum from hich it afterwards subsides. Vauquelin advises the diges-on of the coagulum, drained of serum, in dilute sulphuric cid, at a temperature of 160°. The liquid filtered while hot, to be evaporated to half its bulk, and nearly saturated with mmonia; the colouring matter falls, and is to be washed and ried. (*Annales de Chimie et Phys.* Tom. I.) We must not, owever, trust animal principles to these complex operations; nd there can, I think, be little doubt that the colouring prin-ple has undergone some change in M. Vauquelin's process.

The chemical properties of the colouring matter of the lood show that it is a peculiar animal principle. It is so-uble in cold water, and the solution when boiled, deposits a rown sediment of altered colouring matter. Muriatic, di-ute sulphuric, and several of the vegetable acids, and ne caustic and carbonated alcalis, readily dissolve the colour-ng matter, and form solutions of different tints of red, and of peculiar greenish hue when viewed by transmitted light. itric acid instantly renders these solutions brown, and decom-oses the red principle. These experiments, of which I have iven a detailed account in the *Philosophical Transactions* for 812, led me to regard the colouring matter of the blood as a istinct proximate principle of animal matter, perfectly inde-endent of the presence of iron, to which its peculiarities were one time referred by M. M. Fourcroy and Vauquelin; and the latter of these celebrated chemists has more lately verified my conclusions in the above quoted memoir. Berzelius, whose labours in animal chemistry are so extended and well known, has, however, obtained different results; he finds the crassamentum of the blood to consist of

Colouring matter	64
Fibrin and albumen	36
	100

The colouring matter, when incinerated, affords a residue consisting of

Oxide of iron	50,0
Subphosphate of iron	7,5
Phosphate of lime with magnesia	6,0
Lime	20,0
Carbonic acid and loss	16,5
	100,0

The iron appears to be regarded by Berzelius, as contributing to the red colour of the blood, (Thomson's *System*, Vol. IV. p. 501.) a conclusion which my own experiments, detailed in the paper already quoted, by no means warrant, and which is also at variance with the opinion of M. Vauquelin.

839. Besides the principles now enumerated, and which may be considered as essential to the blood, it often contains carbonic acid, which escapes when the blood is gently heated, or placed under the exhausted receiver of the air-pump.

Experiments on the blood, in different diseases, have thrown no light whatever on their nature, nor have any material differences been found in the blood of the same animal at different periods, or in that of different animals of the same class.

SECTION III. *Milk.*

840. THE chemical properties of this secretion differ some-

what in different animals. The milk of the cow has been most attentively examined, and it has the following properties :

It is nearly opaque ; white, or slightly yellow, of an agreeable sweetish taste, and a peculiar smell. Its specific gravity varies from 1018 to 1020. It boils at a temperature a little above that of water, and freezes at 32°. When allowed to remain a few hours at rest, a thick unctuous liquid collects upon its surface, called *cream ;* the colour of the remaining milk becomes bluish white, and when heated to about 100° with a little *rennet*, it readily separates into a *coagulum*, or *curd*, and a *serum*, or *whey*. In this way the three principal constituents of milk are separable from each other.

841. By the process of churning, cream is separated into *butter* and *butter-milk*, the latter being the whey united to a portion of curd. According to Berzelius, 100 parts of cream of the specific gravity of 1024 consists of

Butter	4,5
Curd	3,5
Whey	92,0
	100,0

Butter may be considered as an animal oil, containing a small portion of curd and whey. It liquefies at about 98°, and by this process the impurities are separated, and it remains a longer time without becoming rancid.

842. The *curd* of milk has the leading properties of coagulated albumen, and like that principle is coagulable by alcohol and acids, and is also similarly affected by Voltaic electricity ; heat slowly produces the same effect, and by boiling milk, the albumen separates in successive films.

Curd in combination with various proportions of butter, constitutes the varieties of cheese; that containing the largest quantity of oil becomes semi-fluid when heated, and is prone to decomposition, when a large quantity of ammonia is formed in it; whereas bad cheese which consists of little else than curd or albumen, shrinks and dries when heated, and curls up like a piece of horn.

843. *Whey* is a transparent fluid of a pale yellow colour, and a sweetish flavour; by evaporation it affords a minute quantity of saline matter, and a considerable portion of sugar of milk.

844. *Sugar of Milk* may be obtained in white rhomboidal crystals, of a sweet taste, and soluble in 7 parts of water at 60°, but insoluble in alcohol. When exposed to heat, it affords nearly the same products as common sugar.

It consists, according to Berzelius, when deprived of water, of

Carbon	45,267
Oxygen	48,348
Hydrogen	6,385
	100,000

845. When sugar of milk is treated with nitric acid, it affords a peculiar acid, similar to that above described, as obtained from gum (712). It is not crystallizable, and is sparingly soluble in water, requiring 60 parts at 212°. It combines with the metallic oxides, and forms a class of salts called *saccholates*. It consists, according to Berzelius, (*Annals of Philosophy*, Vol. V.) of

Carbon	33,430
Oxygen	61,465
Hydrogen	5,105
	100,000

846. When milk, or whey, are exposed to a temperature between 60° and 80°, they undergo a spontaneous change, attended by the production of an acid, which was originally examined by Scheele, and has been termed *lactic acid*. Fourcroy and Vauquelin have shewn reason to suspect its peculiar nature, and were led to regard it as identical with the acetic

acid. Berzelius has more lately revived the opinion of Scheele, but I am induced from my own experiments to believe, that if it be not the acetic acid originally, it becomes so by combination with a base, and subsequent separation by sulphuric acid.

In some cases whey may be made to undergo vinous fermentation; and the Tartars, it is said, prepare a kind of wine from the whey of mares' milk, which they call *Koumiss*. (*Edinburgh Phil. Trans.* Vol. II.)

Section IV. *Bile.*

847. This secretion is formed in the liver, from venous blood. It is an unctuous liquid, of a yellowish green colour, and its specific gravity is between 1020 and 1030. Its taste is intensely bitter, and it readily putrefies, exhaling a most nauseous odour.

When the bile of the ox is distilled, it affords about 90 *per cent.* of insipid water; the residuum is brown, bitter, and may be re-dissolved in water; it affords traces of uncombined alcali, which appears to be soda. The acids render bile turbid, and separate from it a substance which possesses many of the properties of albumen. It is likewise coagulated by alcohol, and upon filtering off the clear liquor, and evaporating it, an inflammable fusible substance is obtained, of an intensely bitter flavour, combined with a portion of soda and common salt: this has been termed the *resin of bile*, and appears to be the principle which confers upon it its chief peculiarities. We should, therefore, conclude as the result of these observations, that bile consists of water, albumen, soda, a bitter resin, and some minute portions of saline matter.

Thenard separated from bile a peculiar substance, which he has termed *picromel;* but the process by which he obtained it, is so complex, that I think it doubtful whether it be a product or an educt. The same chemist has given the following table of the ingredients of ox-bile, but as this secretion is liable to considerable variation in appearance and specific gravity, it is probable that little reliance can be placed in the accuracy of the numbers. (*Traité de Chimie,* Tom. III. p. 556).

Water	700
Resin	15
Picromel	69
Yellow matter	4
Soda	4
Phosphate of soda	2
Muriates of soda and potassa	3,5
Sulphate of soda	0,8
Phosphate of lime and of magnesia	1,2
Oxide of iron	a trace
	1000.

848. *Biliary Calculi* are of two kinds; those which most commonly occur, are soft, fusible, of a crystalline texture, and inflammable. They have generally been considered as closely resembling spermaceti; they are soluble in boiling alcohol, in ether, and difficultly in oil of turpentine. Chevreuil, having remarked some peculiarities in this substance, is induced to regard it as a peculiar animal principle, and distinguishes it by the name of *cholesterine.*

The other kind of biliary calculus resembles inspissated bile in appearance, but differs from it in being insoluble in alcohol and water. It is often mixed with variable proportions of the former, constituting biliary calculi of intermediate characters.

SECTION V. *Lymph, Mucus.*

849. THE liquid which lubricates the different cavities of the body, which is contained in the lymphatics, and which occasionally forms the chief contents of the thoracic duct, has been termed *lymph*. It is colourless, transparent, miscible in all proportions with water, does not affect vegetable blues, is not coagulated by acids or alcohol, but only rendered slightly turbid by the latter. It has the characters of a very weak solution of albumen.

The fluid which collects in cases of dropsy and in vesications, is of a similar nature, but the proportion of albumen is liable to variation, and hence it is differently influenced by tests; when very rapidly thrown out from inflamed surfaces, it sometimes furnishes a coagulum, apparently as abundant as that of the serum of the blood.

850. The term *mucus* has sometimes been applied to these fluids, when they have undergone a certain degree of inspissation; at other times, it has been used to designate a very alcaline albuminous fluid. Dr. Bostock has pointed out some circumstances in which mucus differs from liquid albumen, and has proposed sub-acetate of lead as a test for its presence. (Nicholson's *Journal*, Vol. XI.) But that salt is so easily decomposed by many vegetable and animal substances as to render it of doubtful efficacy for this purpose.

851. *Saliva* consists, according to Dr. Bostock, (Nicholson's *Journal*, Vol. XIV.) of

Water	80
Coagulated albumen	8
Mucus	11
Saline substances	1
	100

I found that it was copiously coagulable by the action of voltaic electricity, and was hence induced to consider the mucus as a peculiar albuminous combination, not coagulable by the usual means. (*Phil. Trans.* 1809.)

852. The *Pancreatic juice* has not been minutely examined, but from the experiments of Dr. Fordyce, it would appear to differ little from saliva.

853. *Tears* contain a small portion of albumen combined with soda, and muriate of soda, and water. There are also small portions of other salts.

854. *The humours of the Eye.* The *aqueous humour* is composed of water holding a minute quantity of albumen and saline matter in solution; the *crystalline lens* also contains more than half its weight of water, the remainder being an albuminous substance with traces of muriates.

855. *Synovia* is the fluid which lubricates the surfaces of joints. It contains, according to Mr. Hatchett, (*Phil. Trans.* 1799.) a small portion of phosphate of lime, and of phosphate of soda and ammonia: the animal principle appeared to be albumen.

Section VI. *Urine, Urinary Calculi,* &c.

856. This secretion presents, perhaps, greater difficulties to the analytical chemist, than any other animal product; it is extremely complex, and subject to constant change in the proportions of its components, and in disease several new substances make their appearance.

The chemical history of the urine is of the utmost importance to the medical practitioner; it teaches the nature of the substances which occasionally predominate, so as to constitute *gravel* and *calculi;* and shews the means of influencing and modifying its composition.

The general characters of the urine are too well known to need description. Its specific gravity is of course liable to much variation, even in the healthy state, fluctuating between 1005 and 1040. The average is about 1020.

857. The substances that are always found in urine are, according to my own experiments, the following:

1. Water.
2. Carbonic acid.
3. Phosphoric acid.
4. Uric acid.
5. Phosphate of lime.
6. Phosphate of ammonia.
7. Phosphate of soda.
8. Phosphate of magnesia.
9. Common salt.
10. Sulphate of soda.
11. Albumen.
12. Urea.

858. The existence of free acid in recently voided urine, is easily demonstrated, by its property of reddening vegetable blues, and it performs the important office of retaining some of the difficultly soluble salts in permanent solution; so that whenever this natural acidity is diminished, the urine has a tendency to deposit the earthy phosphates.

The presence of *carbonic acid* may be shewn by placing urine under the receiver of the air pump; during exhaustion it escapes, sometimes copiously, but at other times in minute quantities only.

The free *phosphoric acid* may be shown by the addition of carbonate of lime, a portion of which is converted into phosphate of lime.

859. *Uric Acid* is one of the peculiar characteristics of the urine; its presence may be shewn by evaporating urine to half its bulk, which produces a precipitate consisting of phosphate of lime and uric acid; the former may be dissolved by dilute

muriatic acid, which leaves the latter in the form of a reddish powder. This acid has been very ably examined by Dr. Henry, who made it the subject of a thesis published in 1807.

Uric acid constitutes the principal ingredient in certain urinary calculi, and may be abundantly obtained by digesting them in caustic potassa, filtering the solution, and adding excess of muriatic acid, which causes a precipitate of uric acid.

Uric acid thus obtained, is a grey powder of scarcely any taste, and requiring 1720 parts of water at 60°, and 1150 parts at 212° for solution. It reddens infusion of litmus, and readily dissolves in caustic potassa, and soda; it is sparingly soluble in ammonia, and insoluble in the alcaline carbonates.

Uric acid dissolves in nitric acid, and upon evaporation a residuum of a fine red tint is obtained, which is peculiar to this combination, and which Dr. Prout has lately shown to possess distinct acid properties; he has called it *purpuric acid*, in consequence of the purple or red colour of its compounds.

860. When uric acid is submitted to destructive distillation it affords carbonate of ammonia, and a peculiar acid sublimate; a quantity of charcoal remains in the retort. Its ultimate constituents, according to Dr. Prout, are

1 proportional of	nitrogen———	13,
2 ———————	carbon	$5{,}7 \times 2 = 11{,}4$
1 ———————	oxygen ———	7,5
1 ———————	hydrogen ——	1,
		32,9

861. The *urates* have principally been examined by Dr. Henry, and an account of many of them is given in his thesis above quoted.

862. *Phosphate of Lime* may be precipitated from urine by the addition of ammonia: its relative quantity is liable to much fluctuation; sometimes it becomes so great as to be deposited

as the urine cools, constituting what has been termed *white sand.*

863. The *Phosphates of Ammonia*, of *Soda*, and of *Magnesia*, and *common Salt*, constitute the principal crystallizable salts contained in the urine; the first of these is probably in great part produced during evaporation, for the saline mass obtained by inspissating urine is no longer acid; the carbonic having escaped, and the phosphoric being saturated by ammonia. The *microcosmic salt*, or *fusible salt of urine*, of the old chemists, is chiefly phosphate of ammonia with a little phosphate of soda, or perhaps a triple *ammonio-phosphate of soda*. (324.)

The *Ammoniaco-magnesian Phosphate*, (403) is a common, and almost constant ingredient in the urine. It forms a part of the white sand voided in certain calculous affections, and is sometimes formed in a film upon the surface of the urine, having been held in solution by carbonic acid, and being deposited as that gas escapes.

864. The existence of *sulphuric acid*, probably combined with *soda*, and perhaps also with *potassa*, may be detected in urine by the addition of nitrate of baryta, which occasions a precipitate of sulphate of baryta.

As urine blackens silver, it has been said to contain *sulphur*; but this is not the case with recent urine, and when it becomes slightly putrid it evolves a little sulphuretted hydrogen.

865. The existence of *albuminous matter* in urine is sometimes easily demonstrated; at others the secretion seems not to contain it. It has been said, by Mr. Cruikshank, that the urine in some dropsical cases contains so much albumen as to be coagulable by heat, (*Phil. Mag.* Vol. II.) but if that ever be the case, the secretion could hardly be called urine. It seems questionable whether the albumen of urine, should not in general be regarded as derived from the mucous secretion of the bladder.

866. *Urea* is the principle which confers upon urine its chief peculiarities. It may be obtained by slowly evaporating urine to the consistency of syrup, which on cooling concretes into a saline mass, and which, by digestion in alcohol furnishes urea. By carefully distilling off the alcohol, the urea remains in the form of a brown crystallized mass.

Other processes have been given for obtaining urea, which are, I think, objectionable, on account of their complexity; indeed it is doubtful, whether by the action of heat and alcohol, as above described, it is not considerably altered.

Urea is very soluble in water, and the solution is resolved, by putrefaction, into acetic acid, and ammonia. Nitric acid produces in it a crystalline precipitate, consisting of the two substances, according to Dr. Prout, in the following proportions:

Nitric acid....................	47,37
Urea	52,63
	100,00

The fixed alcalis decompose urea, and occasion the evolution of ammonia and some other products. It is to this substance that the copious production of volatile alcali, during the destructive distillation of urine, is referable; and the ammonia which is found in combination with the acids, in putrid urine, is derived from the same source.

According to Dr. Prout's analysis (Henry's *Elements*, Vol. II. p. 327,) urea consists of

Oxygen....	26,66 = 1	proportional	7,5
Nitrogen ..	46,66 = 1	————	13,0
Carbon	19,99 = 1	————	5,7
Hydrogen..	6,66 = 2	————	2,0
			28,2

867. Such are the properties of the principal ingredients in human urine, to which several others have been added by

different chemists; but as their existence is only occasional, and often, I think, doubtful, I have hesitated to give them a place among the regular constituents of healthy urine. I now subjoin Berzelius' statement of the average composition of human urine. (Thomson's *Annals*, Vol. II. 423.)

Water	933,00
Urea	30,10
Sulphate of potassa	3,71
Sulphate of soda	3,16
Phosphate of soda	2,94
Muriate of soda	4,45
Phosphate of ammonia	1,65
Muriate of ammonia	1,50
Free lactic acid Lactate of ammonia Animal matter soluble in alcohol Urea not separable from the preceding	17,14
Earthy phosphates, with a trace of fluate of lime	1,00
Uric acid	1,00
Mucus of the bladder	0,32
Silica	0,03
	1000,00

868. The urine suffers some very remarkable changes in certain diseases, which have been but superficially inquired into by chemists. In cases of injury of the spine, affecting the nerves that supply the kidneys, the urine is always turbid, and often alcaline; and there is a considerable tendency in these cases to form calculi.

In the disease called *diabetes*, the urine is not only secreted in excess, but often contains a substance of a sweet taste, having the properties of sugar, and its specific gravity is considerably above the healthy standard. (Henry *on Diabetic Urine. Medico-Chirurgical Transactions*, Vol. II. p. 118.)

869. The urine of graminivorous animals differs considerably from that of the human subject. Carbonates, muriates, and phosphates, are the leading ingredients; it also contains urea, but not uric acid; potassa is usually the predominating alcali. In the *Philosophical Transactions* for 1808, I have given an account of the composition of several species of urine, and in that of the camel I detected a small portion of uric acid; but as the animal was diseased, its presence was probably accidental, more especially as it has not been found by other chemists.

In the urine of the snake, and of birds that feed upon fish and animal matter, uric acid is the leading ingredient.

870. It frequently happens, from a variety of causes, that certain ingredients of human urine are secreted in excess, and deposited in a solid form, constituting *sand*, or *gravel* and *calculi*.

Sand is either *white* or *red;* the former consists of phosphate of lime, and ammoniaco-magnesian phosphate, either separate or mixed, and the latter is chiefly uric acid. The former deposition is prevented by the use of acids; and the latter by alcalis and the alcaline earths. The modes of exhibiting these remedies, and the effects which they produce, I have described in a paper printed in the *Quarterly Journal.* (Vol. VI.)

Urinary calculi are, for the most part, composed of subtances that exist at all times in the urine, though there are a few substances that only make their occasional appearance in them. The following are their component ingredients:

1. Uric acid.
2. Phosphate of lime.
3. Ammonio-magnesian phosphate.
4. Oxalate of lime.
5. Cystic oxide.

The calculi composed of uric acid, of which the chemical properties have already been described (859), are of a brown colour; and when cut through appear of a more or less distinctly laminated texture. Their surface is generally smooth or nearly so.

Phosphate of lime calculus is of a pale brown, or grey colour, smooth, and made up of regular and easily separable laminæ. It is easily soluble in muriatic acid, and precipitated by pure ammonia (352.)

The ammoniaco-magnesian, or triple calculus, is generally white, or pale gray, and the surface often presents minute crystals; heated violently by the blow-pipe, it exhales ammonia, and leaves phosphate of magnesia (403.)

It frequently happens, that calculi consist of a mixture of the two last-mentioned substances, in which case they melt before the blow-pipe, and are hence termed *fusible calculi.* They are white, or nearly so, and softer than the separate substances.

Oxalate of lime forms calculi, the exterior colour of which is generally dark brown, or reddish; they are commonly rough, or tuberculated upon the surface, and have hence been called *mulberry calculi.* Before the blow-pipe they blacken and swell, leaving a white infusible residue, which is easily recognised as quicklime (767.) Small oxalate of lime calculi are, however, sometimes perfectly smooth upon the surface, and much resemble a hempseed in appearance.

Cystic oxide is a peculiar animal substance; the calculi composed of it, which are rare, are in appearance most like those of the ammonio-magnesian phosphate. They are soft, and, when burned by the blow-pipe, exhale a peculiar fœtid odour. They are soluble in nitric, sulphuric, muriatic, phosphoric, and oxalic acids, and also in alcaline solutions.

The substances which have been described, with the exception of cystic oxide, are sometimes intimately blended in calculi; sometimes they form alternating layers; and in a few cases four distinct layers have been observed; the nucleus being uric, upon which the oxalate, and phosphate of lime, and the triple phosphate, are distinctly and separately arranged.

These are the principal chemical facts belonging to the history of urinary calculi. In Dr. Wollaston's valuable papers upon this subject (*Phil. Trans.* 1797 and 1810,) much additional information will be found. In the same work (1806, 1808, 1810,) I have given some account of their peculiarities, depending upon their situation, and have also discussed the operation of solvents; and Dr. Marcet has published a very useful "*Essay on Calculous Disorders,*" containing all that is important upon the subject.

SECTION VII. *Cutis, or Skin; Membrane, &c.*

871. THE skin of animals consists of an exterior albuminous covering, or *cuticle*, under which is a thin stratum of a peculiar substance, called by anatomists *rete mucosum*, and which lies immediately upon the *cutis*, or true skin, of which the principal component is *gelatine*.

872. The following are the chemical properties of pure gelatine. It is colourless, semi-transparent, and nearly tasteless. It is softened by long continued immersion in cold water: in hot water it readily dissolves, and forms a solution of a slightly milky appearance, which, if sufficiently concentrated, concretes on cooling into the tremulous mass usually called *jelly*, and which is easily soluble in cold water; when dried in a gentle heat, it acquires its original appearance, and is as soluble as before. When dry, gelatine undergoes no change, but its solution soon becomes mouldy and putrescent. Submitted to the action of heat, it affords the usual products of animal substances (Hatchett, *Phil. Trans.* Vol. xc.)

It is readily soluble in diluted acids and alcaline solutions, and forms no soap with the latter. Its aqueous solution is not affected by solution of corrosive sublimate, and few of the metallic salts occasion any precipitate in it. Chlorine passed through its solution, occasions a white elastic matter to separate, which is not sóluble in water, and which in some properties resembles albumen. It is insoluble in alcohol and ether. Solution of tannin occasions a white precipitate in solution of gelatine; and hence, vegetable astringents, such as galls or catechu, are generally employed as tests for its presence. But as tannin precipitates albumen, it cannot be relied on as an unequivocal test, unless we previously ascertain the non-existence of albumen by corrosive sublimate. (Bostock. Nicholson's *Journal*, XIV. and XXI.)

873. The different kinds of gelatine differ considerably in viscidity. Mr. Hatchett has remarked, that the gelatine obtained from skins possesses a degree of viscidity inversely as their softness or flexibility; the most adhesive kinds of gelatine, too, are less easily soluble in water than those which are less tenacious. The principal varieties of gelatine, in common use, are,

a, *Glue*, which is prepared from the clippings of hides, hoofs, &c., obtained at the tan-yard; these are first washed in lime-water, and afterwards boiled and skimmed; the whole is then strained through baskets, and gently evaporated to a due consistency; afterwards it is cooled in wooden moulds, cut into slices, and dried upon coarse net-work. Good glue is of a semi-transparent and deep brown colour, and free from clouds and spots. When used it should be broken into pieces, and steeped for about twenty-four hours in cold water, by which it softens and swells; the soaked pieces may then be melted over a gentle fire, or in a water-bath, and in that state applied to the wood by a stiff brush. Glue will not harden in a freezing temperature, the stiffening depending on the evaporation of its superfluous water.

b, *Size* is less adhesive than glue, and is obtained from parchment shavings, fish-skin, and several animal membranes.

It is employed by bookbinders, paper-hangers, and painters in distemper, and is sometimes mixed with flour, gum, &c.

c, Isinglass is prepared from certain parts of the entrails of several fish; the best is derived from the sturgeon, and is almost exclusively prepared in Russia. It should be free from taste and smell, and entirely soluble in warm water, which is seldom the case, in consequence of the presence of some albuminous parts. When the jelly of isinglass is concentrated by evaporation and carefully dried, it forms a very choice kind of glue. (Aikin's *Dictionary*, Art. GELATINE.)

874. *Leather* is a compound of gelatine and vegetable astringent matter, formed by steeping the skins of animals in the infusions of certain barks. The skins are previously prepared by steeping in lime-water, which renders the cuticle and hair easily separable, and are afterwards softened by allowing them to enter into a degree of putrefaction. In this state they are submitted to the action of infusion of oak-bark, or other astringent vegetable matter (733,) the strength of which is gradually increased until a complete combination has taken place, which is known by the leather being of an uniform brown colour throughout; whereas, in imperfectly tanned leather a white streak is perceptible in the centre.

Tawed leather is made by impregnating the skin duly prepared with a solution of alum and common salt; it is afterwards trodden in a mixture of yolk of eggs and water.

Curried leather is made by besmearing the skin, or leather, while yet moist, with common oil, which, as the humidity evaporates, penetrates into the pores of the skin, giving it a peculiar suppleness, and making it, to a considerable extent, water-proof. As familiar examples of these processes, the thick sole-leather for shoes and boots is *tanned*, the upper-leather is *tanned* and *curried*, the white leather for gloves is *tawed*, and fine Turkey-leather is *tawed*, and afterwards slightly *tanned*. (Aikin's *Dictionary*, Art. LEATHER.)

875. The different *membranes* of the body, and the *tendons*, are chiefly composed of gelatine, for by long digestion in warm water they gradually soften, and become ultimately almost perfectly soluble.

SECTION VIII. *Muscle, Ligaments, Horn, Hair, &c.*

876. WHEN the *muscular parts* of animals are washed repeatedly in cold water, the fibrous matter which remains consists chiefly of albumen, and is in its chemical properties analogous to the clot of blood. Muscles also yield a portion of gelatine, and the flesh of beef, and some other parts of animals, afford a peculiar substance of an aromatic flavour, called by Thenard, *osmazome*. *Ligaments, horn, nail,* and *feathers*, consist principally of albumen.

877. *Hair* consists principally of a substance, having the properties of coagulated albumen. It also contains gelatine, and the soft kinds of hair yield it more readily than those which are harsh, strong, and elastic.

Vauquelin discovered in hair two kinds of oil; the one white, and existing in all hair; the other coloured, yellow from red hair, and dark coloured when obtained from dark hair. Black hair also contains iron and sulphur. He supposes that where hair has become suddenly gray, the effect is produced by the evolution of acid matter, which has destroyed the colour of the oil.

878. *Feathers, quill,* and *wool*, are also possessed of the properties of albumen, and appear to contain no gelatine.

SECTION IX. *Fat, Spermaceti, &c.*

879. THE fat of animals, when freed by fusion, or pressure,

from cellular membrane, is of various degrees of consistency, as seen in *tallow*, *lard*, and *oil*. When pure, it has little taste or smell, but it acquires both by keeping, and becomes rancid and slightly sour. The softer varieties fuse at about 90°, and the harder at 120°. Decomposed at a red heat, they afford abundance of olefiant gas, and a small portion of charcoal, products analogous to those of vegetable oil (741.) When burned, they produce water and carbonic acid, containing the same ultimate elements, in the same proportions as vegetable oils : (*see Table*, page 351.) They also produce soaps by combination with alcalis.

Nitric acid, heated in small quantity with any of the fatty substances, renders them harder, and considerably increases their solubility in alcohol. Among the vegetable oils this change is most remarkably produced upon cocoa-nut, and castor-oils, the latter becoming converted into a solid matter, which, when cleansed of adhering acid by washing, resembles soft wax.

880. The experiments of Braconnot and Chevreuil, already quoted (740,) have shewn that the different kinds of oil and fat contain two substances, to which they have given the names *stearine* and *elaine*, the former solid, the latter liquid at common temperatures. The following table shews their relative proportions in different fats and oils :—

	Elaine.	Stearine.
Butter, made in summer	60	40
Ditto, winter	37	63
Hogslard	62	38
Beef-marrow	24	76
Mutton ditto	74	26
Goose-fat	68	32
Ducks'-fat	72	28
Turkeys'-fat	74	26
Olive-oil	72	28
Almond-oil	76	24

These principles may be obtained by boiling hog's-lard in alcohol; the fluid, on cooling, deposits a crystalline matter, which is to be purified by a second solution and crystallization; it is then pure *stearine*, white, brittle, tasteless, and inodorous; it fuses at a little below 120°, and forms soap with alcalis.

When the alcohol, which has deposited the whole of the stearine is distilled, an oily liquid remains, which is *elaine*. It is fluid at 58°; it generally is of a yellow colour, and is convertible into soap.

881. When soap composed of hog's-lard and potassa, is put into water, a portion only is dissolved; the remainder consists of white scales, composed of the alcali united to a peculiar acid, called by Chevreuil, from its pearly appearance, *margaritic acid*, and separable from the above combination by muriatic acid.

It is insoluble in water, tasteless, fusible, at 134°, and crystallizes on cooling in brilliant white needles. It is soluble in alcohol. It unites with potassa in two proportions, the one compound, containing 100 acid, +8,80 potassa; the other, 100 acid, 17,77 potassa. These compounds have been termed *margarates of potassa*.

882. The portion of the hog's-lard soap soluble in water, consists of another peculiar substance united to potassa, which Chevreuil has called *oleic acid*. It may be obtained from its solution by tartaric acid, which causes it to separate in the form of an oily matter, that is to be again united to potassa, and separated as before. This substance solidifies at about 40°, and it forms compounds, called *oleates*. It appears probable that, by the action of alcalis, the stearine is converted into what Chevreuil has termed margaric acid, and the elaine into oleic acid, (*Annales de Chimie*, XCIV.)

883. By mixing 1 volume of carbonic acid with 10 of carburetted hydrogen, and 30 of hydrogen, and passing the mixture through a red-hot porcelain tube, Berard is said to

have produced a substance in small white crystals, having many of the properties of fat (Thomson's *Annals*, XII.)

884. *Spermaceti* is a peculiar matter, which concretes from the oil of the *spermaceti whale*. It fuses at 112°, and at higher temperatures is volatile, but if repeatedly distilled it loses its solid form, and becomes a liquid oil. It is soluble in boiling alcohol, and abundantly so in ether. It forms a soap with potassa, which yields, on decomposition, a substance called by Chevreuil, *cetic acid* (*Annales de Chimie*, XCV.)

885. In the *yolk* of *eggs* there is a considerable quantity of oily matter, which may be obtained by pressure after boiling; it is yellow and tasteless.

886. *Ambergris*, which is a concretion from the intestines of the spermaceti whale, also contains a considerable portion of fatty matter, amounting in some specimens to 60 per cent. It is only found in the unhealthy animal. (Homes' *Lectures on Comparative Anatomy*, Vol. I. p. 470.)

SECTION X. *Cerebral Substance.*

887. ACCORDING to Vauquelin, the cerebral substance consists of

Water	80,00
White fatty matter	4,53
Red fatty matter	0,70
Albumen	7,00
Osmazome	1,12
Phosphorus	1,50
Acids, salts, and sulphur	5,15
	100

The pulp of nerves seems to be of a similar nature, (Thomson's *System*, Vol. IV. p. 482.)

SECTION XI. *Shell and Bone.*

888. WE are indebted to Mr. Hatchett for two excellent dissertations on the chemical properties of these parts of animals, published in the *Philosophical Transactions* for 1799 and 1800.

He has divided *shells* into two classes; the texture of the first is compact, brittle, and resembling porcelain, their surface is smooth, and they are often beautifully variegated. When exposed to a red heat they crackle, and lose the colour of their enamelled surface, without emitting smoke or smell. They dissolve in dilute muriatic acid with copious effervescence, and form a transparent solution, in which neither pure ammonia nor acetate of lead produce any precipitate, but carbonate of ammonia throws down carbonate of lime. Hence these, which are called *porcellaneous shells,* may be considered as composed of carbonate of lime, united to a very small portion of gelatine: most of the univalve shells, such as whelks, limpets, cowries, and many of the beautiful convoluted shells of tropical countries, belong to this class.

889. The second class, or *mother-of-pearl shells,* are tougher, glossy, and often iridescent; they are mostly bivalves, and all the oyster and muscle species belong to it. When heated, they exhale smoke and the smell of burned horn; immersed in muriatic acid, they only partially dissolve, and leave a series of cartilaginous layers, and an outer epidermis. Each membrane appears to have a corresponding stratum of carbonate of lime, the solution indicating no trace of any phosphate. The animal part is in some cases, as in mother-of-pearl, tough and indurated, and when dried becomes exactly like horn; in other instances, as in the bone of the cuttle fish, it appears in the form of delicate and tender membrane.

In both classes of shells, therefore, the hardening principle is carbonate of lime; in porcellaneous shells there is very little animal matter, which is gelatine; and in mother-of-pearl shells, it is albumen, and in larger quantities.

Pearls are exactly similar in composition to what is termed mother-of-pearl, in which Mr. Hatchett found

Carbonate of lime	66
Albumen	24
	100

890. In the *crusts* of lobsters, crabs, prawns, and cray-fish, Mr. Hatchett found the animal portion to consist of cartilage, the hardening part was a mixture of carbonate and phosphate of lime. From lobster-shell, Merat-Guillot obtained

Carbonate of lime	60
Phosphate of lime	14
Cartilage	26
	100

Vauquelin obtained from 100 parts of hen's egg-shell

Carbonate of lime	89,6
Phosphate of lime	5,7
Animal matter	4,7
	100

891. *Zoophytes,* according to Mr. Hatchett's researches, may be divided into four classes; the first resemble porcellaneous shells, and consist entirely of carbonate of lime, with a very minute quantity of gelatinous matter; of this the common white coral (*madrepora virginea*) is an example. The second consist of carbonate of lime, and a cartilaginous substance, and are therefore analogous to mother-of-pearl shell; to this class belong the *madrepora ramea,* and *madrepora fascicularis.* The third class is composed of a cartilaginous matter, with carbonate and phosphate of lime; to this belongs the red

ral (*gorgonia nobilis.*) The fourth class contains sponges, mposed almost entirely of albuminous matter, (*Phil. Trans.* 800.)

892. *Bone*, like the preceding substances, is essentially omposed of soft and hard parts. When ground bone is digested in warm water, a portion of fat is first separated, and y long continued ebullition, a solution which gelatinises on ooling is obtained. If fresh bone be immersed in diluted uriatic acid, the fat, gelatine, and hardening matter are dis-lved, and a kind of skeleton of the bone remains, in the form f a cartilaginous substance, which when dried exactly re-embles horn. It appears, therefore, that the soft parts of one are, *fat*, *gelatine*, and *albumen*.

The earthy salts, which constitute the hardening principle f bone, are phosphate and carbonate of lime, with a minute uantity of sulphate of lime, and traces of phosphate of mag-esia. Fourcroy and Vauquelin obtained from ox-bones,

Animal matter	51
Phosphate of lime	37,7
Carbonate of lime	10
Phosphate of magnesia	1,3
	100

893. The *enamel of teeth* is perfectly destitute of cartilage, nd consists chiefly of phosphate of lime and a portion of gela-ine. Mr. Pepys found its component parts

Phosphate of lime	78
Carbonate of lime	6
Gelatine	16
	100

The same chemist has given the following as the composi-ion of the teeth (Fox *on the Teeth.*)

	Roots of the Teeth.	Teeth of Adults.	First Teeth of Children.
Phosphate of lime	58	64	62
Carbonate of lime	4	6	6
Cartilage	28	20	20
Loss	10	10	12
	100	100	100

894. When bones are submitted to destructive distillation, the gelatine and albumen which they contain is abundantly productive of ammonia ; water, and carbonic acid are also formed (828,) and a portion of highly fœtid empyreumatic oil. There remains in the vessel a quantity of charcoal, mixed with the earthy substances, which is, in that state, called *ivory black*. It is employed as the basis of some black paints and varnishes.

SECTION XII. *Of Animal Functions.*

895. CHEMISTRY has hitherto done little towards elucidating the functions of animals, and it is scarcely possible to describe the little that has been done, without such frequent reference to anatomical and physiological inquiries as would be irrelevant to the present work ; I shall, therefore, only enumerate the principal chemical phenomena that have been experimentally illustrated, in relation to this subject.

896. *Digestion* is a process by which the food of animals is converted into chyle, and which, in conjunction with *respiration*, tends to the production of blood. The mechanism by which it is carried on differs considerably in the different classes of animals ; the present remarks will relate chiefly to man, and to the carnivorous tribe.

The food, duly masticated in the mouth, and blended with a considerable portion of saliva, is propelled into the stomach, here it soon undergoes a remarkable change, and, in the urse of a few hours, is converted into an apparently homoge-eous pulpy mass, which has been termed *chyme*, and which s little or no resemblance to the original food. This very rious change is only referable to the operation of a secretion culiar to certain glands of the stomach ; it has been termed *stric juice*, and all that is known respecting it is, that it has ry energetic solvent powers, in regard to the greater number animal and vegetable bodies ; the remarkable property of ing substances to resist its action is curiously illustrated by e circumstance that the stomach itself, after death, is occa-onally eaten into holes by its action ; it instantly coagulates ll albuminous substances, and afterwards softens and dissolves e coagulum. There are some substances that remarkably sist its action, such as the husk of grain, and of many seeds, hich, if not previously broken by mastication, pass through e stomach and bowels nearly unaltered. It is hardly worth hile to detail the experiments that have been undertaken on e gastric juice, since they are much at variance, and it is npossible to say whether the secretion has ever been examined n a state even approaching to purity. It has been described s a glairy fluid, of a saline taste ; sometimes it is said to be cid, and sometimes bitter, but no light whatever has been hrown by any of these researches upon the cause of its singu-ar solvent energies.

It has sometimes been matter of surprise that, although nimals drink copiously with their food, the consistency of the hyme is not affected by it, and by the time that it reaches the ight, or pyloric extremity of the stomach, the liquid has dis-ppeared. Sir Everard Home's curious physiological re-earches have shewn that liquids are copiously and rapidly re-moved by absorbents belonging principally to the left, or car-diac portion of the stomach, and that during digestion there is an imperfect division of the stomach into two cavities, by the contraction of the bands of muscular fibres about its centre. He has also shewn that these liquids very soon reach the kidneys, and pass off by urine; and was led to believe that the spleen was the channel of communication, an opinion, however, which his subsequent researches tended to disprove. (*Lectures on Comparative Anatomy*, p. 221.)

The chyme passes from the stomach into the small intestines, where it soon changes considerably in appearance; it becomes blended with bile, and is separated into two portions, one of which is white as milk, and is termed *chyle;* the other passes on to the large intestines, and is ultimately voided as excrementitious. The chyle is absorbed by the *lacteals,* which terminate in the common trunk, called the *thoracic duct;* it is there mixed with variable proportions of lymph, and poured into the venous system.

897. *Chyle* has been examined by several chemists, and their results are not widely different. During some physiological researches, in which I assisted Mr. Brodie, I had an opportunity of collecting it in considerable quantities in several carnivorous and graminivorous animals, and presented an account of my experiments upon it to the Royal Society, (*Phil. Trans.* 1812, p. 91.)

Chyle is an opaque white fluid, having a sweetish saline taste; its specific gravity is inferior to that of the blood. It exhibits slight traces of alcaline matter when tested by infusion of violets; soon after removal from the thoracic duct, it gelatinizes spontaneously, and afterwards gradually separates into a firm yellowish white coagulum, and a transparent colourless serum; so that, like the blood, it enjoys the properties of spontaneous coagulation.

The coagulum of chyle possesses properties closely resembling those of the caseous portion of milk, and may hence be considered as a variety of albumen; the serum of the chyle, when heated, deposits a few flakes of albumen, and by evaporation to dryness, affords a small proportion of a substance analogous to sugar of milk. Small portions of phosphate of lime, carbonate of soda, and common salt, may also be detected in the chyle. In these experiments I found no distinctive difference in the chyle of graminivorous and carnivorousanimals; I examined it from the horse, the ass, the dog, and the cat; Dr. Marcet thinks that the former is less abundant in albumen than the latter*, (Thomson's *Annals*, Vol. VII.)

There can be little doubt that the bile performs an important part in the change which the chyme suffers in the small intestines; it has been conjectured that its aqueous, and perhaps its alcaline parts, are employed as components of chyle, while the albumino-resinous matter combines with the excrementitious portion, and tends to stimulate the intestinal canal towards promoting its propulsion. Whether the bile is absolutely necessary to the formation of chyle, is a question that has not been satisfactorily answered; but its importance is demonstrated by the emaciation that attends its deficiency, and by the disordered state of bowels that accompanies its imperfect secretion. Sir Everard Home, in his "Lecture on the Functions of the Lower Intestines," (*Lectures*, p. 468.) has offered some curious facts connected with this subject, to which I refer the physiological reader. He is of opinion that, in the large intestines, a portion of the food unfit for chylification is, by a process not widely different from that above described, converted into fat, which is afterwards absorbed and conveyed to different parts of the body.

In chyle we cannot fail to observe a close approximation to

* It is a curious question, whence the nitrogen, which constitutes an abundant ultimate principle of the chyle of herbivorous animals, is derived; we find it in very small proportion only in their ordinary food, and yet I could discern no difference in the composition of the albuminous portion of their chyle, and that of animals fed exclusively on meat.

blood: it is deficient only in colouring matter, and the albumen which it contains differs a little from that existing in the blood itself; it appears, therefore, that the albumen is perfected, and the colouring matter formed, in the process of circulation; the saccharine principle of the chyle is also no longer perceptible. The difference between arterial and venous blood, has been adverted to in a previous section (833;) the former is of a florid red colour, and circulates in the arterial system; it is contained in the left ventricle of the heart, and thence carried by the *aorta*, and its ramifications, to every part of the body, tending to reproduction and secretion; it afterwards enters the veins which arise from the extremities of the arteries, and form accompanying branches and trunks ultimately uniting in the *venæ cavæ*, which pour their contents into the right auricle of the heart; the venous blood is thence propelled into the right ventricle, from which the pulmonary artery arises, transmitting it through the lungs, whence it is returned by the pulmonary vein into the left auricle, which transmits it to the left ventricle, from which issues the aorta as aforesaid. So that the right cavities of the heart receive venous blood, and transmit it through the lungs, whence it returns to the left side of the heart, in the arterial state. In the lungs the blood is infinitely subdivided, and spread over a very large surface in vessels so delicate as to admit of the operation of the atmospheric air contained in their cells; it enters the pulmonary structure in the *venous* state by the *pulmonary artery*, and returns in the *arterial*, or *aërated* state, by the *pulmonary vein*. It now remains to examine the changes which the blood undergoes during pulmonary circulation.

898. *Respiration* is the process of receiving a quantity of air into the lungs, whence, after having been retained a short time, it is again expelled in the action of exspiration; and, if now examined, a portion of its oxygen is found converted into

carbonic acid, and it is more or less loaded with aqueous vapour.

Obvious circumstances render it very difficult to ascertain the quantity of air taken into the lungs at each natural inspiration, as well as the number of respirations made in a given time; the former is perhaps about 15 or 16 cubic inches, and the latter about 20 in a minute.

It has been by some supposed that the air suffers an absolute diminution of bulk, but the experiments that have been adduced to prove this can, I think, scarcely be regarded as satisfactory; it seems, on the contrary, most probable that the volume of air expired is exactly equal to that inspired, and consequently the only chemical change that is evident is the saturation of a portion of its oxygen with carbon. The quantity of carbonic acid emitted at each expiration, varies at different periods of the day, and probably also in different individuals; it appears at its maximum during digestion, and at its minimum in the morning, when the stomach is empty, and when no chyle is flowing into the blood. Dr. Prout has shewn that fermented liquors and vegetable diet diminish the proportion of carbonic acid, and that the same thing happens when the system is affected by mercury (Thomson's *System*, Vol. IV. p. 621). The air expired may be regarded, I think, as containing, on an average, 3,5 per cent. of carbonic acid, though Messrs. Allen and Pepys, in their valuable Essay on Respiration (*Phil. Trans.* 1808,) have estimated it at about twice that quantity; it amounted in their experiments to 27,5 cubic inches per minute, =39,534 cubic inches in 24 hours, which would contain about 11 troy ounces of carbon; a quantity evidently above the truth, when we reflect upon the proportion of that element existing in our food, and the other means of escape which it has from the body.

The aqueous vapour contained in the expired air is secreted by the exhalents distributed over the surface of the air-vessels of the lungs; attempts have been made to estimate its quantity, but without success; it is probably liable to variation, and can scarcely be considered as a product of respiration.

It has been above stated that the whole of the venous blood is propelled through the vessels of the lungs, where it is subjected to the action of the air; the chyle is of course carried along with it, and when it returns by the pulmonary vein to the left side of the heart, it has undergone a considerable change in appearance, having lost its dingy colour, and acquired a fine florid red; the chyle also has become perfect blood. The change of colour is evidently owing to the action of the air, which takes place through the thin coats of the circulating vessels, and the end thus attained is the removal of the carbon from the venous blood, by which the colouring matter was obscured; the carbon to be thus readily soluble in oxygen must be in some peculiar state; a portion of it is also removed by the absorbents, and transferred to the glands situate at the root of the lungs, between the subdivisions of the bronchiæ, which often contain a large portion of black matter. This has sometimes been referred to soot inhaled with the air, but many circumstances render it more probable that it is a carbonaceous deposit from the blood. The only chemical difference, then, which can be detected between arterial and venous blood, is the existence of a certain excess of carbon in the latter, which it gives off to oxygen, forming carbonic acid; the blood is thus fitted for the renovation of parts, for the formation of secretions, and for the sustenance of life by its action on the cerebral system; for although the heart does not directly refuse to circulate venous blood, paralysis and torpor ensue when blood, not aërated, passes into the vessels of the brain.

899. It has already been shewn that the blood suffers very important changes in the kidneys and liver; the function of *perspiration* also must be considered as connected with an

alteration of the circulating fluid, for moisture, carbonic acid, and minute quantities of phosphoric acid, and saline matter, among which is common salt, are evacuated by the cutaneous vessels. This quantity of humidity is sometimes very considerable, especially during violent exercise in warm weather, and it contributes materially to diminish the temperature of the body; a portion of water, however, is at all times passing off by the skin, as may be seen by putting the hand into a dry and cold glass, which soon becomes dimmed by the condensation of vapour.

900. Different animals require very different quantities of oxygen for the purposes of respiration. Man and warm-blooded animals, of course, consume the largest quantity; the amphibious tribes not only require less, but can breathe in an atmosphere which will not support the life of the former; and many insects take such small quantity, as sometimes to have been supposed capable of living without air, which is not the case. In the production of carbonic acid all animals agree, and consequently the nature of the deterioration suffered by the air, is similar throughout the animal creation.

Fishes breathe the air which is dissolved in water; they therefore soon deprive it of its oxygen, the place of which is supplied by carbonic acid; this is in many instances decomposed by aquatic vegetables, which restore oxygen, and absorb the carbon (703;) hence the advantage of cultivating growing vegetables in artificial fish-ponds.

901. The production of *animal heat* is perhaps the most recondite of all the functions; the power appears to belong to all animals, though to some in a very inferior degree. The higher orders of animals always maintain a temperature of about 100°; it varies a little in different parts of the body, the extremities and surfaces being a degree or two colder than the interior vital organs. This temperature is probably very little affected by external circumstances, a hot or cold atmosphere produc-

ing no corresponding change in the heat of the circulating blood.

When the chemical changes that take place during respiration had been inquired into, and when it was found that the capacity of carbonic acid for heat was less than that of oxygen, it was supposed that the conversion of oxygen into carbonic acid was the cause of the rise of temperature; and as the heat of the lungs does not exceed that of other parts, it was asserted that the air was absorbed by the blood, and that the production of carbonic acid, and consequent evolution of heat, took place gradually during the circulation. To these opinions many strong objections have from time to time been urged by different physiologists, but their complete subversion followed the researches of Mr. Brodie (*Phil. Trans.* 1812,) who found that the heart was capable of retaining its functions for some hours, and of carrying on circulation, in a decapitated animal, and consequently independent of the influence of the brain, when respiration was artificially carried on. Under these circumstances it was observed that, although the change of blood from the venous to the arterial state was perfect, no heat was generated, and that the animal cooled regularly and gradually down to the atmospheric standard. In more than one instance I examined, at his request, the expired air, and found that it contained as much carbonic acid as was produced by the healthy animal; so that here, circulation went on, there was the change of oxygen into carbonic acid, and the alteration of colour in the blood, and yet no heat whatever appeared to be generated.

In these cases a period was also put to the secretory functions; and it has been observed by other physiologists, that if the nerves that supply any of the glands are injured or divided, there is a corresponding change or suspension of their secretion. Electricity has sometimes been supposed to have some connexion with the nervous influence, and the fact of some of the secretions being alcaline, while others are acid (corresponding to negative and positive influence,) has been adduced in favour of the supposition *; but experiment has gone little way to sanction such a notion, and although it has been proved that the nervous influence contributes to the generation of heat in animals, that it presides over the phenomena of secretion, as well as of voluntary motion, the actual cause of this influence, or energy, remains among those mysteries of nature which, doubtless, for the wisest purposes, are hidden to the human understanding.

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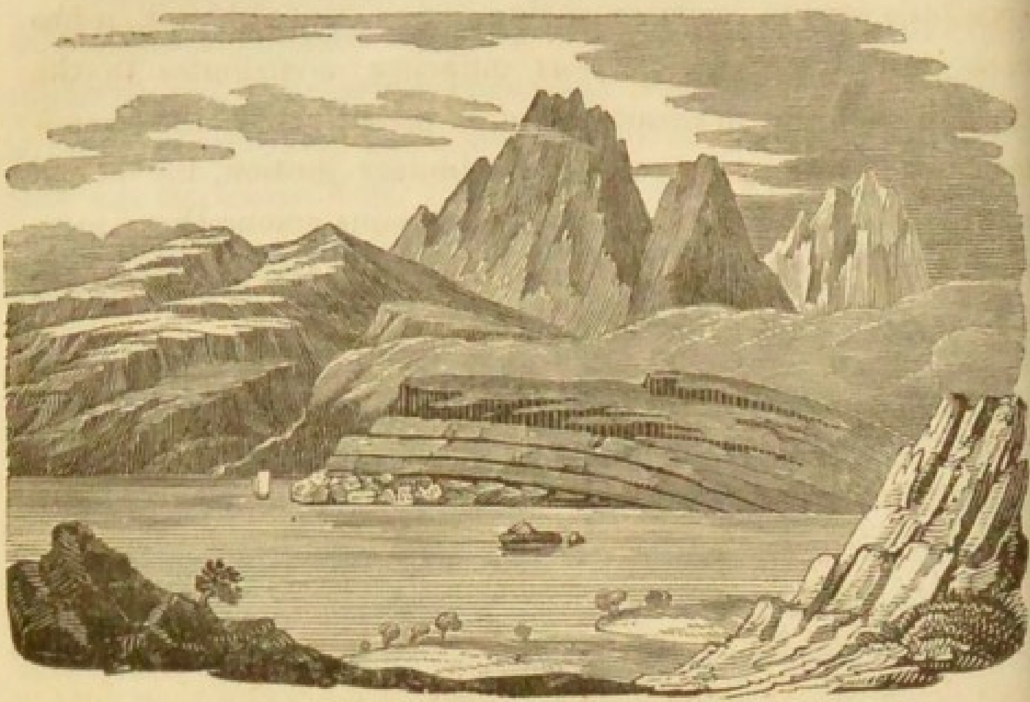
* In the *Philosophical Transactions* for 1809, p. 385, Sir Everard Home has given an account of these views, in a paper entitled "*Hints on the Subject of Animal Secretions.*"



CHAPTER VII.

Geology.

902. HAVING detailed the properties of the elementary bodies, and of their natural and artificial combinations, and having described the products of the vegetable and animal creation, it remains in this, the concluding chapter, to notice the general arrangements of the mineral world, to describe the mutual relations of the substances constituting the surface of our globe, and to examine their characters and composition: these investigations form the object of geological science.

SECTION I. *General Remarks on the Objects of Geological Science—Sketch of the Theories of Burnet, Woodward, Leibnitz, Whiston, Whitehurst, and Buffon. Wernerian, and Huttonian Theories.*

903. GEOLOGY embraces so many topics of discussion, its range is so extensive, and the meanings given to the term are so various and opposite, as to throw no inconsiderable difficulties in his way who would enumerate and expound them. Persons have been called geologists, who, gifted with prolific imaginations, have indulged in fanciful speculation concerning a former order of things, and have reared hypotheses respecting the origin of our planet, upon foundations so flimsy and unsubstantial, as to deserve no other appellation than flighty excursions of a poetic mind. Others, by careful, diligent, and extended observations of the present state of the earth's surface, have endeavoured, in the path of induction, to trace the nature of the agents which have once been active, to ascertain how far they are now operating, and to anticipitate the results of their continuance. If they frame theories, they do so upon the results of actual research; if they indulge in speculation, they assign to it its proper place. These are really geologists, and their aim is, not to imagine or suppose, but to *dicover* the nature of all changes of the earth's surface and interior, and thence to arrive at the laws that regulate them.

Geology, as a branch of inductive science, is of very modern date; for though the attention of men has long been turned to a theory of the earth, the formation of such a theory is incompatible with any but an advanced state of physical knowledge. There appear, indeed, few studies of more difficulty; none in which the subject is more complex; appearances so diversified and scattered; and where the causes that have operated are so remote from the sphere of ordinary observation.

904. The first writer upon this subject, whose name merits notice, is Thomas Burnet *, who may justly be said to have adorned the latter half of the seventeenth century. And though it be true that his pen has rather recorded the sallies of a vivid imagination, than the inferences of sober argument, he will still be read with some profit, though certainly with more pleasure, even in these times. The objection to Burnet and his contemporaries, and immediate successors, is, that they fancifully go back to the chaotic state of the earth, and after enlarging, embellishing, and obscuring the Mosaic history, they pretend to have illustrated and proved it. Accordingly, Burnet, in his "*Sacred Theory of the Earth*," begins with the separation of elements from a fluid mass. The heaviest particles sank, and formed a nucleus, and water and air took their respective stations: upon the water, however, the air afterwards deposited a rich unctuous crust, which begat vegetation, and a beautiful verdure clothed the whole. There were no mountains, no seas, no protuberances, or inequalities; and the equator being coincident with the plane of the ecliptic, all the charms of spring were perpetual. This state of things, however, did not thus continue for many centuries; for the sun caused large cracks and fissures in the exterior, which, by gradual increase, extended to the great aqueous abyss; the waters rose higher and higher, the surface was utterly broken up and destroyed, and an universal deluge took place: at length dry land began again to appear, owing to a gradual subsidence of the waters, which retired into caverns and

* *The Sacred Theory of the Earth, containing an Account of the Original of the Earth, and of all the General Changes which it hath already undergone, or is to undergo, till the Consummation of all Things.* (8vo. London 1726.) Published originally in Latin in 1681 and 1689.

crevices originally existing in the nucleus, or formed by the disruption of the crust; upon the increasing dry land, vegetation began again to exist, and our present islands and continents were formed, while the sea still occupies in part its original bed.

I do not recite the minutiæ of Burnet's romance, nor shall I meddle with the adjustments of these and the like speculations to the records of Holy Writ. If, in the laborious path of experimental investigation, we are occasionally rewarded with the discovery of some new adaptations of causes and effects, which had before escaped notice, but which demonstrate how all things on earth are made to work together for good, the discovery strengthens our faith, and calls forth the best feelings of which the human heart is susceptible; but we must not presume to submit the aptitude of nature's arrangements to the feeble powers of human decision, to doubt her perfection because our imbecile capacities cannot attain its comprehension, or to found our proofs of the existence, or even of the attributes, of the Deity, upon the limited, imperfect, or ideal conception of the excellence of nature's works, of which the human understanding is capable. Although Burnet's Theory, as he calls it, was a mere hypothetical product of the imagination, unsupported by a single fact, or by the slightest observed phenomenon, it excited much admiration and some discussion, and was criticised with much acrimony and some ability *; more especially by Keill, of Oxford †. His style is in general terse and elegant, though it occasionally degenerates into the predominant pomposity of the period at which he wrote. He was the translator of his own work from Latin into English. Two brief samples from

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* By Dr. Herbert Crofte, in 1685; by Dr. Beaumont, in 1693, and by Erasmus Warren.

† *An Examination of Dr. Burnet's Theory*, &c., by J. Keill, A. M., of Baliol Coll. Oxon. Second Edition, 1734, 8vo. "He (Burnet) begins

the latter will be sufficient for elucidation. After observing that the obscurity and remoteness of his subject has by some been used as an argument against undertaking it, "This," says he, "does but add to the pleasure of the contest where there are hopes of victory, and success more than recompenses all the pains. No joy is more grateful to man than the discovery of truth, especially where it is hard to come by. Every man has a delight suited to his genius, and as there is pleasure in the right exercise of any faculty, so especially in that of right reasoning, which is still the greater by how much the consequences are more clear, and the chains of them more long. There is no chace so pleasant, methinks, as to drive a thought from one end of the world to the other, and never to lose sight of it till it falls into eternity, where all things are lost, as to our knowledge."

The following passage from Burnet's work has been highly eulogized by Steele *, and certainly it merits praise; it is a funeral oration over the globe: "Let us now," says he, "reflect on the transient glory of the earth; how, by the force of one element breaking loose on the rest, all the beauties of nature, each work of art, and every labour of man, are reduced to

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his discourse with a saying of an old heathen, that philosophy is the greatest gift that ever God bestowed on man; but it is plain to any who will be at the pains to read his book, that God has thought fit to bestow but very little of that great gift upon him, and, that the world may not say this is ill nature, I will give them a taste of his philosophy," &c.

This is the general style of the "*Examination*."

* *Spectator*, No. 146.

Attached to the English edition of Burnet's work, above referred to, is an "Ode to the Author, by Mr. Addison," in the ordinary fulsome style of that period. The following stanza is a specimen:

Jamque alta Cœli mœnia corruunt,
Et vestra tandem pagina, (proh nefas!)
Burnette, vestra augebit ignes,
Heu! socio peritura Mundo.

nothing; all that once seemed admirable, is now obliterated; all that was great and magnificent, has vanished; and another form and face of things, plain, simple, and uniform, overspreads the earth. Where are now the empires of the world? where the imperial cities, the pillars, trophies, and monuments of glory? what remains, what impressions or distinctions do you now behold? what is become of Rome, the great city; of eternal Rome, the empress of the world, whose foundations were so deep, whose palaces were so sumptuous?—her hour is come; she is wiped from the face of the earth, and buried in everlasting oblivion. But not the cities only, and the works of men's hands, but the hills and mountains, and rocks of the earth are melted as wax before the sun, and their place is no where found; all have vanished and dropped away, like the snow that once rested upon their summits *."

It is impossible to read this quotation, without being reminded of one of the most beautiful passages in the *Art of Preserving Health*, where Armstrong has happily introduced very similar ideas:

> What does not fade? the tower that long had stood
> The crash of thunder and the warring winds,
> Shook by the slow, but sure destroyer, Time,
> Now hangs in doubtful ruins o'er its base;
> And flinty pyramids, and walls of brass
> Descend; the Babylonian spires are sunk;
> Achaia, Rome, and Egypt moulder down.
> Time shakes the stable tyranny of thrones,
> And tottering empires rush by their own weight.
> This huge rotundity we tread grows old,
> And all those worlds that roll around the sun.
> The sun himself shall die, and ancient night
> Again involve the desolate abyss †.

* *Burnet's Theory*, Vol. II. p. 25. † *Art of Preserving Health*, B. II.

I might select many more beauties from the *Sacred Theory of the Earth*. The passages I have quoted, however, shew the general strain of the author, and it would be irrelevant amusement to pursue them.

905. A very different reasoner from Burnet was Woodward; he was nothing of a poet, and not much of a philosopher; he pretends to be a matter-of-fact man; but having collected a few observations respecting the contents of strata, hastily proceeded to the erection of a theory; "to build a ship," as Lord Bacon says, "with materials insufficient for the rowing pins of a boat." Woodward observed the existence of fossil shells, and remarked that the lower strata of the earth's surface were generally harder than the upper, which were of more light and pulverulent materials: whence he concluded, that, at the period of the deluge, the earth had acquired a new crust deposited upon it by the waters, in the succession of the specific gravity of the materials; the heaviest, coarsest, and hardest bodies forming what to us seem a nucleus, covered by finer and lighter deposits.*

About this time Leibnitz published his *Protogæa*†; he supposes the earth to have been in a state of combustion for many ages, and at length to have gone out for want of fuel. A glassy crust was thus formed, which gave rise to sand and gravel; other kinds of earth resulted from sand and salt; and

* Woodward applied the geological observations he had made in England to other countries. "I was abundantly assured that the circumstances of these things in remoter countries were much the same with those of ours here, that the stone and other terrestrial matter in France, Flanders, Holland, Spain, Italy, Germany, Denmark, Norway, and Sweden, was distinguished into layers as it is in England, &c. &c. To be short, I got intelligence that these things were the same in Africa, Arabia, Persia, and other Asiatic provinces; in America, &c. See "*An Essay towards a Natural History of the Earth and Terrestrial Bodies.*" By John Woodward, M.D., &c. London, 1702.

† *Leibnitzii Opera Omnia.* Genevæ, 1768. Vol. II. p. 199.

as the globe cooled, the water which had before been kept in the state of steam, assumed fluidity, and, falling to the earth, produced the ocean. The particulars of these notions are, of course, not worth reciting.

906. Whiston * having blended the follies of Burnet, Woodward, and Leibnitz, endeavours to conceal his imbecility under the lion's skin of mathematical calculation; and taking many things for granted, of which there is not the most distant probability, leaves us bewildered and perplexed; he is neither plausible nor amusing, and is best known as having called forth the libellous witticism of Swift.

907. But there was a contemporary of Whiston, whose works deserve more attention; John Whitehurst†, a native of Congleton, in Cheshire: he passed much of his time in Derbyshire, and investigated, with considerable ability, the stratification of that rich and interesting county; "hoping," as he expresses it, "to obtain such knowledge of subterraneous geography, as might be subservient to the purposes of life, by exposing new treasures which are concealed in the lower regions ‡. In his inquiry into the original state and formation

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* *New Theory of the Earth*, &c. By William Whiston, M. A. 4th Edition, London, 1725.

† *The Works of John Whitehurst, F. R. S.*, London, 1792. "It is my intention (says Whitehurst, in his preface to the Inquiry into the Original State and Formation of the Earth,) to trace appearances in nature from causes truly existent; and to inquire after those laws by which the Creator chose to form the world, not those by which He might have formed it, had He so pleased."

‡ Whitehurst particularly notices the similarity of succession in the strata of England; and in his description of Derbyshire, he mentions the resemblance of the toadstone to lava; and infers, from its appearance, situation, and effects, that it must have issued from below in an ignited state; that it must have been projected with great violence amidst the superincumbent strata, and that their displacements and irregularities are the consequence.

of the earth, he has assiduously collected facts, among which his account of the strata of Derbyshire retains much value at the present day, though repeated investigations have since been made, with all the advantages of modern improvements. And as to his theoretical views, I think it is scarcely going too far to say, they are the best extant: for, unlike later geologists, he first collected facts and then constructed his theories; and those, if any now there be, who are unbiassed by speculative doctrine, and really think for themselves, will consequently accede to by far the greater number of his leading propositions.

908. But no one has proceeded to the forming of a theory of the earth with the pomp and circumstance of Buffon *. It merits attention, not on account of its accordance with present appearances, or as affording plausible solutions of observed phenomena, but from the eloquence with which it is adorned, the extent of information it displays, and the popularity it derived from these sources.

He supposes the planets in general to have been struck off from the sun by a comet; that they consisted of fluid matter, and thence assumed a spherical form; and that by the union of centrifugal and centripetal forces, they are restrained in their present orbits. The earth gradually cooled, and the circumambient vapours condensed upon its surface, while sulphureous, saline, and other matters, penetrated its cracks and fissures, and formed veins of metallic and mineral products. The scorified, or pumice-like surface of the earth, acted upon by water, produced clay, mud, and loose soils, and the atmosphere was constituted of subtile effluvia, floating above all the more ponderous materials. Then the sun, and winds, and tides, and the earth's motion, and other causes, became

* *Histoire et Théorie de la Terre et des Epoques de la Nature.* 4 Vol. 8vo. Paris, 1800.

effective in producing new changes. The waters were much elevated in the equatorial regions, and mud, gravel, and fragments were transported thither from the poles; hence, says Buffon, the highest mountains lie between the tropics, the lowest towards the poles; and hence the infinity of islands which stud the tropical seas. The globe's surface, once even and regular, became now rough and irregular; excavations were formed in one part, and land was elevated in another; and during a period of ages, the fragments of the original materials, the shells of various fish, and different other exuviæ, were ground up by the ocean, and produced calcareous strata, and other low-land depositions. These relics of marine animals we find at such heights above the present level of the sea, as to render it more than probable that the ocean once entirely overwhelmed the earth.

Of the phenomena I have hinted at, Buffon takes particular and extended notice, and draws from them a series of curious and minute conclusions; not, however, satisfactory or logical, inasmuch as many of the data they are founded upon are imaginary, not real. Every one who now contemplates the earth's surface, must trace upon it marks of the most dire and unsparing revolutions, which, from the present order of things, it appears impossible should re-occur, except by the united and continuous agency of the most active powers of destruction. This, says Buffon, arose from the soft state of the former crust of the earth; and those causes, now imbecile and slow in their operation, were then more effectually exerted, and results were obtained in a few years, for which centuries would now be insufficient.

This amusing theorist next proceeds to contemplate the production of rivers, which he regards as having cut their own way to the ocean, as gradually wearing down the mountainous lands, filling up valleys, and choking their exits into the ocean by the transportation of finely divided materials. Thus every thing is slowly returning to its former state ; the mountains will be levelled, the valleys heightened, excavations filled up, and the ocean will again cover the earth.

I shall not enter into the various confutations of these speculative notions, nor dwell upon many modern theories to which they have given rise. Pallas, Kirwan, De Luc, and others, have animadverted upon, but can scarcely be said to have improved, Buffon's hypothesis; and as we set out with granting it to be the mere fabric of imagination, it would be folly to submit it to the solemnity of philosophic criticism.

909. Many other theories of the earth I pass over in silence, as containing nothing not to be met with in some of the already mentioned cosmogonists. The authors have sometimes clothed their fictions in new dresses, or presented them under new forms; but, if we remove the mask, Burnet or Buffon are instantly recognized. Thus, in pretending to advance learning, they have rather obstructed it, and have accumulated hypotheses without enriching science. They deserve that censure thrown upon certain writers by Dr. Johnson, who calls them the "persecutors of students, and the thieves of time." Such at least I have found them.

There are other geological writers who have accumulated many interesting facts, and whose insulated observations are truly curious and valuable ; but their general hypotheses are of so chimerical a cast, as rather to resemble Eastern allegories than European philosophy ; they defy all criticism, and therefore lie out of our present track, which now leads us to review the prevailing theories of the present day. These are the inventions of Professor Werner, of Freyburgh *, and Dr. Hutton, of Edinburgh †, each of whom has been ably supported and

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* *A Comparative View of the Huttonian and Neptunian Systems of Geology, in answer to the "Illustrations,"* by Professor Playfair. Edinburgh, 1802.

† *Theory of the Earth,* by James Hutton, M. D. F. R. S., Edinburgh, 1795. 2 vol. 8vo.

elucidated by the proofs, illustrations, and comparative views of acute and eloquent controversialists *; and two sects have been formed, under the appellation of Wernerians and Huttonians. The disputes and differences of these contending geologists would now be prematurely noticed. They each profess to proceed, as rigidly as the subject allows, in the path of induction; to reject mere hypothesis, and raise their theories upon accumulated facts; and yet they arrive at conclusions diametrically opposite; upon which a clever writer remarks, "that among all the wonders geology presents to our view the confidence of the theorists is by far the most unaccountable."

910. The first principle of the Wernerian theory assumes, that our globe was once covered with a sort of chaotic compost, holding either in solution or suspension the various rocks and strata which now present themselves as its exterior crust. From some unexplained cause, this fluid began first to deposit those bodies which it held in chemical solution, and thus a variety of crystallized, or *primitive rocks*, were formed. In these we find no vegetable or animal remains, nor even any rounded pebbles; but in the strata which lie upon the crystalline, or first deposits, shells and fragments occasionally occur: these, therefore, have been termed *transition strata:* and it is imagined that the peopling of the ocean commenced about this period. The waters upon the earth began now more rapidly to subside, and finely divided particles, chiefly resulting from disintegration of the first formations, were its chief contents; these were deposited upon the transition rocks chiefly in horizontal layers. They abound in organic remains, and are termed by Werner *floetz*, or *secondary rocks*.

It is now conceived that the exposure of the *primitive, tran-*

* *Illustrations of the Huttonian Theory of the Earth*, by John Playfair, F.R.S., *&c.*, Edinburgh, 1802.

sition, and *secondary* rocks to the agencies of wind and weather, and to the turbulent state of the remaining ocean, produced inequalities of surface, and that the water retreated into lowlands and valleys, where a further deposition took place, constituting clay, gravel, and other *alluvial* formations.

There are also certain substances which, instead of being found in regularly alternating layers over the earth, are met with in very limited and occasional patches. Rock-salt, coal, basalt, and some other bodies are of this character, and Werner has called them *subordinate* formations. Lastly, subterraneous fires have sometimes given birth to peculiar and very limited products; and these are called *volcanic* rocks. Such is Werner's account of the production of rocks, which he arranges under the terms *primitive, transition, secondary, alluvial, subordinate,* and *volcanic formations.*

A number of nice distinctions and accurate minutiæ of description attend this theory, which we cannot notice in this bird's-eye view, and which do not affect the general conclusions.

If we examine the stratification of our globe, we shall doubtless find that certain substances do occur in a certain order of arrangement, and that they appear to have been successively deposited, one upon the other, in the manner Werner would have us believe. He, therefore, and his disciples, have perhaps given a satisfactory account of their own country; but when we examine other parts of the earth's surface, so many incongruities are discovered, and so much is at variance with their leading doctrines, that we are obliged to give them up in favour of views more generally applicable.

911. Dr. Hutton gives a very different account of the present order of things. Looking upon the face of nature, he observes every thing in a state of decay; and as she has obviously provided for the regeneration of animal and vegetable tribes, so the philosophic mind will descry, in this apparent

destruction of the earth's surface, the real source of its renovation. The lofty mountains exposed to the action of the varying temperature of the atmosphere, and the waters of the clouds, are by slow degrees suffering constant diminution; their fragments are dislodged; masses are rolled into the valley, or carried by the rushing torrents into rivers, and thence transported to the sea. The lower and softer rocks are undergoing similar, but more rapid, destruction. The result of all this must be, the accumulation of much new matter in the ocean, which will be deposited in horizontal layers. Looking at the transition rocks of Werner, he perceives that, though not strictly crystalline, they appear made up of finely-divided matter, more or less indurated, and sometimes very hard in texture, and of a vitreous fracture; and that this hardening is most perceptible when in contact with the primitive or inferior rock, which often pervades them in veins, or appears to have broken up or luxated the superincumbent masses. According, then, to Dr. Hutton, the transition or secondary rocks of Werner were deposited at the bottom of the ocean, in consequence of operations similar to those which are now active; and the primary rocks were formed beneath them by the action of subterraneous fires; their crystalline texture, their hardness, their shape, and fracture, and the alterations they have produced upon their neighbours, are the proofs of the correctness of these views. It is by the action of subterraneous fire, then, that rocks have been elevated, that strata have been hardened, and that those changes have resulted which an examination of the earth's surface unfolds. The production of soils, and of alluvial land, is considered as dependant upon causes the same as those referred to in the other theory.

It will be observed that Hutton refers to fire as well as water for the production of our present rocks, the former consolidating, hardening, and elevating, the latter collecting and depositing the strata. This system has been happily illustrated by many of the phenomena that occur among the mountains of Scotland, the birth-place of its inventor, and the seat of his speculations; it has been elucidated by the eloquent and philosophic pen of Mr. Playfair; and has received other advantages and aids, which the Wernerian theory has not enjoyed. But these circumstances must not be suffered to bias an impartial story; it is to facts we must attend, and upon them found our verdict.

Much as has been said upon the mischief of geological theories, which by some are represented as ingenious, though dangerous fictions, no one can justly deny their importance and utility, as furnishing strong incitements to the labour of observation and experiment. He that has framed a theory, is fond of searching for confirmations; and he proceeds with a real enthusiasm widely distinct from the cold accuracy of the mere accumulator of insulated facts. In all physical inquiries, theory and observation should go together, like mind and body, the one guiding and directing the other. It is quite true that the impartiality of an observer may often be affected by system; but upon this it has been justly remarked by Mr. Playfair, that it is a misfortune, against which the want of theory is no security. The partialities in favour of opinions are not more dangerous than the prejudices against them; for such is the spirit of system, and so naturally do all men's notions tend to reduce themselves into some regular form, that the very belief that there can be no theory, becomes a theory itself, and may have no inconsiderable sway over the mind of an observer. Besides, one man may have as much delight in pulling down, as another in building up, and may choose to display his dexterity in the one occupation as well as in the other. The want of theory, then, does not secure the candour of an observer, and may greatly diminish his skill. The discipline best calculated to promote both, is a thorough knowledge of the methods of inductive investigation, an acquaintance with the history of physical discovery, and the study of those sciences in which the rules of philosophizing have been most successfully applied.

SECTION II. *Of the Succession of Strata incrusting the Globe, and of the Stratification of Britain in particular.—Of Granite, and other primary Rocks.*

912. THE terms primitive and secondary rocks, employed in the description of Werner's theory, were introduced into geology by Lehman*, a correct and sensible writer of

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* *Traités de Physique, d'Histoire Naturelle, de Minéralogie, et de Métallurgie.* Par J. G. Lehman, *et traduits de l'Allemand.* Paris, 1759. "Les montagnes sont des élévations de la terre de différentes hauteurs, dont quelques-unes sont composées de parties dures, solides, et pierreuses; d'autres sont composées seulement de parties terreuses; quelques-unes ont été créés en même tems que la terre, d'autres ont été formées par des accidens, ou par des évènemens qui ont eu lieu, en différens tems."—Vol. III. Sect. 3. "Il n'y a rien de plus naturel que de partager toutes les montagnes en trois classes. La première classe sera celle de montagnes qui ont été formées avec le monde. La seconde sera celle des montagnes qui ont été formées par une révolution générale qui s'est fait sentir à tout le globe. La troisième classe, enfin, sera celle de montagnes qui doivent leur formation à des accidens particuliers, ou à des révolutions locales." "Les montagnes de la première classe sont élevées, dont quelques-unes se trouvent isolées dans des plaines; mais qui, le plus ordinairement, suivent une longue chaine et traversent des parties considérables de la terre. Elles diffèrent des montagnes de la seconde classe: 1. Par leur élévation et par leur grandeur, qui surpassent celles de toutes les autres. 2. Par leur structure intérieure. 3. Par les substances minérales qui s'y trouvent." *Ibid.*

These passages are sufficient to shew the merits of Lehman as an original and acute observer, and have furnished subsequent geologists with the foundations of their arrangements.

the middle of the last century. He considered the crust of the earth as presenting three distinct series of substances. The first, coeval with the world, he calls primitive, or primary rocks. The second series are of more recent formation, and seem to have resulted from some great catastrophe, probably the deluge, tearing up, and modifying the former order of things; and the third class owe their formation to partial or local revolutions, as indicated by their structure and situation.

913. In taking a general view of the substances which incrust our globe, for of its nucleus we know nothing, we perceive certain distinctions of texture and disposition, which are at once curious and important. The rocks which I have elsewhere called primitive, or primary, are generally found in huge masses or blocks, not regularly stratified, and affecting, in their fractures and fissures, a vertical arrangement. Sometimes they are of a perfectly homogeneous texture, commonly hard and durable, and sometimes composed of two or three ingredients blended together; they are generally crystalline in their texture, and usually constitute the loftiest mountains.

914. The transition series of rocks, or those deemed by the Wernerians next in point of antiquity to the primitive, are less lofty than the former; they, in many instances, present a slaty texture; they seem to have been deposited in strata or layers, and these are seldom either vertical or horizontal, but variously inclined to the horizon. The secondary rocks, or the more recent series, are nearly, if not quite, horizontal in their position. In their texture they are soft, and consequently easy of decay: and they appear rather as mechanical deposits, than as chemical compounds which have resulted from fusion, crystallization, or solution.

915. These different series are tolerably regularly arranged in regard to each other. The primary rocks form the bases upon which the others rest; the transition are immediately recumbent upon these; and these are succeeded by the varieties of

secondary rocks, and by their detritus constituting alluvial matter and soils.

916. In selecting illustrations from nature of the different geological phenomena that come before us, I shall in all cases prefer reference to our own country; and I do presume that it would, on the whole, be difficult to select a better spot for the study of geology than Great Britain. We have every variety of rock presented under its various aspects; and, though in foreign climes nature may have more liberally dispersed the sublime, she has no where more instructively or delicately diversified the earth's surface, than in the small space allotted to the British isles.

A section of the south of England, from the coast of Cornwall, for instance, in the west, to London in the east, will furnish a good exhibition of the phenomena of stratification to which I have just alluded. It will begin at the Land's-End, with primitive rocks, massive and amorphous. Upon this rest several species of transition rocks, especially slates of different kinds, having various inclinations; and these are succeeded by secondary strata, deviating more and more from the vertical, and acquiring the horizontal position; and ultimately we attain the alluvial matter upon which the metropolis stands. It is principally clay, and has once perhaps formed the mud at the bottom of a salt-water lake*.

Proceeding from London northwards, towards the Scotch border, the order of stratification is reversed; and traversing a highly interesting series of secondary rocks, we arrive in Cumberland at some of the primitive series. The whole arrangement is such as to include the highest and oldest rocks upon

* Mr. Smith's Geological Map of England and Wales will be found very useful to the student, to whom I also recommend Mr. W. Phillips' "*Selection of Facts*," *&c.*, as a valuable abridgment of the important materials contained in the Geological Transactions.

the west side of England, forming a chain extending from the Land's-End, in Cornwall, to Cumberland, and thence to the northern extremity of Scotland. So that the length of Great Britain, and its general shape, appear in a considerable degree dependant upon this chain of mountainous land, and upon two lower ridges, which extend in one direction from Devonshire, through Dorsetshire, Hampshire, and Sussex, into Kent; and in another, nearly from the same point, to the east of Yorkshire.

The western ridge is broken in upon in several places by plains and rivers, giving rise to so many chasms in the great chain.

In the Descriptive Catalogue of the Geological Specimens in the Royal Institution *, an attempt has been made to follow the natural succession of strata in Britain, and to shew their successive alternations; and I trust that it will prove serviceable in connecting the following observations, with their respective illustrative districts of our island.

917. Of the primitive rocks †, one of the most abundant in nature, and the most useful in its applications, is GRANITE, so called from its appearing to be made up of a number of distinct grains or particles. Its essential component parts are *quartz*, *felspar*, and *mica*.

918. *Quartz* is the substance commonly called *rock crystal*, and has already been described (686.) It is sometimes met with in mountain masses, which usually present a conical appearance. The quartz is milk white, and of a more or less granular texture. The Sugar-Loaf Mountains near Dublin, the Paps of Jura in Argyleshire, and some of the mountains

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* *A Descriptive Catalogue of the British Specimens, deposited in the Geological Collection of the Royal Institution.* Longman & Co., 1816.

† In selecting specimens of rocks and strata for the geological cabinet, we should endeavour to shew their recent fracture, as well as their weather-worn surface, which is generally easily attainable.

of Sutherland and Caithness, present instances of this formation.

919. *Felspar*, the next constituent of granite, is a compound body, of which silica and alumina are predominant ingredients; it generally contains a little lime and potassa, and is often coloured by minute portions of oxide of iron*. Sometimes it is found crystallized, when it assumes the form of four and six-sided prisms, bevelled on the extremities; its usual colours are red, white, and gray. It is softer than quartz, but harder than glass, and is characteristically marked by fusibility before the blow-pipe.

Felspar is a very important ingredient in many kinds of pottery; and the substance used by the Chinese, under the name of *petuntz*, is probably of a similar nature. The decomposing felspar of Cornwall is abundantly employed in the English porcelain manufactories, and, as it contains no iron, it retains its perfect whiteness. According to Mr. Wedgwood, it consists of,

60 Alumine,
20 Silex,
20 Moisture and loss.

There are some beautiful varieties of felspar employed in ornamental jewellery, such as the *green* and *blue* or *Amazon-*

* In a fine specimen of pale flesh-red felspar, from the Alps, crystallized in the form of the oblique four-sided prism, I found the following constituent parts:

Silica	68,00
Alumina	20,00
Potassa	8,30
Lime	2,00
Oxide of iron	0,50
	99,00
Loss	1
	100,00

stone, of Siberia and America; the *foliated, pearly*, or *resplendent felspar*, called *adularia* and *moon-stone*; and the felspar of the island of St. Paul, upon the coast of Labrador, distinguished by the property of reflecting very beautiful colours when the light falls upon it in certain directions. Felspar is an important component of several other rocks, besides granite.

920. *Mica*, the third and last of the essential ingredients of granite, is a well-marked compound mineral, consisting principally of alumina and silica, with a little magnesia and oxide of iron. Its texture is lamellar, and it is easily split into thin, flexible, elastic, and transparent plates. It is so soft as readily to yield to the nail; it is sometimes met with crystallized in four and six-sided plates and prisms. Its usual colours are shades of brown and gray; sometimes it is red, and sometimes black. In some parts of Siberia mica is copiously quarried, and is employed as a substitute for glass in windows and lanterns. It has been thus used in Russian ships of war, where it has the advantage of not being shattered, like glass, by the discharge of artillery. The extreme tenuity of the plates into which it may be divided, and their elasticity, renders it very useful for the enclosure of objects to be submitted to microscopic inspection.

921. Such are the characters of the components of granite; in some specimens of which they may be distinctly traced and separated from each other, but sometimes the particles are so small as to produce a compound, which to the unaided eye will seem almost homogeneous. We have, therefore, *fine* and *coarse grained granite*. The former is abundant in Scotland, the latter in Devonshire and Cornwall. Indeed, the Cornish granite is remarkable for the well defined and large crystals of felspar which it contains, and which may be seen in many parts of London, where this rock has been used for paving, and where the crystals of white felspar have become evi-

dent in the mass, from the constant attrition to which it has been subjected. It is of this stone that the Strand Bridge is mainly constructed. The colour of granite is principally dependent upon that of the felspar it contains, though a dark mica will often give it a gloomy hue. It is commonly gray or reddish.

922. There are two rocks very closely allied to granite, and usually associated with it; I mean slaty granite, or GNEISS, composed of precisely the same materials as granite, but slaty in its fracture, owing to the comparatively large quantity of mica it contains; and the other rock is a compound of mica and quartz; it has a slaty texture, and also derives its leading characters from the large quantity of mica which it contains. It is called MICA SLATE.

923. On the origin of granite, geologists widely differ. As it constitutes the basis upon which all other rocks appear to lie, Werner has regarded it as the first formation of that chaotic rock-depositing fluid, in which he imagines the earth once to have been enveloped. But many peculiarities of granite have been adduced by Dr. Hutton, as contrary to such an opinion. If we examine a granitic district in nature, we shall observe, in regard to it, two leading phenomena. The one is, that veins of granite frequently shoot from the great mass into the superincumbent strata. The other, that the bodies lying upon granite, especially if they be stratified, either bear evidence of having been broken up, dislocated, and penetrated by the granite, whilst in a fluid state; or they seem as if gradually elevated by some power which has thrown the granite up from below. So that, upon this view of the subject, the date of granite as far as concerns its present position, is posterior to that of the strata that rest upon it. They were first deposited, and the granite then erupted from beneath, and elevated the other strata, throwing them out of the horizontal, and giving them various inclinations to the horizon, or sometimes a

vertical position. The Brocken Mountain, in the Hartz Forest, in Germany, St. Michael's Mount in Cornwall, and the granitic district at Aviemore in the Scotch Highlands, will furnish illustrations of this subject. The first I select as being, at the same time, one of the favourite proofs with the Wernerians of their master's theory, while the Huttonians may regard it no less favourable to the truth of their views.

Of this mountain the peak is granite, and upon it are regular layers of other rocks, the dip or inclination of which is regulated by the surface of the central granite. In inspecting a section of the Hartz mountain, it will, I think, hardly be denied, that the appearance is rather in favour of the elevation of the strata, by the eruption of the granite, than of the original deposition of the granitic nucleus, and the successive subsidence of the other strata upon it.

At St. Michael's Mount, in Cornwall, a schistose, or slaty rock, is invaded by a mass of granite from beneath; veins of the latter penetrate the former, which is hardened, and broken, apparently by the force with which the granite has been protruded. Indeed, the whole granite district of the west of England, beginning at Dartmoor, in Devonshire, and extending to the Land's End, in Cornwall, presents appearances, which are no way so well accounted for as upon that hypothesis which considers the granite to have been thrown up from below in a fused state, and to have forced its way through the superincumbent strata. There are four granitic summits in the promontory of Cornwall, all probably connected with each other, and with that at Dartmoor: and the surrounding country is principally clay slate, which every where inclines to the granite, in the same manner as the strata of the Brocken, in the Hartz Forest.

In the hill at Aviemore, to which I have alluded, veins of granite are seen penetrating the slaty rock in all directions;

and upon the weather-worn side, facing the north-east, a large vein of granite may be perceived, widest at bottom, running nearly perpendicular, and enlarging into a mass, or stratum, of granite, between the schistose layers.

Such, then, is the appearance of granite, and such the arguments of the Huttonian geologist concerning its origin. I have mentioned that the superincumbent rocks are frequently penetrated by granite veins, and it is obvious that every vein must be of a date posterior to that of the body which contains it; and further, as the veins are often observed to proceed from the main body of the granite, into the superincumbent strata, it may be argued, *that the mass of granite, and the veins proceeding from it, are coeval, and both of later formation, than the immediately superincumbent strata.*

Veins of granite, however, are frequently discovered, which cannot be traced to any original mass, or mountain; they seem to be insulated, as it were, among other strata. This is the case at Portsoy, and in Glentilt; and in some of the Western Isles of Scotland, especially Tiree and Coll; and is also observed in many parts of Cornwall. Dr. Hutton, from collateral evidence, conceives that these are always united to some granitic mass, though too deep, or at too great distance, to be traced and discovered.

It may now be asked, how the pupil of Werner accounts for phenomena of this kind? I have already said that he regards granite as having been deposited before all other strata, though its irregularity and its want of stratification are decided objections to such an idea, and that the other substances were precipitated upon it, in the order we find them. In these strata, cracks and fissures occurred, and a new deposition of granite took place from the chaotic fluid, confined to the said cracks and fissures, and producing the appearance of granitic veins; and the hardening of the neighbouring rocks, referred by the Huttonians to the heat of the injected granite, is accounted for by the infiltration of the aqueous solution, which has, as it were, lapidified the softer materials. Now, though we may imagine granite to have been in igneous fusion, we cannot easily conceive it susceptible of aqueous solution; and if so dissolved, why should its second deposition have been confined to the cracks and fissures; Why should it not have formed a new stratum? With these facts before us, it is useless to enter into further comments, and we can only embrace that hypothesis (for after all it is but hypothesis,) which appears best supported by evidence derived from actual observation*.

924. The aspect of a granite district in nature, is subject to variation; it, however, exhibits traits sufficiently peculiar, which are readily recognised by the traveller in his approach to it.

In Cornwall, and in some parts of Ireland, especially in the county of Donegal, the granitic rocks are marked by the bold and abrupt precipices which they present to the attacks of the ocean: and by the barren and dreary aspect of the inland plains, that seem like fields, in which blocks of the stone have been torn from their beds, and indiscriminately scattered over the moss-grown surface. The elevation of these districts is not considerable, the granite is coarse grained, and splits into immense blocks, separated from each other by

* Some have regarded granite as a congeries of crystals of mica, felspar, and quartz, accidentally blended and united; the inspection, however, of the rock, clearly proves that all its materials have been together in fusion; for we find in some granites the quartz impressed by the crystals of felspar, and in others the felspar receives impression from the quartz. Dr. Hutton has looked upon this as demonstrating the igneous fusion of granite, for, (says Mr. Playfair,) "had the materials been dissolved in water, one kind of crystal ought not to impress another, but each enjoy its own peculiar shape." This, however, I do not hold to be sound argument.

natural seams, and appearing like the ruins of edifices constructed by a giant race.

In other cases, granite forms irregular and broken peaks, of prodigious elevation, and does not split into the blocks and masses just alluded to. This is the case in the Alps and Pyrenees, in the highest Scotch mountains, in the Hartz, and in the Tyrol. In Asia and Africa granite constitutes the Uralian, Altaian, and Himalayan chains, and the Atlas mountains; and in South America, the lofty ranges of Cordilleras are of a similar description.

925. Some kinds of granite are prone to decomposition, being dissolved into a fine clay, containing siliceous particles: this probably arises from a peculiarity of the felspar, afterwards to be noticed. In general, granite is the most durable of nature's productions, and long resists the destroying hand of time; as a building material, therefore, granite is unrivalled: and, though in common cases its extreme hardness is against its employment, its use should be enjoined for public edifices. Dublin furnishes some noble examples of buildings constructed of granite, which is there procured in the immediate vicinity of the city, and of a very beautiful kind. In Wales there is very little granite; in the north of Scotland it is abundant; and in England it occurs in Cornwall, Devon, Westmoreland, and Cumberland. It is also met with in smaller quantities in Worcestershire, at the Malvern Hills, and in Leicestershire, in Charnwood Forest.

926. Although granite probably exists in great abundance below the earth's surface, the quantity visible above ground is comparatively small, perhaps not amounting to a hundredth part of the other primitive and transition rocks. In some parts of Scotland the granite superficies, however, is very considerable, and much exceeds the limits assigned to it by Dr. Hutton. Upon this subject a very acrimonious controversy arose be-

tween Dr. Hutton and Mr. Kirwan; the general statements, however, of the former, in this and other cases, commonly make much nearer approach to truth than those of the latter; but as human reason is not infallible, he who always contradicts must sometimes be right, and thus the mere cavilling disputant may occasionally discover the errors of the slow and cautious observer of nature.

927. To the class of massive unstratified rocks belongs PORPHYRY, a substance which is ranked by Werner among the primitive formations. Its essential constituent is felspar; and genuine porphyry may be defined as massive felspar, containing embedded crystals of the same substance. Any rock including distinct crystals of felspar, is called *porphyritic*, as *porphyritic granite*, &c. The colour of porphyry, which is usually reddish, brown, and green, is principally derived from the base, or paste including the crystals. The common aspect of porphyry is that of blocks and masses, not very unlike some of the varieties of granite, but its fragments are generally smaller, and are in a more decaying condition. Porphyry is an extremely durable material for architectural purposes, and as such was highly esteemed among the nations of antiquity. It is met with in many parts of Britain: and in the north, the porphyry districts are of singular grandeur, as at the base of Ben Cruachan, on the banks of the Awe; and amidst the precipices of Ben Nevis, the highest of the British mountains.

The British porphyries are many of them of great beauty, and might well be substituted for all ornamental purposes, for the more rare and expensive foreign varieties.

928. Granitic rocks frequently contain a large proportion of *hornblende*, a mineral of a greenish black colour, which sometimes forms prismatic crystals; it consists of silica and alumina, with magnesia, and appears to derive its colour from oxide of iron, of which it contains from 20 to 30 per

cent. Hornblende sometimes passes into mica; and if the component parts of the two bodies be compared by analysis, the principal difference will often be found to consist in the hornblende containing excess of iron.

These aggregates are termed SYENITES, or *syenitic* rocks, and are of various hues, according as one or other of the constituents predominates. Sometimes the place of the quartz is wholly occupied by hornblende, and the rock is principally an aggregate of felspar and hornblende. The term *syenite* is derived from Syene, in Upper Egypt, where this rock is plentiful, and was used for architectural purposes by the Egyptian and Roman sculptors. The aspect of syenitic rocks is allied to that of granite and porphyry. They may be observed rising from the slaty district of St. David's, in Pembrokeshire; and in Cumberland near Wastdale and Buttermere. A beautiful syenite is noticed by Mr. Bakewell as occurring in Leicestershire, at Markfield Knowle, a hill on Charnwood Forest. Syenite very often contains magnetic oxide of iron.

929. Another substance belonging to the class of rocks we are now describing, is SERPENTINE; its appearance is singularly picturesque and beautiful; and it forms a delightful contrast to the sublimity of granitic districts. Serpentine has its name from the variety of tints which it exhibits, such as bright red, green, brown, yellow, and their various shades, and it often is prettily traversed by veins of a soft substance, to which the term *steatite* or *soapstone* has been given. (408)*.

Some of the varieties of serpentine admit of a tolerable polish, and such are very desirable for many ornamental purposes.

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* Serpentine has been repeatedly analysed; but the results are very discordant; no doubt owing to the indeterminate nature of the rock. See Jameson's *Mineralogy*, 2d.edit. Vol. I. p. 509. Its principal constituents appear to be silica, magnesia, oxide of iron, and a little carbonate of lime.

Serpentine is seen in Cornwall in characteristic beauty, forming part of the Lizard promontory on the southern coast of the county. It appears in variously shaped and coloured blocks and masses; it forms natural arches, columns, and caves; and the district is of very singular interest from many concomitant circumstances, especially from the blocks of porphyry upon which the serpentine is incumbent, and the veins of granite associating with those of steatite, which pervade it.

Serpentine is met with also in the Isle of Anglesea, upon the northern coast near the celebrated Parys Mine *, and at

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* Some of the serpentine of this district is of more brilliant colours, more hard and transparent than the ordinary serpentine; it belongs to the species called by mineralogists *noble serpentine*, of which the following analysis has been given by Dr. John.

Silica	42,50
Magnesia	38,63
Lime	0,20
Alumina	1,20
Oxide of iron	1,50
Oxide of manganese	0,52
Oxide of chrome	0,25
Water	15,20
	100

The following is the analysis of *common serpentine*, by the same chemist.

Silica	31,50
Magnesia	47,25
Alumina	3,00
Lime	0,50
Iron	5,50
Oxide of manganese	1,50
Water	10,50
	99,75

Vide *Chemische Untersuchunge.* Th. II. s. 208, 94.

Portsoy on the Murray firth in Banffshire, where it is associated with granite. The composition of serpentine, as relates to its proximate components, has been variously described. It is generally so fine grained as to appear of an uniform texture; but in Cornwall a coarsely aggregated rock, consisting of *felspar, talc,* and *schiller spar,* may be traced passing into the fine grained serpentine. I have already alluded to the nature of felspar. *Talc* is a body somewhat resembling mica in appearance, but the plates into which it is divisible are not elastic. Its usual colours are various shades of green. It consists of nearly equal parts of silica and magnesia, with a little lime; not more than six per cent. It is met with in small tabular crystals.

Schiller stone, or *schiller spar,* is a term from the Germans, implying glistening or changeable spar: it is one of the varieties of *diallage* of the French authors; it is a silico-ferruginous fossil, containing

44 silex,
24 iron,
18 alumina,
12 magnesia:

Its colour is dark green; its usual lustre is semi-metallic, varying according to its position in regard to incident light.

Steatite is a substance of different tints of grey and green, and from its very singular unctuous feel, has been called *soapstone.* It is somewhat abundant in the serpentine of Cornwall, one of the masses of which is called the *soapy rock;* it is here carefully collected for the porcelain works of Swansea, in which it forms a very important ingredient. It also occurs in the serpentine of Banff. Varieties of this substance are the *nephritic stone,* or *jade,* (p. 333.) and the *axe-stone,* employed by the natives of the South-Sea Islands, for making cutting instruments. According to Klaproth, Cornish steatite consists of

Silica	45,00
Magnesia	24,75
Alumina	9,25
Iron	1,00
Potash	0,75
Water and loss	18,00
	98,75*

930. MARBLE is the last of the rocks belonging to the class I am now describing (356). It is also very abundant in the secondary rocks, but its characters are there different. Among primary rocks, marble is associated with mica slate, and serpentine; and it differs from marble belonging to other rocks, in its granularly foliated texture, and in the absence of organic remains. The most esteemed varieties are perfectly white, and free from veins; somewhat translucent, and susceptible of a good polish. These marbles are imported for ornamental purposes, especially for those of the sculptor. Nearly all the sublime works of the Grecian artists were sculptured in the marble from the isle of Paros in the Archipelago. Next in point of estimation is that of Carrara in Italy. Of the coloured varieties, that of the isle of Tiree is extremely beautiful; it is of a pale red, spotted with green hornblende. Marble is found in several parts of Scotland, and in some places of characteristic beauty, and alternating within small limits, with other rocks. In Inverary park it may be seen in contact with mica slate and porphyry. Serpentine and marble are sometimes blended together, and they then form a valuable compound for ornamental purposes, which has been called *Verd Antique*. In the splendid serpentine of Anglesea, patches of marble are found which much enhance its beauty.

A very remarkable marble quarry is that of Icolmkil, or Iona. Syenitic rocks constitute the leading feature of this island, but

* Vide Klaproth's *Beiträge*, V. Band, S. 24.

at the south-west point, is a bed of marble about 40 feet wide, bounded by vertical walls of hornblende rocks*. Near it is a mass of hornstone, and above the whole protrudes an immense vein of granite, surrounded by the marble, but from which it has been loosened, so as just to admit a person to pass between the two walls. That they have once been in contact, is proved by the granitic protuberances having correspondent indentations in the marble, and *vice versâ*.

931. We have now considered a highly important series of rocks, and have enumerated their characters as insulated individuals. As a class they present analogies which distinguish them from their superincumbent neighbours, and give them the stamp of a peculiar and distinct formation, either formed before organic beings, or under circumstances which have destroyed such remains.

In these rocks we seldom observe any regular stratification; they are constituted of amorphous, irregular, and various masses, and present no appearances of having been deposited from water. They are crystalline aggregates; and they are deeper in their situation than other rocks, which always appear

* The marble is of the species called *dolomite* (408) distinguished from the true primary marble or granular lime-stone, by the tardy effervescence excited by pouring muriatic acid upon it, and by its containing magnesia; it is also finer grained, and its fracture more splintery than that of common marble. The dolomite of Iona yielded to Mr. Tennant,

Carbonic acid	48,82
Lime	31,12
Magnesia	17,06
Insoluble matter	4,00

Phil. Trans. 1799.

The dolomite of the Apennines yielded to Klaproth,

Carbonate of lime	65
Carbonate of magnesia	35

Beiträge B. 4. S. 215.

incumbent upon them, and often elevated or heaved, as it were, by their operation.

They often break through the beds or layers that cover them, and rise to a very great elevation, forming the summits and peaks of the loftiest mountains. In England they are comparatively rare; in Cornwall there is abundance of granite, but it rises to no great height. Granite and its associates are found in Cumberland, but they are sparingly scattered over the county; and the romantic and picturesque aspect of the hills is chiefly derived from other species of rocks. In Wales the primary rocks are uncommon, and I know of no granite; but there is a portion to be found in the centre of Anglesea, near Gwindy, where its associations merit notice.

In Scotland the districts composed of primitive rocks, and presenting their various aspects, junctions, and transitions, are full of grandeur and interest. Travelling northwards from Edinburgh, we enter upon mica slate at one of the highland passes, and crossing the Grampians, find their principal summits of the same materials. From Loch Tay to Killin, the same rocks continue, with beds of limestone. Ben More is a mica slate rock, of exceeding grandeur; it rises to about four thousand feet above the sea's level, and is thickly intersected with quartz veins. Ben Lawers, to the north of Loch Tay, is of similar composition; it is chiefly gneiss, associated with mica slate and quartz; and the same substances are found at Crag Caillach, and Schehallion, and contribute to the magnificence of the celebrated pass of Killikrankie, between Dunkeld and Blair in Athol.

I have thus represented the highest mountains in Britain as composed of granite and its associates; but these are mere trifling protuberances upon the earth's face, when compared with the exceeding heights of the Alpine chain, or the yet more elevated mountains of South America, and of Asia; which consist of the same materials. Ben Nevis the loftiest of the British mountains, is situated in the south of Inverness-shire, and is 4,370 feet high. Cairngorm, in the same county, is 4,050 feet high. Mont Blanc in Switzerland has its peak elevated 15,600 feet above the level of the sea; it is the highest mountain of Europe; Chimboraso, the highest summit of the Andes, is 20,280 feet above the sea's level; many of the peaks of the Himálaya chain are as high, and the loftiest appears to exceed 25,000 feet *.

The reason why these excessive elevations present nothing but primitive rocks, and especially granite, (excepting, indeed, where they are volcanic) may not at first appear quite obvious, for in the low lands the primitive are generally covered by secondary strata, which were also once probably incumbent upon their loftiest summits. It is likely that the destructive agencies of the elements have been so powerfully exerted in these elevated and unprotected regions, that the secondary rocks have yielded to their unceasing attacks, and have been carried towards the valleys by the rills and torrents, while granite and its durable accompaniments have more obstinately opposed the inroads of such resistless assailants.

952. At the same time, however, it will seem probable that the granitic mountains have themselves suffered tremendous degradation, and that at a former period their summits were beyond their present elevation. All this will appear more clear when the general characters of mountain chains, and the phenomena of their decay, are taken into the account. But several circumstances present themselves to the most superficial observer, which, in a language that it is impossible to misinterpret, announce the influence of destructive agents upon these apparently invulnerable materials. Prodigious masses of granite are often found among the secondary

* See an article on this subject in the sixth Volume of the *Quarterly Journal of Science*, p. 55.

strata that form the valleys under primary mountain chains; they are insulated and unconnected with any general mass of the same material; and the more distant they are from the granite range, the more they are rounded and smootheued upon the surface. Of this description are the boulders, or blocks of granite, observed by Saussure upon the east side of the lake of Geneva. One of these, called *Pierre de Gouté*, is ten feet high, with an horizontal section of fifteen feet by twenty. In the valley of Chamouny, several similar blocks have fallen from the Aiguilles. Some of these have been transported between thirty and forty miles, and as several mountains and valleys are now interposed, their transportation must have taken place at a very remote date*.

In the glen which separates the Great from the Little Saleve, there are many granite boulder stones strewed over a calcareous plain; and of these several are supported upon a short pillar of limestone, resulting from the protection afforded to the calcareous rocks by the harder boulder, so that the height of the column becomes a measure of the wearing away of the surrounding country. This appearance has induced Saussure to assert, that these stones are now in the very situation where they were left by the great aqueous torrent, or debacle, which tore them from their original bed, and brought them down from the high Alps; a conclusion, however, as Mr. Playfair has remarked, not altogether warranted by the fact. In some of the recesses of the Jura there are large, and somewhat angular, blocks of granite, which have evidently been deposited in their present situations at very remote periods, the surrounding and impending heights being composed of limestone rocks, which form an amphitheatre round the present valleys. In the neighbourhood of Neufchatel, too, there is an enormous insulated mass of granite. It is as large as the ce-

* See Dr. Kidd's *Geological Essay*, Chapter XVIII. which contains an account of the most remarkable boulders.

lebrated foundation of the statue of Peter the Great, erected at Petersburgh, by Catherine II., which is composed of a boulder, or detached block of granite, found in a bay of the Gulf of Finland, whence it was transported to the capital ; its length was 42 feet, its breadth 27 feet, its height 21 feet*.

In the Isle of Arran, an immense block of granite is found upon the shore, not only three miles from the nearest granite rock, but having also a bay of the sea intervening ; and several similar instances might be adduced, proving the great ravages that have been committed upon even so hard and unyielding a body as granite. We shall not, then, be surprised that the same agents, acting upon softer materials, have made more successful depredations ; and have, in many instances, completely denuded those granitic surfaces, which were once clothed by secondary strata.

933. In Cornwall, granite is sometimes of very rapid decomposition, and the streams which traverse these districts deposit a finely-divided earthy matter, resulting principally from the felspar, and much used in the potteries. Carglaise tin-mine is situated in a decomposing granite of this kind, and presents a spectacle highly worthy the attention of the curious. The mine is a vast chasm in the granite rocks, and exposed to the day. The tin ore and schorl rock traverse it in abundant veins, and the surrounding peaks strongly remind the beholder of a miniature representation or model of the Alps. Possibly the rapid decay of the granite here depends upon the quantity of alcali contained in its felspar.

Dr. Mac Culloch, in a dissertation on the granite Tors of Cornwall, published in the *Geological Transactions*, has made some interesting remarks upon the peculiarities which they present, and which have given rise to much idle and ignorant speculation. A very remarkable Tor is the *Cheese-wring*, upon an

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* See the "*Relation*," par le Comte Marin Carburi de Ceffalonie, &c. Paris, 1777.

eminence near Liskeard. It is a cairn consisting of five stones, of which the upper ones are larger than and overhang the lower, the whole pile being 15 feet high. The stones of which it consists, are yielding to the weather most rapidly at their angles and edges; they are thus becoming rounded, and approaching that tottering state which will soon hurry them down the precipice to their former companions in the plains below.

This tendency of square blocks of stone to become spherical, independent of friction, is productive, in other cases, of very curious consequences, and has often been considered as demonstrating the agency of streams or currents by which the masses have been transported from distant regions. The present Tor has, by some antiquarians, been considered as a druidical statue of Saturn. The same cause appears to have produced the celebrated Logging-stone.

934. Before we quit the subject of primary rocks, it will be right to mention a district of Britain, which, for grandeur of scenery, and geological interest, can I think, scarcely be surpassed. I allude to the country between the eastern extremity of Loch Ness and Fort George, and especially to the rocks over which the river Fyers pursues its turbulent and winding course.

These are seen in characteristic grandeur in the neighbourhood of the small inn called the General's-hut, and the scenery becomes more and more impressive and interesting until we arrive at the celebrated falls of the river. I should call the rock a *granitic breccia;* it appears made up of numerous angular fragments of granitic materials, held together by a siliceous cement, and the aggregate is of extreme hardness and durability; masses resembling jasper and agate may also be observed in it. Dr. Garnet compares the cement, or basis of the rock, to a *lava* of a reddish hue; and a common observer would consider the whole as fragments of granite which had been united by semi-fusion, which had been softened and glued together, as it were, in the fire. The general aspect of the surrounding scenery is such as to impress the mind with the idea of some vast convulsion of nature having torn the rocks asunder, and shattered them into gigantic fragments; rugged crags and abrupt precipices present themselves on all sides, and the river rushes with tremendous impetuosity through deep and obstructed chasms. A rude bridge is thrown over the upper fall, whence the spectator beholds the waters of the Fyers, at the distance of 200 feet beneath him, rushing into a cavity of 70 feet in depth, whence they again emerge in perfect stillness, and, running over an uneven and fragmented channel, approach the lower or grand fall. Here the waters, previously pent up and exasperated, suddenly discharge all their violence, and are lost in a deep abyss. The depth of the chasm in which the river flows is 400 feet, and it bursts forth in an unbroken stream, constituting a fall of 212 feet perpendicular height. The rugged irregularities of this district, the fragments that lie thickly strewed upon the sides of its mountains, the caverns that abound in its rocks, and the perpendicular precipice of the great cascade, considered conjointly with the peculiar texture and composition of the materials that form it, present many objects worthy the attention of the geologist, and may be regarded as recording some great natural convulsion, which has not only broken up and reunited certain primary rocks, but has again disturbed their tranquillity, and thrown them into the stupendous confusion they now exhibit.

SECTION III. *Of Stratified Rocks, and of the Transition and Secondary Formations of Werner.—Rock-salt, Coal, Alluvial Matters, Basalt.*

935. WE now descend from the primitive, to the *transition*

rocks of Werner; these are more particularly the *stratified rocks* of the Huttonian geologists, and they are distinguished by several well-marked characters from the unstratified and primary rocks.

One leading and general circumstance may be observed in regard to them, which is, that they never attain the great elevation of the primary bodies; this has been elsewhere referred to the comparative readiness with which they yield to the assaults of decomposition and disintegration.

The highest known mountains in the world are those of Thibet, constituting the Himálayan chain. They are alluded to by Col. Kirkpatrick, in his *History of Nepaul*, and an extended and interesting account of them has been published by Mr. Colebrooke, in the *Asiatic Researches*, Vol. XII.

Of this chain, the highest peak, covered with eternal snow, is called Dwawala-giri, or White Mountain ; it is the Mont-Blanc of the Indian Alps, and rises to the astonishing altitude of 26,462 feet above the level of the plains of Gorakh'púr ; or, upon the lowest computation, 26,862 feet above the level of the ocean (p. 503). This is about 6,000 feet higher than Chimboraso, 11,000 feet higher than Mont-Blanc, and 22,000 feet higher than the most elevated peak of the British dominions, which, indeed, makes Ben Nevis seem very insignificant, though its summit is close upon the verge of perpetual snow in this climate. There can be no doubt that the lofty peaks of the Thibet chain are granite, though we learn that the hills which border them are secondary, and contain remains of spiral shells. The elevation of secondary rocks will, in a great measure depend upon that of the primary materials beneath them ; thus, in the Andes they attain 12,000 feet, in the Alps 7,000, and in this country not more than 3,500.

936. In respect to the original formation of secondary rocks, the notions of the Wernerians and Huttonians are not so widely different as we have found them formerly; they both agree

that they are depositions from water; but how, then, have they lost their necessary horizontality, and acquired positions more or less inclined, or even sometimes vertical? Dr. Hutton conceived they were elevated and hardened by the throwing up of the primary or unstratified rocks from below, in the state of igneous fusion. It was once a great difficulty to imagine a combustible which should thus furnish fuel to melt these immense masses of primary materials, and to conceive the real cause of that expansive power of heat which Dr. Hutton always flies to. But the discoveries of Sir H. Davy, concerning the true nature of earthy bodies, have furnished unexpected evidence in defence of these apparent incongruities of the Huttonian doctrines, and it is bestowing no small praise upon a theory, to allow that it is strengthened by the progress of knowledge, and elucidated by the advances of experimental research. However, that these elevating powers do exist, is proved by the sudden throwing up of a hill in the Bay of Naples, which was raised 1,000 feet in a single night*, and by the appearance of a new island at the Azores, in water, between 50 and 60 fathoms deep†. We must afterwards refer to the *cause* of these phenomena. At present, possession of the fact is the main requisite. In the Neptunian system, it is conceived that the position of the strata has depended upon the ground they have been deposited upon, and that they have partly crystallized, and partly subsided, upon the inclined, or nearly vertical sides of primary rocks; or that the falling in of caverns has occasioned their present irregularities; but, when we observe the mischief which the primary rocks seem to have done the secondary, and when we take into the account all the phenomena of granite veins, before discussed, I think that he who is not unduly biassed, will feel inclined to

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* See Sir W. Hamilton's account, in the *Philosophical Transactions*, 1771.

† *Philosophical Transactions*. 1812. See Dr. Kidd's *Essay*, Chap. XXVI.

acquiesce in the Huttonian interpretation. It is probable, then, that the materials of the transition rocks, or, as I would rather put it, of those secondary and stratified rocks which are immediately incumbent upon the unstratified primitive rocks, are derived from the destruction of a former order of things; that they have been delivered into the ocean by the rivers, that they have covered the bottom of the sea, and have been hardened, elevated, and traversed by the eruption of granitic and other substances belonging to that class, from the bowels of the earth.

937. The next peculiarity of the secondary rocks that presents itself, is their containing fragments, pebbles, and organic remains; whence cosmogonists have framed sundry conclusions, concerning the particular period of their formation, which, it will be unwise and useless here to discuss. At the same time, the presence of bodies which once belonged to the organized kingdoms, but which, although still retaining their original forms, are completely fossilized, furnishes us with many interesting conclusions, and holds out to the inquisitive, unfailing matter of useful discussion. In the oldest secondary rocks fragments are often found, and rounded pebbles, whence we learn their origin from former rocks. Upon these beds occur, which contain remains of shells, corals, and fish, all of marine origin; and oftentimes the races are extinct. Approaching the newer rocks, relics of quadrupeds now no longer known, are observed; and, following the deposition of strata, we ultimately arrive at remains of lizards, crocodiles, elephants, deer, and some other animals; and we occasionally discover districts containing land and sea-shells in alternating layers.

I merely make allusion to these facts, to shew how curious and new is the field of inquiry, which modern geology has opened. It has taught us that whole races of animals have been swept from the earth's surface; that not only species, but likewise genera, have become extinct; that fresh water and dry land existed before the formation of many of our secondary strata; that oviparous quadrupeds began to exist along with fish, nearly at the commencement of the secondary formations; that mammiferous sea animals are of more ancient formation than land animals; that a few of those now known, existed towards the termination of secondary formations, but that by far the greater number are of later date, and probably contemporary with the present order of the earth's surface, for their bones are only discovered in very recent depositions, and are in a state of inferior preservation to those of more ancient date; and, lastly, it is to be observed that no fossil human remains have yet been found.

Such are some of the topics which this part of geology presents for consideration, and which shew us that the earth is indeed "as a book, in which men may read strange matters." Though the existence of fossil remains must have been noticed from the earliest ages, the philosophical discussions to which they have given rise are of very modern date, and the merit of fixing the geologist's attention upon them, as recording certain revolutions of the globe, belongs chiefly to Cuvier.

Further, to promote attention to the nature and arrangement of the secondary rocks, it may be suggested that they are the chief repositories of metallic substances; and that, by their decomposition and decay they furnish the principal materials of the soil in which the vegetable has its habitation, and consequently upon which the existence of animals ultimately depends.

938. Of the secondary rocks, CLAY-SLATE may be first noticed; it is extremely abundant, and generally immediately incumbent upon the primary series. It is often micaceous near the junction, and we frequently observe it fragmented, and penetrated by quartz, or felspar, or mica, or by granite itself. Before the blow-pipe, it fuses into a black mass; its usual

colours are various shades of gray, and it is generally so soft as to yield to the nail. Siliceous and argillaceous earths, and oxide of iron, with a little lime and magnesia, are its principal ingredients*. The varieties of slate are applied to various useful purposes; that which is easily separable into thin plates, compact, sonorous, and not injured by the application of a moderate heat, is employed for roofing houses. London is chiefly supplied from Bangor, in Caernarvonshire; and from the neighbourhood of Kendal, in Westmoreland: there are also very large quarries at Easdale, in Argyleshire; according to Mr. Jameson, five millions of slates are there annually manufactured, which gives employment to 300 men. There are several slate quarries of note in Dumbartonshire; one ought particularly to be mentioned, at Luss; it is of geological interest, and commands a captivating view of the lake, and the neighbouring mountains. Here the clay-slate rests upon mica slate; the former is of a purplish tint, penetrated by veins of pink carbonate of lime, and of quartz; the latter is very remarkably contorted.

939. Other varieties of clay-slate are used for writing-slates, slate-pencil, *&c.*; and where slate is very abundant, we observe it employed for monumental tablets, pavements, and walls. Crystals of iron pyrites, and some other extraneous bodies are not rare in slate; these generally render it unfit for the

* I obtained, as the results of the analysis of a specimen from Luss, near Dumbarton, the following component parts:

Siliceous earth	48
Aluminous earth	28
Magnesia	5
Lime	2,5
Oxide of iron	10
Loss	6,5
	100,0

applications I have alluded to. Slate often contains fragments of other rocks, embedded masses, and nodules of various kinds, frequently pebbles, and, occasionally, a few impressions of shells; it also often derives a green colour from the presence of a mineral called *chlorite*, consisting of oxide of iron united to siliceous and aluminous earths. The slates containing embedded matters are called *grauwacke-slates*, or, when of a less slaty fracture, simply GRAUWACKE, a substance which is abundant in this country.

940. The slate district of England is of considerable extent, and neither wants sublimity nor grandeur; it follows the great primary chain which I before alluded to, as running north and south upon the west side of England; in Cornwall the slate is seen immediately incumbent upon granite, and the slaty districts form very beautiful scenery upon many parts of the coast. The term *killas* has been applied to it by the miners. Nothing, I think, can exceed the scenery about Looe, Fowey, and thé country between it and Falmouth; and upon the north coast, Tintagell is yet more remarkable.

There is some grauwacke in Cornwall, but it is not abundant. The best marked specimens I have seen, are from Mawnan near Falmouth, where it alternates with clay slate.

941. The slate district of Wales is of singular interest and magnificence, as those will acknowledge who have visited the chain of mountains, including Snowdon, Plynlimmon, and Cader Idris. These mountains attain an elevation of between three and four thousand feet, their summits are jagged and irregular, their declivities steep and barren, and the neighbouring passes and valleys have all the peculiarities that slate confers; among them, the Dell of Aberglaslyn, viewed from the bridge which unites Merionethshire to the county of Caernarvon, presents a grand and awful feature. The rocks are lofty, lonesome, and black; their sides exhibit terrific and inaccessible precipices; or where the slopes are more gentle, they are covered with

the sharp angular fragments, which time and the elements have dislodged from above.

Advancing northwards, the mountain chain is broken by the lowlands of Lancashire; but in Westmorland and Cumberland slate again presents itself, plentifully accompanied by grauwacke, which contributes to the enchanting scenery of the lakes. As black peaks and precipices strewed with slippery and cutting fragments mark the mountains of common slate, so have the grauwacke rocks peculiarities by which they are recognized, and which are no where more evident than in the rounded summits that embosom Derwentwater. In their forms, tints, and outlines there is something indescribably delightful, and they present that rare union of the sublime and beautiful of which no better idea can be formed, than that suggested by Mr. Burke's comparison: "Sublime objects are vast in their dimensioms; beautiful ones comparatively small; beauty should be smooth and polished; the great, rugged and negligent; beauty should shun the right line, yet deviate from it insensibly; the great, in many cases loves the right line, and when it deviates, it often makes a strong deviation; beauty should not be obscure; the great ought to be dark and gloomy; beauty should be light and delicate; the great ought to be solid and even massive." These qualities of that which is sublime, well apply to the rocks I have before described, and, when blended with the parallel definition of the beautiful, furnish a just notion of the aspect of those now under consideration.

942. The TRANSITION LIMESTONES of the Wernerians, are the substances that next occur. They are frequently seen immediately incumbent upon clay-slate, and are further distinguished from primitive limestone, or statuary marble, by having a less decidedly crystalline texture. Where this rock lies directly upon slate, it contains few organic remains; but where red sandstone is interposed between it and the slate-rocks, or in

proportion as it is distant from the primary and slate-rocks, the relics of organization become more frequent. It then abounds in remains of corals and zoophytes, which now are not known to exist. It often is traversed by veins of calcareous spar, and presents a great variety of colours. It is abundant in Devonshire, South-Wales, Derbyshire, and Yorkshire, and is commonly known by the name of *Mountain Limestone.* At Plymouth this rock is seen immediately incumbent upon slate, in a quarry between the Dock and the Town. Its colours are red and gray, streaked with white crystalline veins. It is also seen to great perfection in the Breakwater quarries at Oreston.

943. Slate districts often present very curious inflexions and incurvations of their strata. The slate at Plymouth, and the grauwacke of Clovelly in the north of Devon, and the killas upon the coast of Cornwall near Charlestown, are in many places very singularly contorted; and sometimes small undulations present themselves in the laminæ, exactly resembling those left by the ebbing tide upon a gently inclining sand bank. These appearances may, perhaps, be referred to the action of water upon the materials before they were consolidated.

944. Limestone strata are also very remarkable for the inflexions and curvatures, referred by Dr. Hutton to their having been in a soft state at the time they were disturbed from their horizontal position. There are some very curious instances of these curvatures noticed by Saussure; one in particular on the road from Geneva to Chamouny, where the small stream of *Nant D'Arpenay* forms a cascade by falling over a perpendicular surface of limestone rock; the strata are bent into regular arches, with the concavity to the left; while in another neighbouring mountain they turn to the right; so that a vertical section of the two would present the figure of S. The top of Ben-lawers in Perthshire, and the coast of Berwickshire, with many

other districts in Scotland, present instances of these singular contortions. Dr. Hutton has given a plate of the bent strata in Berwickshire, from a drawing made by Sir James Hall. I cannot here follow Dr. Hutton and his sagacious commentator through their arguments founded upon these phenomena, which are at once ingenious and satisfactory; they seem to prove that the undulated strata have received their peculiarities upon level ground; that they have then been elevated, hardened, and often bent and contorted during these processes; and that their irregularities, as to position, and their fractures and dislocations have thus occurred, and do not result, as the opposite school would have it, from the falling in of caverns,—a position which they assume as at once accounting for such appearances, and for the retreat of the ocean. Hutton considers the land to have been raised, Werner supposes the waters to have retreated.

945. The aspect of a country of mountain limestone is peculiar, and generally extremely picturesque. The hills, which, in this country at least, are not very lofty, abound in precipices, caverns, and chasms; and, when upon the coast, form small promontories, and jut out in low but grotesque pillars. The even surfaces are covered with a stinted turf, but the rifts and cracks contain often a soft rich soil in which stately timber trees flourish. The chasms of limestone rocks are often filled with a fine clay, which has, perhaps, sometimes been derived from the decomposition of shaly strata, or sometimes deposited from other causes in the fissures, and the singularities of aspect, and much of the beauty of this rock, is referable to these peculiarities. Thus, upon the banks of the Wye, large and luxuriant trees grace the abrupt precipices, and jut forth from what appears a solid rock. Their roots are firmly attached in some crevice filled with a favourable soil. Sometimes rivers force their way through the chasms; at other times they are empty, and

the roofs ornamented by nature's hand with stalactitical concretions of white and glistening spar, which seem like the fretted sculpture of Gothic architecture.

The views of Matlock, and its vicinity; and the caves of Castleton, are admirably illustrative of the scenery of mountain limestone. Pont-Neath Vaughn, in Glamorganshire, is full of its beauties; and the Panorama of Swansea Bay, seen from the Mumbles Point, furnishes a pleasing, characteristic, and perhaps unrivalled, prospect of these rocks.

The banks of the Avon too, in the vicinity of Chepstow, are of mountain limestone. The rock is there impregnated with bitumen, and hence exhales a peculiar and fetid odour when submitted to the blows of the axe or hammer. This is by no means uncommonly the case where the lime-stone rock, as in the present instance, is in the vicinity of coal.

946. Mountain limestone is an excellent material for building, and many of its varieties are sufficiently indurated to receive a good polish, and are thus employed for ornamental purposes, being cut into vases, chimney-pieces, and the like. Where they abound in corals, and other organic remains, these frequently add to their beauty.

The colours of transition limestone are various, but its essential constituent part is always carbonate of lime. The black variety known under the name of *Lucullite**, or black marble, has long been admired, and is often tastefully manufactured and ornamented by etching upon its surface. It is found in Derbyshire, Sutherlandshire, and Galloway, and appears to derive its colour from carbonaceous matter.

All these limestones are converted into a more or less pure *quick lime* by the operation of a red heat, and are thus often valuable as affording manures, and for other purposes, (705).

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* A name given to the marble in consequence of the admiration bestowed upon it by Lucius Lucullus. Vide *Plinii Hist. Nat.* 36. 8.

947. The next rock that occurs in point of succession, is RED SANDTONE. It often rests upon slate, and from its position has acquired the term of *old red sandstone.* Although the metals begin to fail in this and the superior strata, yet it is connected with coal, and rock salt.

Entering upon this substance, we come upon distinctly stratified ground; it is very abundant in England, especially in Lancashire, Cheshire, Staffordshire, Shropshire, and Worcestershire; and independent of its embowelled treasures, its surface is generally favourable to vegetation, and its soil sufficiently luxuriant. It consists principally of siliceous particles, and oxide of iron, with some argillaceous earth, and more or less calcareous matter. Its beds are often of great thickness, as may be seen in the quarries; it is much used as a building stone, but moulders in consequence of the action of air and moisture upon the oxide of iron. It often contains particles of mica, and fragments and pebbles of old rocks.

948. Red sandstone rocks are seen in some parts of Britain in great beauty and perfection, especially where they occur on the coast, or are intersected by rivers. At Ilfracomb, the red sandstone of the Somersetshire coast is seen lying upon slate; and the junction is interesting to the geologist, the sandstone becoming somewhat slaty, and the slate having a tendency to a granular fracture. Hawthornden, near Edinburgh, shews the characteristic features of the rock; and the ancient castle, with its dungeons and vaults, is constructed of this material. Ridges of red sandstone, containing mica and fragments, sometimes accompany primary rocks, of which a very singular instance occurs upon the banks of Loch Beauly, near Inverness; a high range of granite is here bordered by a breccia, very like that of the bed of the Fyers; and a low ridge of red sandstone, of which the valley is also composed, accompanies the series, and seems the detritus of the more ancient and lofty formations.

949. The slates, grauwackes, and limestones, are the prin-

cipal seats of the metallic ores; and they form scenery which, gradually decreasing in grandeur and sublimity, increases in softness, variety and luxuriance. In the lowest sandstone formation, we meet with a variety of bodies of the utmost importance in our arts and manufactures.

950. A substance which occurs in abundance in many parts of the red strata, is *gypsum* or *sulphate of lime*, known also under the name of *plaster-stone*, *selenite*, and *alabaster*. Near Tutbury in Staffordshire, and near Nottingham, it is found in blocks and veins, and lately a variety, new in England, has been found, called *Anhydrite*, (see page 207.) These minerals constitute valuable materials for the ornamental manufactures of Derbyshire.

951. In the county of Cheshire the red sandstone contains immense beds of *common salt*, most abundant in the valley of the Weaver, and near Middlewich, Northwich, and Nantwich: it is accompanied by gypsum. The first stratum was discovered about 150 years ago, in searching for coal. It begins about 30 yards from the surface, and is 25 yards thick; below this, and separated from it by 10 or 12 yards of indurated clay, is another bed of salt, the extent of which is unknown; in many places of extreme purity, in others tinged with oxide of iron and clay. This pit is at Northwich; and at other places there are very abundant brine springs. A most remarkable circumstance in the Northwich mine is the arrangement of the salt, giving rise to an appearance something like a mosaic roof and pavement, where it has been horizontally cut. The salt is compact, but it is arranged in round masses, five or six feet in diameter, not truly spherical, but each compressed by those that surround it, so as to have the shape of an irregular polyhædron. The Wernerians regard the salt as having merely crystallized here from its aqueous solutions; the Huttonians consider the water to have been evaporated by heat. The large pit at Northwich presents a

very singular spectacle when duly illuminated; it is a circle of nearly two miles in circumference; the roof is supported by massive pillars of salt, and the effect is heightened by the variety of colours it presents.

952. *Coal* is the most important product of these middle strata. What is called a *coal field*, or *district*, or sometimes a *coal basin*, may be regarded as a concavity, varying greatly in extent, from a few to many miles, and containing numerous strata or seams of coal of very various thickness, alternating with sandstone and clays, and soft slate or *shale* containing impressions of vegetables, and sometimes the remains of fresh water shell-fish. The parallelism of these strata is generally well preserved. The whole arrangement is seldom any where quite horizontal, and never vertical, but almost always more or less inclined. Beneath each stratum of coal, there is often one of soft clay or *clunch*, which rarely contains the organic remains of the overlying shale; and although the alternating strata of coal be very numerous, it is seldom that more than three or four will afford profitable occupation to the miner. The upper seam is commonly broken and impure; and few beds, less than two or three feet in thickness, are followed down to any considerable depth. The depth of the mines will of course greatly vary, according to the inclination of the strata, the time they have been worked, and other circumstances. Our deepest mines are in the counties of Durham and Northumberland, and the thickest beds are found in Staffordshire. The most productive vary from six to nine feet.

953. There are several varieties of coal, but, as far as their economical applications are concerned, they may principally be reduced to two. The coals of Lancashire, Scotland, and most of those raised upon the West of England, burn quickly and brilliantly into a light ash: while the coal of Northumberland and Durham, becomes soft and puffy, spouts out bright jets of flame, requires poking to continue in combustion, and pro-

duces bulky cinders, which, if urged in a violent fire, or mixed with fresh coals, run into slags and clinkers.

954. Though coal is chiefly found in the geological position I have mentioned, constituting the *independent coal formation* of Werner, it is likewise found in other situations, amongst newer rocks, and sparingly in alluvial soils. But in this country, the main coal formations are marked by their position, their contiguity to limestone, and often to slate, by micaceous grits and sandstones, and, above all, by shale with vegetable impressions, decomposing into tenacious blue clay.

955. The greater number of geologists are now unanimous as to the vegetable origin of coal; and indeed its composition, the abundance of vegetable bodies with which it is often associated, and the gradual transitions of wood into coal, discoverable in many parts of the world, may be considered as satisfactory evidence upon this subject: but how it has been formed, is another and more intricate question.

Dr. Hutton considered coal strata to have been produced by the operation of subterranean heat, in the manner already described, acting upon vegetable bodies and charcoal under exceeding pressure, which prevented the usual phenomena of combustion, and hindered the escape of the inflammable part. Sometimes, he observes, more or less bitumen has been driven off, for we find it in other strata.

By Mr. Williams, antediluvian timber and peat bog, are regarded as the source of our present coal; and a variety of curious circumstances, which the minute history of coal fields present, have been adduced as favourable to his conclusions.

956. The coal miner is often seriously interrupted in his proceedings by large fissures or breaks in the strata, and by veins of a hard black rock, which cut through the coal; sometimes merely dividing it, at others, throwing it out of its former position. It is in the neighbourhood of these *dykes* and

troubles, as they are called by the miners, that immense quantities of carburetted hydrogen gas are frequently evolved, though the coals themselves, and the cavities in the strata, also yield it; it constitutes the *fire-damp* of the mines; and when it has any where collected so as to constitute more than $\frac{1}{13}$ of the volume of atmosphere, it becomes explosive whenever a flame is presented to it, and the source of such dreadful destruction, that the mind recoils from the recital. Hitherto the miners, in these dangerous situations, availed themselves of the light obtained by the collision of flint and steel, which, however, was by no means free from danger, and has been completely superseded by Sir Humphry Davy's safety lamp, (page 159).

957. Another substance which very often attends coal formations, is *argillaceous iron-stone*, both in layers and nodules; and although a poor ore of iron, very seldom yielding more than 30 per cent. of metal, it becomes from its association with coal and limestone (substances required for its reduction), a most important natural product; it is the main source of the enormous quantities of iron manufactured in this country; and the history of the various difficulties which have been surmounted in completing the processes of its reduction, presents an unrivalled picture of skill, ingenuity, and perseverance, (page 230).

958. Leaving the districts of red sandstone and red marl, we observe a change in the general aspect of the country. There are no steep or abrupt precipices; the hills assume a more picturesque and luxuriant character, and the rugged features of primary country, are here softened down into gentle slopes and verdant plains.

The rocks which now occur are chiefly varieties of limestone and sandstone, particularly prolific in organic remains; among them we discern a number of species of which no living semblance is now in existence.

Corals, zoophytes, ammonites, belemnites, nautili, and a variety of other fossil remains, are found in the ARGILLACEOUS LIMESTONES, which succeed in position to the red sandstone, and which are often called *white* and *blue lias limestone*. The coast of Dorsetshire, between Weymouth and Lyme, presents a very interesting section of these strata; and their continuation through the country is well entitled to the notice of the geologist. They decompose into marl, and furnish an ingredient in the best water-cements. Sometimes they are of a peculiar yellow colour, and contain magnesia, when the fossil remains are less frequent.

959. These strata are succeeded by a species of stone, often called *Bath-stone*, from its abundant occurrence in the vicinity of that city, and *freestone*, or OOLITE, of which *Portland-stone* is a notorious variety. There then commonly occur various SANDSTONES, with veins of chert and oxide of iron; and, lastly, we arrive at CHALK, and superincumbent ALLUVIAL MATTER.

960. The examination of the fossil remains in these strata, leads to conclusions of much interest and importance. In the strata upon the coast of Dorsetshire, below the chalk, we find the remains of an animal, which has generally been regarded as a crocodile, or alligator*, but there are no fossil relics of mammiferous land animals, either here, or in the chalk itself; whence it has been concluded, that oviparous quadrupeds are of more ancient date than those of the viviparous class, and that dry land and fresh water existed before the formation of our present chalk. In the vicinity of Paris the chalk is covered by a coarse shell limestone, in which the bones of mammiferous sea animals have been found by Cuvier; but

* Sir Everard Home, in examining the fossil bones of this animal, has thrown considerable doubt upon the above conclusion; and, from a peculiarity in the structure of its spine, resembling that of the *proteus*, has called it *proteorrhachius*.

no bones of mammiferous land quadrupeds occur, till we reach the more recent and superincumbent strata.

961. The *chalk* presents the geologist with much matter of speculation. In England it is a very abundant formation; and the round-backed hills covered with verdure, which mark the eastern counties, are very characteristic of it. Salisbury Plain and Marlborough Downs form a centre, whence the chalk emanates, in a north-eastern direction, through the counties of Buckingham, Bedford, and Cambridge, and terminate on the Norfolk coast. In an easterly direction it traverses Hampshire, Surry, and Kent, and terminates at Dover; and another arm passing through Sussex, east south-east, forms the South Downs, and the lofty promontory of Beachy Head. Parallel ridges of sandstone generally accompany the chalk, and in Wiltshire, Berkshire, and some other counties, large blocks of granular siliceous sandstone lie scattered upon its surface: of these the celebrated druidical relics, called *Stonehenge*, appear to have been constructed, with the exception of one of the blocks, which is of greenstone. The lower beds of chalk are generally argillaceous, or marly, and contain no flints, and few organic remains. The upper beds abound in fossil relics, of the kinds before alluded to, and in flints sometimes regularly arranged in distinct nodules, at other times remarkably intersecting the chalk in thin seams. The formation of flint has been much speculated upon, but no plausible theory has yet been adduced in regard to it.

962. In the south of England the chalk is covered with gravel and clay, the history of which is extremely curious, on account of the fossils which they contain, and the evidence they afford of repeated inundations of salt and fresh water upon the same spot. There are two celebrated concavities filled with such materials, which have been called the London and the Isle of Wight Basins. The former is bounded by the chalk-hills proceeding from Wiltshire to the south of the

Kentish coast, in one direction, and to the northern point of the Norfolk coast in another; and it is open to the ocean upon the Essex, Suffolk, and Norfolk coasts, which shew sections of its contents.

The numerous wells which have been dug in the neighbourhood of London, and the canals, tunnels, and other excavations and public works which have been carried on, have lately made us acquainted with many curious facts respecting the contents of this basin.

It deserves remark, that all the bones of viviparous land quadrupeds have either been found in the uppermost fresh water deposits, or in those alluvial formations of the ocean, which appear to have been the result of violent transportations of materials, rather than of quiet depositions; so that it is probable these animals began to exist during that state of the world which preceded the last inundation of the sea.

The *palæotheria*, *anaplotheria*, and other unknown genera described by Cuvier, are found in the lowest parts of the upper fresh water formation, placed immediately under the upper marine formation. Some oviparous quadrupeds and fresh-water fish are found along with them, and they are covered by alluvial deposits, containing marine relics.

The unknown or extinct species belonging to known genera, such as the *mastodon*, *elephant*, *hippopotamus*, and *rhinoceros*, are never associated with the more ancient or extinct genera, but are discovered usually in the sea-water deposits; and the bones of species resembling those that now exist, are found upon the sides of rivers, or in the bottoms of ancient lakes and marshes, or in peat-bogs, or in caverns and fissures of rocks; and, in consequence of their superficial situation, they are generally much injured.

963. Of a very singular and important series of rocks, I have yet made no mention. They occur indiscriminately in primary and secondary countries, and are not less varied in

their characters and aspects, than in their situation. These are the *trap-rocks* of the Wernerians, and the WHINSTONES of Dr. Hutton. They include the rocks called GREENSTONE, BASALT, AMYGDALOID, and TOADSTONE, and are distinguished into primary, transition, and floetz traps, by the school of Freyburgh.

By the term *greenstone*, we mean a compound of hornblende and felspar, differing extremely in its appearance, being sometimes so fine-grained as to appear homogeneous; at other times presenting distinct, and often large, crystals of hornblende.

Basalt is always a homogeneous rock, and abounds in black oxide of iron. Greenstone is met with in many parts of England, immediately upon granite and primary rocks; and it assumes the character of its neighbours, breaking into large blocks and masses of very irregular appearance. In this state it is seen in Cornwall, at the Lizard-Point. Upon the north side of the Welsh mountains, a chain of greenstone follows the slate, which, in some places, is columnar, as upon Cader Idris, and it forms a singular concavity near the summit of that mountain, very like the crater of a volcano. In Derbyshire these rocks are among the transition series of Werner. They form strata, and fill cavities in the limestone. In coal-fields they constitute dykes or veins, and, among secondary strata, they are seen in sandstone at Edinburgh, and upon the coast of Antrim they are incumbent upon, and alternate with chalk. Cavities in basalt are often filled with calcareous spar, zeolite, and agate nodules.

964. The common observer, to whom a piece of basalt is presented, would presently announce it to be the produce of a volcano, and the analogy between it and lava is most striking. This alone would justify us in concluding, that whinstone is the produce of fire. But the Huttonian hypothesis, as applied to its origin, becomes much more satisfactory, when we contemplate the effects produced upon the strata into which it

has been thrown, or upon the substances in its vicinity. Thus the sandstone of Salisbury Craigs, near Edinburgh, is broken, indurated, and even apparently fused by its irruption. The soft white limestone of the county of Antrim, where in contact with the basaltic dyke, is hardened and rendered crystalline, like marble and calcareous spar; and the coal in the same county is coaked, as it were, where touched by the whinstone. At the same time, the dykes themselves bear evident marks of igneous fusion. They are more regularly crystallized in the centre than upon the surface, an effect which may be well referred to the different rates of cooling, in the melted mass, and which may even be imitated artificially with the slag of an iron furnace.

Perhaps the most remarkable phenomenon concerning basalt is its occasional columnar structure, an appearance which lava sometimes assumes. Upon this subject, Sir James Hall's experiments are of extreme interest; and, when conjoined with those of Mr. Watt, produce a further, and, indeed, irresistible, evidence in favour of the igneous origin of basalt.

965. In accounting for the humid origin of basalt, the Neptunists refer to the columnar cracking of clay, mud, starch, *&c.*, during drying; and in this they fancy an analogy to basaltic columns; but, in these cases, there are always chasms and vacuities produced by the shrinking of the mass; whereas the columns of basalt are so closely connected, that the thin blade of a knife can scarcely be thrust between them. Upon the whole, the Huttonian theory may be considered as no where more free from objections, than where it applies to basalt; while the hardening, contortions, and breaking of the strata by whin dykes, and the numerous analogies of basalt and lava, are to the Neptunians paradoxes which admit of no solution.

966. Of columnar basalt, the British dominions present the noblest specimens in the known world. Upon the coast of Antrim, in Ireland, massive and columnar basalt is seen in all

its varieties, the former abounding in deep and lofty caverns, the latter presenting various façades to the ocean. The Giant's Causeway consists of three piers of columns, which extend some hundred feet into the sea. It is surrounded by precipitous rocks, from 200 to 400 feet high, in which there are several striking assemblages of columns, some vertical, some bent, or inclined, and some horizontal, and, as it were, driven into the rock. Bengore, which bounds the Causeway on the east, consists of alternate ranges of tabular and massive, with columnar basalt. But amongst the various and grand objects on this coast, Pleskin is perhaps the most striking; it presents several colonnades of great height and regularity, separated from each other by tabular basalt; and at Fairhead there is a range of columns of from ten to twenty feet in diameter, and between 200 and 300 feet high, supported upon a steep declivity, and forming a terrace which towers nearly 600 feet above the waves beneath. He who would really see the sublime, should visit this stupendous promontory.

Another basaltic district, which I am inclined to regard as exceeding the former in magnificent peculiarities, is that which presents itself in sailing down Loch Nagaul in Mull, towards the Isle of Tiree. The coast of Múll, upon the right and left, exhibits the step-like appearance of basaltic rocks in great perfection, and has fine caverns and columns; the islands of Ulva and Gometra rise with the abrupt and irregular precipices common to this formation. The Treshamish Isles exhibit columnar and massive basalt, and in the midst of this curious panorama, Staffa presents itself. The columns, which are from sixty to ninety feet high, are approached by a fine causeway, rising gradually from the deep, and they appear to support an immense weight of tabular basalt. The pillars are perpendicular, inclined, and in places extremely curved; and in the Cave of Fingal the ranges of columns extend, in long perspective, into the interior of the rock, presenting a scene of such unrivalled grandeur, as hitherto to have foiled all attempts of the poet to describe, or of the painter to represent.

SECTION IV. *Of Metallic Veins. Of the General Causes of the Decomposition of Rocks. Of Volcanoes: and of the Analysis of Soils.*

967. BESIDES the veins of lapideous substances, the fissures filled with debris and rubbish, the dykes, the beds of salt, and the fields of coal, there are diffused through the strata a variety of other treasures, among which the metals are of the utmost interest and importance. By the term *Mineral Vein,* we mean a separation in the continuity of a rock of determinate width, but extending indefinitely in length and depth, filled with metallic ores, and crystalline substances, differing from the rock itself.

Nearly all rocks are occasionally thus traversed, but the middle series are those in which metals are most abundant. In Cornwall, for instance, tin occurs both in the granite and slate; but it is most abundant in the latter; and the vein occasionally runs between the two rocks, so that one wall consists of granite, and the other of slate. The metal is often separated from the rock by thin layers of clay, or of stony materials, called *Deads,* which also intermix with the ore, and form its *gangue*, or *matrix*.

968. The richest metallic veins run, without exception, east and west. Those which run north and south being usually filled with stony materials. The latter veins appear of posterior date to the former, for they often intersect them, throwing them out of their regular course; generally a few inches only east and west, but many fathoms north and south. These *cross courses* often interfere with the treasures of the metallic vein, though, when solid, they are sometimes of great service in keeping out water.

969. The extent to which veins may be pursued, is extremely various, and depends much upon accidental circumstances. Sometimes a cross course cuts the vein, and puts an end to the miner's hopes, he being unable to discover its continuation after such interruption; sometimes the depth of the vein becomes so great, that it cannot be prudently pursued; sometimes a rich lode of metal suddenly disappears, or vanishes into thin strings, which, though often quite lost, occasionally reunite into a good vein, or bunch of metal. So that, taking all these circumstances into account, between two or three miles is usually the utmost extent to which a vein has been pursued *.

970. Veins vary in width, from an inch or two, to thirty or forty feet, but the middle-sized veins are usually most prolific, the larger becoming relatively poor. The influx of water was formerly an insuperable impediment to the pursuit of a vein, and remains now a serious and expensive obstacle to mining. Formerly many veins in Cornwall were only worked for tin, which, at greater depths, have lately yielded abundance of copper; but in Cornwall, copper is never found without water, and all the mines of that metal require drainage by engines, or other means.

971. Concerning the original formation of metallic veins, there has been considerable collision of sentiment among geologists; but two circumstances seem sufficiently obvious; one, that they are of later date than the containing strata, that they are not contemporaneous; and the other, that their contents have been in a fluid state. The former position is indicated by their intersecting different strata; the latter, by the crystalline forms of the substances they contain. The Neptunists tell us that veins have been filled by metallic and lapideous solutions flowing in from above, but they do not inform us

* See a valuable paper on the Veins of Cornwall, by Mr. W. Phillips. *Geol. Trans.* Vol. II., and also annexed to his *"Selection of Facts."*

of the nature of the solvent which held the different bodies they present; nor can we guess why its contents are deposited exclusively in the vein, and not found upon the adjacent surface.

972. The Plutonists consider veins as filled from below, by the injection of matters in igneous fusion; and in the shifting, breaking, and dislodgement of the strata, they read the force with which these operations have been performed. The validity of hypotheses is only to be estimated by their accordance with facts; and, although there be many inexplicable phenomena attending metallic veins, yet the nature of their contents is such as to favour the igneous hypothesis, and to lead to the belief that fire, not water, has been the grand solvent of which nature has here availed herself. That the metals have passed from the fluid to the solid state, seems sufficiently obvious, from their crystalline form; and it is much more probable that they should have been liquefied by heat than by any other solvent.

Sulphur is very commonly found united to metallic bodies, and the greater number of metallic ores contain that element. Such compounds are easily produced by the artificial agency of fire, but with great difficulty by any other process.

973. A very curious fact in the history of veins is, that they are of different dates, for one vein often intersects another, and we are thus enabled to judge of their relative ages. In the county of Cornwall, one of the richest mining districts of the world, we observe some remarkable circumstances of this kind. Where a copper and a tin vein, for instance, meet, the former alway cuts through the latter, and generally throws it out of its old course, greatly to the distress of the miner, who sometimes cannot find its continuation, or at least is put to much difficulty and expense to do so. It appears, therefore, that tin veins are invariably older than those of copper. Sometimes, as in Derbyshire, the metallic ores lie in large longitudinal cavities, called *pipe veins*.

974. In searching for veins of the useful metals, there are certain indications of which the experienced miner sometimes profitably avails himself. Thus, a green earthy matter is a good symptom in a tin mine; a brown ochrey earth, and compact iron pyrites, are regarded as favourable omens in a copper mine.

Detached pebbles of ore, or fragments of vein-stones, have sometimes led to the riches of the vein, and tin has especially been thus discovered in Cornwall.

In older mineralogical works we read much upon these and other subjects. Flames of light have been described as playing over a district which afterwards has been found to contain subterranean riches, and this may have arisen from the good electrical conducting powers of the vein. The waters issuing from the soil sometimes hold metallic salts in solution, and repositories of the metals have been discovered by circumstances of this kind. Copper veins tinge waters blue, and a piece of grease put into them becomes rapidly stained of that colour.

There is no popular notion more common than that metals grow in the veins: an idea which may very probably have originated from observing the depositions of one metal by the introduction of another into its solution, as when silver is precipitated by the introduction of a plate of copper into its solution, or copper by iron.

975. Districts rich in the metals are generally barren, and seem peculiarly dreary and desolate to the traveller. This partly arises from the nature of the strata, partly from the heaps of rubbish and hills of stone thrown upon the surface, and partly from the operations carrying on in the vicinity, being inimical to vegetation. The high road through Cornwall, especially near Redruth, is an excellent specimen of this kind of country; while, at the same time, the romantic beauty and luxuriant vegetation of many parts of that county, and of Devonshire, prove that exterior cultivation is not always incompatible with

internal riches. The neighbourhood of the Parys Mountain, in Anglesea, is singularly marked by sterility and gloominess. The soil, naturally unproductive, is rendered more so by the poisonous waters that traverse it, and the sulphurous vapours that float around. There are not only no shrubs and trees, but the barrenness is unrelieved even by a single blade of grass, or the rusty green of a hardy lichen.

976. I have hinted above at the relative permanence and durability of the different kinds of rocks, and it has been found that the unstratified, or primary substances, are least acted upon by the elements; that these have retained their great and pristine elevation, while the secondary strata have been washed from their sides and summits, whose rugged and abrupt outline records this devastation. Every one who views the mountain side strewed with immense blocks of materials transported from distant summits, and discovers the dells and valleys filled with fragments and pebbles of the neighbouring rocks, will allow that a constant system of disintegration and decay is there carrying on; but the geologist, not content with the mere observance of the fact, will endeavour to trace it to its source, and follow it up to its ultimate effect.

977. The change of temperature to which the earth's surface is constantly submitted, is one great cause of the slow destruction of its most solid and durable constituents; and when to this is added the gigantic powers with which water, in becoming ice, opposes the obstacles to its expansion, we have an agent nearly resistless. The fissures that occur between the blocks and masses of the granites, porphyries, and similar rocks, become filled with water, which, in the act of freezing, expands so as slowly to remove them from each other; their edges and angles become thus open to the attacks of the weather, and by a slow dislodgement they fall into the valleys or rivers; or are at once cast into the ocean. Where the materials are of a more yielding and frangible texture, this destruction is propor-

tionally rapid, and the influence of the weather upon slate mountains, is often such as to produce hills of fragments at their feet: the softer substance of the secondary and horizontal strata is, of course, yet more easily and quickly degraded.

978. Masses of rock, thus loosened from their original beds, become new and powerful instruments of destruction; they roll down the precipices, wearing themselves and the surface that bears them, and, if near the sea, or carried thither by rivers, they become "a part of the mighty artillery with which the ocean assails the bulwarks of the land;" they are impelled against the coasts, from which they break off other fragments; and the whole thus ground against each other, whatever be their hardness, are reduced to gravel, the smooth surface and rounded masses of which are convincing proofs of the manner in which it was formed.

979. It is by operations of this kind, not performed in a day, but in ages, that nature has indented and carved out the earth's surface; that the rivers seem to have cut their own beds; that the land is undergoing gradual demolition; and that the materials which we have elsewhere considered as consolidated at, and elevated from the bottom of the ocean, are gradually restoring to the parent deep. These are mechanical agents, but they are not unassisted by the chemical energies of matter; and, in this respect, the solvent powers of water may be contemplated as effecting most important changes, (Kidd's *Essay*, p. 181.)

980. By impregnation with carbonic acid, water acquires a great solvent power over carbonate of lime (224.) and in trickling through, such strata becomes saturated with it, and, on exposure, again deposits it, in consequence of the escape of the gaseous solvent: it is thus that the stalactitical concretions of limestone caverns are produced, as in the Fluor Mine, and Peak Cavern of Derbyshire; and, in many cases, the once

empty chasms are entirely choaked up by this sparry deposit. The power of incrustation, thus possessed by some waters, is such as rapidly to cover extraneous bodies thrown into them with a calcareous coating, of which the petrifying spring of Matlock furnishes a good example.

981. The sands upon flat coasts are sometimes agglutinated by this action of water, so as to produce a new rock; or, as the Wernerians would call it, a new formation. This has probably been the case with the stone in which the *galibi*, or human skeletons, of Guadaloupe, are found (*Phil. Trans.* 1816,) and the process is constantly going on upon the coast of Cornwall, in the parish of St. Columb, where the water, having percolated the neighbouring rocks, becomes slightly carbonated and ferruginous, and thus serving as a cement to the sand, produces a hard stone, which is used as a building material, and for making cattle-troughs. In the walls of some of the oldest churches in Cornwall, as in St. Burian, Gwithian, Crantock, Cubert, *&c.*, are large masses of this *sandstone*, which has thus long resisted decomposition. When water is hot, and slightly alcaline, it dissolves siliceous earth, as shewn by the deposits of the Geysers, or boiling fountains of Iceland.

982. Some rocks suffer, in consequence of the action of air and water upon the black oxide of iron which they contain, and which, in passing into the state of brown oxide, occasions a crumbling of the mass. Much of the soil upon the coast of the county of Antrim, in Ireland, is thus derived from the decomposition of basalt, which, however, in other cases, singularly resists change, as in Staffa, where the columns, though exposed to the violence of the ocean, retain a sharp angularity and black colour. These differences depend upon the degree of induration of the basalt.

983. Rocks containing alcali, seem often to decompose rapidly, in consequence of the loss of that ingredient. The quick disintegration of much of the Cornish granite is well

known, and it furnishes a valuable material for the manufacture of pottery. The felspar of this granite contains a considerable portion of potassa, but the white earth into which it is resolved, yields no traces of it.

984. The chemical agencies of different bodies presented to each other in the strata, are also often connected with the production of entire new substances. Thus the decomposition of pyrites in chalk produces sulphate of lime; in aluminous slate it gives rise to the production of alum; and in the cliffs at Newhaven, on the Sussex coast, a very curious series of changes is going on. A stratum of marl, containing decomposing pyrites, lies upon the chalk, which gives rise to the formation of sulphate of alumine; this is decomposed by the chalk, and aluminous earth, selenite, and oxide of iron, are the results

985. Thus, by mechanical operations and chemical changes, sometimes separate and sometimes united, the rugged peaks and abrupt precipices are gradually wearing and softening down, and giving rise to rounded summits, gentle slopes, and habitable surfaces. The detritus so produced is carried by rills, and brooks, and rivers, towards the low lands, where it is deposited; or it is transported towards the sea, where it forms bars and islands at the mouths of rivers; or it is employed in levelling uneven surfaces, and filling cavities and basins, as where the rivers are broken in their course by the intervention of lakes, all of which are filling up, as may be learned even by hasty inspection. This is no where more conspicuous than in the waters which adorn the scenery of Westmorland and Cumberland, especially Derwent Water, at the Borrowdale extremity of which the meadow is annually increasing, and adding to the circumjacent field; and the examination of the bank between Derwent and Bassenthwaite, shews that the two lakes were once united, and that the present separation is alluvial matter, or a bar thrown up by the concurrent streams of Newland's Water, on the west, and the Greta on the east. The filling up of lakes, until they ultimately become merely

a part of the river that now traverses, but once fed them, is too obvious to require further illustration; it is the reason why the stream, which has its exit from a lake, is generally clear, while the torrents which supply it are loaded with matters in minute mechanical division.

986. While the destructive agencies of the elements are thus called into action, for the production and increase of habitable surface, we observe other causes tending to the same effect, and none more wonderful than the incessant labours of those insect tribes which collect and accumulate solid matter from the ocean, and form the rocks of coral common in the seas of warm climates, (Kidd's *Essay*, p. 219.)

987. But the most striking sources of decay and reproduction, are those dependent upon volcanic phenomena.

The form of volcanic hills is usually conical, of which the outline of the Bay of Naples presents a fine panorama. One of its hills serves to give some idea of the vast powers of the subterranean agents; it is about 1,000 feet high, and three miles in circumference, and was raised, in 1538, in a single night*.

988. In June 1811, a volcano was discovered in the sea off St. Michael, and it formed an island about a mile in circumference. (*Phil. Trans.* 1812.)

989. To describe the phenomena of volcanic eruptions with all attending circumstances, would be foreign to our present purpose; but as the same causes may have been active in producing other geological phenomena, it becomes right to mention the subject.

Until lately, the cause of volcanic fire was referred to sulphur, coal, and other common inflammable matters, which were supposed to be burning in immense masses within the earth, and thus to give rise to the tremendous explosions and ejections of lava and stones attending the eruption; but the products ill accord with such an explanation. Earthy, alcaline,

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* See Sir Wm. Hamilton's Paper in the *Phil. Trans.* for 1771.

metallic, and stony bodies united form the lava; and steam and hydrogen gas accompany its throwing forth; and as the products of combustion always have a reference to the combustible, such matters were not likely to be produced from sulphur or coal.

The discoveries of Sir H. Davy have enlightened this, as well as every other branch of chemistry, and from them we may deduce a very adequate solution of the problem of volcanoes, for we have only to suppose the access of water to large masses of those peculiar metals which constitute the alcaline and earthy bases, and we are possessed of all that is wanted to produce the tremendous effects of earthquakes and volcanoes; for what power can resist the expansive force of steam, and the sudden evolution of gaseous fluids, accompanied by torrents of the earths in igneous fusion, which such a concurrence of circumstances would give rise to, and which are the actual concomitants of volcanic eruptions?

From the same source the Huttonian theory derives great additional plausibility, for its feeble parts were those which related to the required expansive forces, to the intense continuance of heat, to its occasional increase and decrease, and to the existence of a species of fuel adequate to the various effects that have been described. The metals of the earths are equal to the production of all these complicated and apparently incompatible effects, and these and water are the sole agents required.

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990. The principal circumstances that tend to the formation of soils, and to modify their composition, have been adverted to in this Chapter; and, from the properties of their component parts, elsewhere detailed, the means of analyzing them are to be deduced; but as this is a subject upon which the agriculturist may sometimes find it expedient to employ himself, I insert the following instructions upon it, from Sir H. Davy's *Elements of Agricultural Chemistry*.

"In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and, in this case, one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences; and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

"Soils when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground-glass stoppers.

"The quantity of soil most convenient for a perfect analysis, is from 200 to 400 grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

"The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil, and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus, if the bottle contains 400 grains of water, and gains 200 grains when half filled with water and half with soil, the specific gravity of the soil, will be 2, that is, it will be twice as heavy as water; and if it gained 165 grains, its specific gravity would be 1,825, water being 1,000.

"It is of importance that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains; these substances being always most abundant in the lighter soils.

"The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus, siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it: ferruginous soils are of a red or yellow colour; and calcareous soils are soft.

"1. Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without, in other respects, affecting its composition; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a basin of porcelain, to a temperature equal to 300 Fahrenheit; and if a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish; as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and, in consequence, the experiment be wholly unsatisfactory.

"The loss of weight in the process should be carefully noted, and when in 400 grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain much vegetable or animal matter, or a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and siliceous earth probably forms the greatest part of it.

"2. None of the loose stones, gravel, or large vegetable fibres should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and, in consequence, influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the vegetable fibres, or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common aluminous class of stones, they will be soft, easily cut with a knife, and incapable of effervescing with acids.

"3. The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand, of different degrees of fineness: and it is a necessary operation, the next in the process of analysis, to detach them from the parts in a state of more minute division, such as clay, loam, marl, vegetable and animal matter, and the matter soluble in water. This may be effected in a way sufficiently accurate, by boiling the soil in three or four times its weight of water; and when the texture of the soil is broken down, and the water cool, by agitating the parts together, and then suffering them to rest. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the highly-divided earthy, animal, or vegetable matter will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel, after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and, after the water has passed through, collected, dried, and weighed. The sand must likewise be weighed, and the respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline and soluble animal or vegetable matters, if any exist in the soil.

"4. By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely-divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part; it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it, and the weight of the whole, indicates the proportion of calcareous sand.

"5. The finely-divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy, is the most difficult part of the subject.

"The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of muriatic acid. This substance should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy matter; but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

"If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron; but very seldom any alumina.

"The fluid should be passed through a filter; the solid matter collected, washed with rain-water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of prussiate of potassa and iron must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in till no farther effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red; the result is oxide of iron, which may be mixed with a little oxide of manganesum.

"Into the fluid freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

"The precipitate that falls down is carbonate of lime, it must be collected on the filter, and dried at a heat below that of redness.

"The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

"If any minute proportion of alumina should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling it for a few minutes with soap lye, sufficient to cover the solid matter; this substance dissolves alumina, without acting upon carbonate of lime.

"Should the finely-divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

" Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.*, nearly 43 per cent., so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

" When the process by diminution of weight is employed, two parts of the acid and one part of the matter of the soil must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases; the difference between their weight before and after the experiment, denotes the quantity of carbonic acid lost; for every four grains and a quarter of which, 10 grains of carbonate of lime must be estimated.

" 6. After the calcareous parts of the soil have been acted upon by muriatic acid, the next process is to ascertain the quantity of finely-divided insoluble animal and vegetable matter that it contains.

" This may be done with sufficient precision, by strongly igniting it in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic rod, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

" It is not possible, without very refined and difficult experiments, to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some substance either animal or analogous to animal matter; and a copious blue flame at the time of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when it is necessary that the experiment should be very quickly performed, the destruction of the decomposable substances may be assisted by the agency of nitrate of ammonia, which at the time of ignition may be thrown gradually upon the heated mass in the quantity of 20 grains for every hundred of residual soil. It accelerates the dissipation of the animal and vegetable matter, which it causes to be converted into elastic fluids; and it is itself at the same time decomposed and lost.

" 7. The substances remaining after the destruction of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumina and silica, with combined oxide of iron or of manganesum.

" To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or 120 grains, of acid.

" The substance remaining after the action of the acid, may be considered as siliceous: and it must be separated and its weight ascertained, after washing and drying in the usual manner.

" The alumina, and the oxide of iron and manganesum, if any exist, are all dissolved by the sulphuric acid; they may be separated by succinate of ammonia, added to excess, which throws down the oxide of iron; and by soap lye, which will dissolve the alumina, but not the oxide of manganesum: the weights of the oxides ascertained after they have been heated to redness will denote their quantities.

" Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid; this, however, is rarely the case; but the process for detecting them, and ascertaining their quantities, is the same in both instances.

"The method of analysis by sulphuric acid, is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potassa must be employed as the agent, and the residuum of the incineration (6) must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver, or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron and all the earths, except silica, will be dissolved in combination as muriates. The silica, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

"This process is the one usually employed by chemical philosophers for the analysis of stones.

"8. If any saline matter, or soluble vegetable or animal matter is suspected in the soil, it will be found in the water of lixivation used for separating the sand.

"This water must be evaporated to dryness in a proper dish, at a heat below its boiling point.

"If the solid matter obtained is of a brown colour and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be like that of burnt feathers, it contains animal or albuminous matter; if it be white, crystalline, and not destructible by heat, it may be considered as principally saline matter.

"9. Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance, 400 grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any notable quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

" Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

" It would not fall within the limits assigned to this Lecture, to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Other earths and metallic oxides are now and then found in them, but in quantities too minute to bear any relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

" 10. When the examination of a soil is completed, the products should be numerically arranged, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process just described, (9), a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

" In arranging the products, the form should be in the order of the experiments by which they were procured.

" Thus, I obtained from 400 grains of a good siliceous sandy soil, from a hop garden near Tunbridge, Kent,

		Grains.
Of water of absorption		19
Of loose stones and gravel principally siliceous		53
Of undecompounded vegetable fibres		14
Of fine siliceous sand		212
Of minutely divided matter separated by agitation and filtration, and consisting of		
Carbonate of lime	19	
Carbonate of magnesia	3	
Matter destructible by heat, principally vegetable	15	
Silica	21	
Alumina	13	
Oxide of iron	5	
Soluble matter, principally common salt and vegetable extract	3	
Gypsum	2	
	—	81
Amount of all the products		379
Loss		21

"The loss in this analysis is not more than usually occurs, and it depends upon the impossibility of collecting the whole quantities of the different precipitates; and upon the presence of more moisture than is accounted for in the water of absorption, and which is lost in the different processes.

"When the experimenter is become acquainted with the use of the different instruments, the properties of the reagents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid (7) may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air (8); and in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid (9).

"In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with: but in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but, perhaps, there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn the properties of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

"Plants being possessed of no locomotive powers, can grow only in places where they are supplied with food; and the soil is necessary to their existence, both as affording them nourishment, and enabling them to fix themselves in such a manner as to obey those mechanical laws by which their radicles are kept below the surface, and their leaves exposed to the free atmosphere. As the systems of roots, branches, and leaves, are very different in different vegetables, so they flourish most in different soils; the plants that have bulbous roots require a looser and a lighter soil than such as have fibrous roots; and the plants possessing only short fibrous radicles demand a firmer soil than such as have tap roots, or extensive lateral roots.

"A good turnip soil from Holkham, Norfolk, afforded me eight parts out of nine siliceous sand; and the finely-divided matter consisted

Of carbonate of lime	63
— silica	15
— alumina	11
— oxide of iron	3

Of vegetable and saline matter	5
— moisture	3

"I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely-divided matter. And 100 parts of the entire soil, submitted to analysis, produced

	Parts.
Silica	54
Alumina	28
Carbonate of lime	3
Oxide of iron	5
Decomposing vegetable matter	4
Moisture and loss	3

"An excellent wheat soil, from the neighbourhood of West Drayton, Middlesex, gave three parts in five of siliceous sand; and the finely-divided matter consisted of

Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

"Of these soils the last was by far the most, and the first the least, coherent in texture. In all cases the constituent parts of the soil which give tenacity and coherence are the finely-divided matters; and they possess the power of giving those qualities in the highest degree when they contain much alumina. A small quantity of finely-divided matter is sufficient to fit a soil for the production of turnips and barley; and I have seen a tolerable crop of turnips on a soil containing 11 parts out of 12 sand. A much greater proportion of sand, however, always produces absolute sterility. The soil of Bagshot heath, which is entirely devoid of vegetable covering, contains less than $\frac{1}{20}$ of finely-divided matter. 400 parts of it, which had been heated red, afforded me 380 parts of coarse siliceous sand, nine parts of fine siliceous sand, and 11 parts of impalpable matter, which was a mixture of ferruginous clay, with carbonate of lime. Vegetable or animal matters, when finely divided, not only give coherence, but likewise softness and penetrability; but neither they nor any other part of the soil must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matters.

"Pure alumina or silica, pure carbonate of lime, or carbonate of magnesia, are incapable of supporting healthy vegetation.

"No soil is fertile that contains as much as 19 parts out of 20 of any of the constituents that have been mentioned.

"It will be asked, are the pure earths in the soil merely active as mechanical or indirect chemical agents, or do they actually afford food to the plant? This is an important question; and not difficult of solution.

"The earths consist, as I have before stated, of metals united to oxygene; and these metals have not been decomposed; there is consequently no reason to suppose that the earths are convertible into the elements of organized compounds, into carbon, hydrogen, and azote.

"Plants have been made to grow in given quantities of earth. They consume very small portions only; and what is lost may be accounted for by the quantities found in their ashes; that is to say, it has not been converted into any new products.

"The carbonic acid united to lime or magnesia, if any stronger acid happens to be formed in the soil during the fermentation of vegetable matter which will disengage it from the earths, may be decomposed: but the earths themselves cannot be supposed convertible into other substances, by any process taking place in the soil.

"In all cases the ashes of plants contain some of the earths of the soil in which they grow; but these earths, as may be seen from the table of the ashes afforded by different plants given in the last Lecture*, never equal more than $\frac{1}{50}$ of the weight of the plant consumed.

"If they be considered as necessary to the vegetable, it is as giving hardness and firmness to its organization. Thus, it has been mentioned that wheat, oats, and many of the hollow grasses, have an epidermis principally of siliceous earth; the use of which seems to be to strengthen them, and defend them from the attacks of insects and parasitical plants.

"Many soils are popularly distinguished as *cold;* and the distinction, though at first view it may appear to be founded on prejudice, is really just.

"Some soils are much more heated by the rays of the sun, all other circumstances being equal, than others; and soils brought to the same degree of heat cool in different times, *i. e.*, some cool much faster than others.

"This property has been very little attended to in a philosophical point of view; yet it is of the highest importance in agriculture. In general, soils that consist principally of a stiff white clay are difficultly heated; and being usually very moist they retain their heat only for a short time. *Chalks* are similar in one respect, that they are difficultly heated; but being drier they retain their heat longer, less being consumed in causing the evaporation of their moisture.

"A black soil, containing much soft vegetable matter, is most heated by the sun and air; and the coloured soils, and the soils containing much carbonaceous matter, or ferruginous matter, exposed under equal circumstances to sun, acquire a much higher temperature than pale-coloured soils.

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* See Sir Humphrey Davy's *Elements of Agricultural Chemistry*, 4to. p. 102.

"When soils are perfectly dry, those that most readily become heated by the solar rays likewise cool most rapidly; but I have ascertained by experiment, that the darkest-coloured dry soil (that which contains abundance of animal or vegetable matter, substances which most facilitate the diminution of temperature,) when heated to the same degree, provided it be within the common limits of the effect of solar heat, will cool more slowly than a wet pale soil, entirely composed of earthy matter.

"I found that a rich black mould, which contained nearly $\frac{1}{4}$ of vegetable matter, had its temperature increased in an hour from 65° to 88° by exposure to sunshine; whilst a chalk soil was heated only to 69° under the same circumstances. But the mould, removed into the shade, where the temperature was 62°, lost, in half an hour, 15°; whereas the chalk, under the same circumstances, had lost only 4°.

"Brown fertile soil, and a cold barren clay were each artificially heated to 88°, having been previously dried: they were then exposed in a temperature of 57°; in half an hour the dark soil was found to have lost 9° of heat; the clay had lost only 6°. An equal portion of the clay containing moisture, after being heated to 88°, was exposed in a temperature of 55°; in less than a quarter of an hour it was found to have gained the temperature of the room. The soils in all these experiments were placed in small tin plate trays, two inches square and half an inch in depth; and the temperature ascertained by a delicate thermometer.

"Nothing can be more evident, than that the genial heat of the soil, particularly in spring, must be of the highest importance to the rising plant. And when the leaves are fully developed, the ground is shaded; and any injurious influence, which in the summer might be expected from too great a heat, entirely prevented: so that the temperature of the surface, when bare and exposed to the rays of the sun, affords at least one indication of the degrees of its fertility; and the thermometer may be sometimes a useful instrument to the purchaser or improver of lands.

"The moisture in the soil influences its temperature; and the manner in which it is distributed through, or combined with, the earthy materials, is of great importance in relation to the nutriment of the plant. If water is too strongly attracted by the earths, it will not be absorbed by the roots of the plants: if it is in too great quantity, or too loosely united to them, it tends to injure or destroy the fibrous parts of the roots.

"There are two states in which water seems to exist in the earths, and in animal and vegetable substances: in the first state it is united by chemical, in the other by cohesive, attraction.

"If pure solution of ammonia or potassa be poured into a solution of alum, alumina falls down combined with water; and the powder dried by exposure to air will afford more than half its weight of water by distillation; in this instance the water is united by chemical attraction. The moisture which wood, or muscular fibre, or gum, that have been heated to 212°, afford by distillation at a red heat, is likewise water, the elements of which were united in the substance by chemical combination.

"When pipe-clay dried at the temperature of the atmosphere is brought in contact with water, the fluid is rapidly absorbed; this is owing to cohesive attraction. Soils in general, vegetable, and animal substances, that have been dried at a heat below that of boiling water, increase in weight by exposure to air, owing to their absorbing water existing in the state of vapour in the air, in consequence of cohesive attraction.

"The water *chemically combined* amongst the elements of soils, unless in the case of the decomposition of animal or vegetable substances, cannot be absorbed by the roots of plants; but that *adhering* to the parts of the soil is in constant use in vegetation. Indeed there are few mixtures of the earths found in soils that contain any chemically combined water; water is expelled from the earths by most substances that combine with them. Thus, if a combination of lime and water be exposed to carbonic acid, the carbonic acid takes the place of water; and compounds of alumina and silica, or other compounds of the earths, do not chemically unite with water: and soils, as it has been stated, are formed either by earthy carbonates, or compounds of the pure earths and metallic oxides.

"When saline substances exist in soils, they may be united to water both chemically and mechanically; but they are always in too small a quantity to influence materially the relations of the soil to water.

"The power of the soil to absorb water by cohesive attraction, depends in great measure upon the state of division of its parts; the more divided they are, the greater is their absorbent power. The different constituent parts of soils likewise appear to act, even by cohesive attraction, with different degrees of energy. Thus vegetable substances seem to be more absorbent than animal substances; animal substances more so than compounds of alumina and silica; and compounds of alumina and silica more absorbent than carbonates of lime and magnesia: these differences may, however, possibly depend upon the differences in their state of division, and upon the surface exposed.

"The power of soils to absorb water from air, is much connected with fertility. When this power is great, the plant is supplied with moisture in dry seasons; and the effect of evaporation in the day is counteracted by the absorption of aqueous vapour from the atmosphere, by the interior parts of the soil during the day, and by both the exterior and interior during night.

"The stiff clays approaching to pipe-clays in their nature, which take up the greatest quantity of water when it is poured upon them in a fluid form, are not the soils which absorb most moisture from the atmosphere in dry weather. They cake, and present only a small surface to the air, and the vegetation on them is generally burnt up almost as readily as on sands.

"The soils that are most efficient in supplying the plant with water by atmospheric absorption, are those in which there is a due mixture of sand, finely-divided clay, and carbonate of lime, with some animal or vegetable matter; and which are so loose and light as to be freely permeable to the atmosphere. With respect to this quality, carbonate of lime and animal and vegetable matter are of great use in soils: they give absorbent power to the soil without giving it likewise tenacity: sand, which also destroys tenacity, on the contrary, gives little absorbent power.

"I have compared the absorbent powers of many soils with respect to atmospheric moisture, and I have always found it greatest in the most fertile soils; so that it affords one method of judging of the productiveness of land.

"1,000 parts of a celebrated soil from Ormiston, in East Lothian, which contained more than half its weight of finely-divided matter, of which 11 parts were carbonate of lime, and nine parts vegetable matter, when dried at 212°, gained in an hour by exposure to air saturated with moisture, at temperature 62°, 18 grains.

"1,000 parts of a very fertile soil from the banks of the river Parret, in Somersetshire, under the same circumstances, gained 16 grains.

"1,000 parts of a soil from Mersea, in Essex, worth 45 shillings an acre, gained 13 grains.

" 1,000 grains of a fine sand from Essex, worth 28 shillings an acre, gained 11 grains.

" 1,000 of a coarse sand worth 15 shillings an acre, gained only eight grains.

" 1,000 of the soil of Bagshot-heath gained only three grains.

" Water, and the decomposing animal and vegetable matter existing in the soil, constitute the true nourishment of plants; and as the earthy parts of the soil are useful in retaining water, so as to supply it in the proper proportions to the roots of the vegetables, so they are likewise efficacious in producing the proper distribution of the animal or vegetable matter; when equally mixed with it they prevent it from decomposing too rapidly; and by their means the soluble parts are supplied in proper proportions.

" Besides this agency, which may be considered as mechanical, there is another agency between soils and organizable matters, which may be regarded as chemical in its nature. The earths, and even the earthy carbonates, have a certain degree of chemical attraction for many of the principles of vegetable and animal substances. This is easily exemplified in the instance of alumina and oil; if an acid solution of alumina be mixed with a solution of soap, which consists of oily matter and potassa, the oil and the alumina will unite and form a white powder, which will sink to the bottom of the fluid.

" The extract from decomposing vegetable matter when boiled with pipe-clay or chalk, forms a combination by which the vegetable matter is rendered more difficult of decomposition and of solution. Pure silica and siliceous sands have little action of this kind; and the soils which contain the most alumina and carbonate of lime, are these which act with the greatest chemical energy in preserving manures. Such soils merit the appellation which is commonly given to them of rich soils; for the vegetable nourishment is long preserved in them, unless taken up by the organs of plants. Siliceous sands, on the contrary, deserve the term hungry, which is commonly applied to them; for the vegetable and animal matters they contain not being attracted by the earthy constituent parts of the soil, are more liable to be decomposed by the action of the atmosphere, or carried off from them by water.

"In most of the black and brown rich vegetable moulds, the earths seem to be in combination with a peculiar extractive matter, afforded during the decomposition of vegetables: this is slowly taken up, or attracted from the earths by water, and appears to constitute a prime cause of the fertility of the soil.

"The standard of fertility of soils for different plants must vary with the climate; and must be particularly influenced by the quantity of rain.

"The power of soils to absorb moisture ought to be much greater in warm or dry countries, than in cold and moist ones; and the quantity of clay, or vegetable or animal matter they contain greater. Soils also on declivities ought to be more absorbent than in plains or in the bottom of valleys. Their productiveness likewise is influenced by the nature of the subsoil or the stratum on which they rest.

"When soils are immediately situated upon a bed of rock or stone, they are much sooner rendered dry by evaporation, than where the subsoil is of clay or marl; and a prime cause of the great fertility of the land in the moist climate of Ireland, is the proximity of the rocky strata to the soil.

"A clayey subsoil will sometimes be of material advantage to a sandy soil; and in this case it will retain moisture in such a manner as to be capable of supplying that lost by the earth above, in consequence of evaporation, or the consumption of it by plants.

" A sandy or gravelly subsoil, often corrects the imperfections of too great a degree of absorbent power in the true soil.

" In calcareous countries, where the surface is a species of marl, the soil is often found only a few inches above the limestone; and its fertility is not impaired by the proximity of the rock; though in a less absorbent soil, this situation would occasion barrenness; and the sandstone and limestone hills in Derbyshire and North Wales, may be easily distinguished at a distance in summer by the different tints of the vegetation. The grass on the sandstone hills usually appears brown and burnt up; that on the limestone hills, flourishing and green.

" In devoting the different parts of an estate to the necessary crops, it is perfectly evident from what has been said, that no general principle can be laid down, except when all the circumstances of the nature, composition, and situation of the soil and subsoil are known.

" The methods of cultivation likewise must be different for different soils. The same practice which will be excellent in one case may be destructive in another.

" Deep ploughing may be a very profitable practice in a rich thick soil; and in a fertile shallow soil, situated upon cold clay or sandy subsoil, it may be extremely prejudicial.

" In a moist climate where the quantity of rain that falls annually equals from 40 to 60 inches, as in Lancashire, Cornwall, and some parts of Ireland, a siliceous sandy soil is much more productive than in dry districts; and in such situations wheat and beans will require a less coherent and absorbent soil than in drier situations; and plants, having bulbous roots, will flourish in a soil containing as much as 14 parts out of 15 of sand.

" Even the exhausting powers of crops will be influenced by like circumstances. In cases where plants cannot absorb sufficient moisture, they must take up more manure. And in Ireland, Cornwall, and the western Highlands of Scotland, corn will exhaust less than in dry inland situations. Oats, particularly in dry climates, are impoverishing in a much higher degree than in moist ones."

APPENDIX,

CONTAINING

A TABULAR VIEW OF SPECIFIC GRAVITIES, REPRESENTATIVE NUMBERS, &c.;

TABLES OF WEIGHTS AND MEASURES;

TABLE OF THE DENSITIES, &c., OF SULPHURIC AND NITRIC ACIDS;

AND

A TABULAR VIEW OF THE COMPOSITION OF MINERAL WATERS.

TABULAR VIEW of SPECIFIC GRAVITIES, REPRESENTATIVE NUMBERS, COMPOSITION, &c.

I. *Supporters of Combustion and Acidifiable Substances.*

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to Hydrogen	Specific Gravity compared to Air	Specific Gravity compared to Water	Number	COMPOSITION
I. OXYGEN	33,75	15	1,1175	....	7,5	
II. CHLORINE	75,375	33,5	2,49575	....	33,5	
Euchlorine, or Oxide of Chlorine	71,4375	31,75	2,365375	....	63,5	30 oxy. + 33,5 chl.
Chloric acid	....	....	....	....	71,	37,5 oxy. + 33,5 chl.
Oxychloric acid	....	....	....	....	86,	52,5 oxy. + 33,5 chl.
III. IODINE	264,9375	117,75	8,772375	4,948	117,75	
Oxiodic acid	....	....	....	....	155,25	37,5 oxy. + 117,75 iodine.
Chloriodic acid	....	....	....	....	151,25	33,5 chl. + 117,75 iodine
I. HYDROGEN	2,25	1	,0745	....	1	
Water	25295,3	11242,3	837,55	1	8,5	7,5 oxy. + 1 hy.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Number	COMPOSITION
		Hydrogen	Air	Water		
Steam	18,829	8,3686	0,6235	1343,3		
Muriatic acid gas	38,8125	17,25	1,285125	....	34,5	33,5 chl.+1 hy.
———— solution	....	....	....	1,21	....	480 vol. of gas.
Hydriodic acid	133,59375	59,375	4,4234375	....	118,75	117,75 iode+1 hy.
II. NITROGEN	29,25	13	,96815	....	13,	
Nitrous oxide......................	46,125	20,5	1,52725	....	20,5	13 nit. + 7,5 oxy.
Nitric oxide........................	31,5	14	1,043	....	28	13 nit. + 15 oxy.
Nitrous acid	64,5024	$28{,}666\not{6}$	$2{,}13566\not{6}$	....	43	13 nit. + 30 oxy.
Nitric acid	....	....	....	....	50,5	13 nit. + 37,5 oxy.
Hydro-nitric acid	....	....	....	1,5	67,5	50,5 nit. ac. + 17 w.
Common air	30,1995	13,422	1	....	....	21 oxy. + 79 n.
Chloride of nitrogen................	....	....	....	1,6	147	13 n. + 134 chlo.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Number	COMPOSITION
		Hydrogen	Air	Water		
Iodide of nitrogen						
Ammonia	18,	8	,596	....	16	13 n. + 3 hy.
——— - solution	....	....	....	,875	....	670 volumes.
Chlorate of ammonia	....	....	....	....	87	71 chl. ac. + 16 am.
Oxiodate of ammonia						
Chloriodate of ammonia						
Muriate of ammonia	....	....	....	1,45	50,5	16 am. + 34,5 m. a.
Hydriodate of ammonia	....	....	....	....	134,75	16 am. + 118,75 hy. a.
Nitrite of ammonia						
Nitrate of ammonia	....	....	....	1,5785	66,5	16 am. + 50,5 n. a.
III. SULPHUR	....	....	....	1,99	15	
Sulphurous acid	67,5	30	2,235	....	30	15 sul. + 15 oxy.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to Hydrogen	Air	Water	Number	COMPOSITION
Hydro-sulphuro-nitric oxide?						
Sulphite of ammonia	....	....	....	....	76,	16 am. + 60 sul. acid.
Sulphuric acid (dry)................	....	....	....	....	37,5	15 sul. + 22,5 oxy.
Hydro-sulphuric acid (liquid)	....	....	....	1,9	46	37,5 s. a. + 8,5 water.
Glacial sulphuric acid?						
Sulphate of ammonia	....	....	....	....	53,5	37,5 s. a. + 16 am.
Chloride of sulphur	....	....	....	1,6	48,5	15 sul. + 33,5 chl.
Iodide of sulphur						
Sulphuretted hydrogen..............	36	16	1,192	....	16	15 sul. + 1 hy.
Hydroguretted sulphur						
Hydrosulphuret of ammonia	....	....	....	....	48	32 s. h. + 16 am.
IV. PHOSPHORUS	....	....	....	1,77	11	

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Number	COMPOSITION
		Hydrogen	Air	Water		
Oxide of phosphorus						
Hypophosphorous acid	....	....	....	....	29,5 ?	22 P. + 7,5 oxy.
Phosphorous acid	....	....	....	....	18,5	11 P. + 7,5 oxy.
Hydrophosphorous acid	....	....	....	....	45,5	37 P. a. + 8,5 water.
Phosphite of ammonia..............	....	....	....	....	34,5	18,5 P. a. + 16 am.
Phosphoric acid..........	....	....	....	2,85	26	11 P. + 15 oxy.
Phosphate of ammonia	....	....	....	....	42	26 P. a. + 16 am.
Chloride of phosphorus	....	....	....	1,45	44,5	11 P. + 33,5 chl.
Bichloride of phosphorus...........	....	....	....	....	78	11 P. + 67 chl.
Ammoniaco-bichloride of phosphorus						
Iodide of phosphorus						
Hydro-phosphoric gas..............	29,25	13	,9685	....	13	P. 11 + hy. 2.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to			Number	COMPOSITION
		Hydrogen	Air	Water		
Phosphuretted hydrogen	27	12	,894	....	12	P. 11 + hy. 1.
Sulphuret of phosphorus	....	....	....	....	37	P. 22 + sul. 15.
V. CARBON (Diamond)	....	....	....	3,5	5,7	
Carbonic oxide	29,7	13,2	,9834	....	13,2	Carb. 5,7 + oxy. 7,5.
Chlorocarbonic acid.................	105,075	46,7	3,47915	....	46,7	C. 0. 13,2 + chl. 33,5.
Carbonic acid.......................	46,575	20,7	1,54215	....	20,7	Carb. 5,7 + oxy.15.
Carbonate of ammonia................	....	....	....	....	36,7	C. a. 20,7 + am. 16.
Bicarbonate of ammonia..............	....	....	....	....	57,4	C. a. 41,4 + am. 16.
Carburetted hydrogen (light)........	17,325	7,7	,57365	....	7,7	Carb. 5,7 + hy. 2.
Bicarburetted hydrogen (olefiant)....	30,15	13,4	,9983	....	6,7	Carb. 5,7 + hy. 1.
Chloric ether	....	....	....	1,2201	46,9	Olef. 13,4 + chl. 33,5.
Cyanogen	54,9	24,4	1,8178	....	24,4	Carb. 11,4 + n. 13.

Supporters of Combustion and Acidifiable Substances (continued.)

SUBSTANCES	100 Cubic Inches weigh grs.	Specific Gravity compared to Hydrogen	Air	Water	Number	COMPOSITION
Chloro-cyanic acid	65,1375	28,95	2,152775	....	57,9	Cy. 24,4 + ch. 33,5.
Hydro-cyanic acid..................	28,575	12,7	,94615	....	25,4	Carb. 11,4 + nit. 13 + hy. 1.
Hydro-cyanate of ammonia						
Sulphocyanic acid						
Sulphuret of carbon................	....	....	....	1,272	35,7	Carb. 5,7 + sul. 30
Phosphuret of carbon						
VI. BORON........................	....	....	....	....	5,	
Boracic acid	....	....	....	1,803	20,	B. 5, + oxy. 15.
Hydro-boracic acid	....	....	....	1,479	37,	B. a. 20, + w. 17.
Borate of ammonia (Hydro)	....	....	....	....	53,	B. a. 20, + am. 16 + w. 17.

II. *Metals and their Combinations.*

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
I. POTASSIUM	0,85	37,5		The following characters belong to the Salts of Potassium: they are all soluble in water, and afford no precipitates with pure or carbonated alcalies; they produce a precipitate in muriate of platinum, which is a triple compound of potassa, oxide of platinum, and muriatic acid. They are not changed by sulphuretted hydrogen, nor by prussiate of potassa. Added to sulphate of alumine, they enable it to crystallize so as to form alum.
—— protoxide, or dry potassa	2,5	45	37,5 P. + 7,5 oxygen.	
—— hydrate	1,7	53,5	45 Ox. potassium + 8,5 water.	
—— peroxide	....	60	37,5 P. + 22,5 oxygen.	
—— chloride	....	71	37,5 P. + 33,5 C.	
—— chlorate	....	116	45 O. P. + 71 C.A.	
—— oxychlorate	....	131	45 O. P. + 86 oxych. a.	
—— iodide	....	155,25	37,5 P. + 117,75 I.	
—— hydriodate	....	163,75	45 O. P. + 118,75 H. A.	
—— oxiodate				
—— hydruret				
—— (hydrogen potassuretted)				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
POTASSIUM nitrate	1,99	95, 5	45 O. P. + 50,5 N. A.	
——— sulphuret	....	52,5	37,5 P. + 15 S.	
——— sulphite	....	75	45 O. P. + 30 S. A.	
——— sulphate	2,4	82,5	45 P. + 37,5 S. A.	
——— bisulphate	....	120	45 O. P. + 75 S. A.	
——— phosphuret	....	48,5	37,5 P. + 11 Phos.	
——— phosphite	....	63,5	45 O. P. + 18,5 P. A.	
——— phosphate	....	71	45 O. P. + 26 P. A.	
——— carbonate	....	65,7	45 O. P. + 20,7 C. A.	
——— bicarbonate	2,01	86,4	45 O. P. + 41,4 C. A.	
——— cyanuret				
——— prussiate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
II. SODIUM	0,9	22		All the Salts of Soda are soluble in water; they are not precipitated by pure or carbonated alcalies, nor by hydrosulphuret of ammonia, nor prussiate of potassa; nor do they produce any precipitate in solution of muriate of platinum. They do not convert sulphate of alumine into alum.
—— 1. oxide	....	29,5	22 S. + 7,5 O.	
———— hydrated	....	38	29,5 O. S. + 8,5 W.	
—— peroxide				
—— chloride	....	55,5	22 S. + 33,5 C.	
—— chlorate	....	100,5	29,5. O. S. + 71 C. A.	
—— iodide	....	139,75	22 S. + 117,75 I.	
—— oxiodate	....	184,75	29,5 O. S. + 155,25 O. A.	
—— hydriodate	....	148,25	29,5 O. S. + 118,75 H. A.	
—— nitrate	2,09	80	29,5 O. S. + 50,5 A. N.	
—— sulphuret	....	37	22 S. + 15 Sul.	
—— sulphite	....	59,5	29,5 O. S. + 30 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
SODIUM sulphate	....	67	29,5 O. S.+37,5 S. A.	
—— phosphuret	....	33	22 S.+11 P.	
—— phosphite	....	48	29,5 O. S.+18,5 P. A.	
—— phosphate	....	55,5	29,5 O. S.+26 P. A.	
—— biphosphate	....	81,5	29,5 O. S.+52 P. A.	
—— subcarbonate	1,35	50,2	29,5 O. S.+20,7 C. A.	
—— bicarbonate	....	70,9	29,5 O. S.+41,4 C. A.	
—— cyanuret				
—— prussiate				
—— subborate, or borax	1,74			
III. LITHIUM	....	9		Lithia is distinguished from potassa and soda, by its high saturating power, by the difficult solubility of its carbonate, by
—— oxide	....	16,5	9 L.+7,5 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
LITHIUM. chloride	....	42,5	9 L. + 33,5 C.	the deliquescency and ready solubility of its chloride, and by the characters of its sulphate.
——— chlorate	....	87,5	16,5 O. L. + 71 chl. ac.	
——— nitrate	....	67	16,5 O. L. + 50,5 N. A.	
——— sulphate	....	54	16,5 O. L. + 37,5 S. A.	
——— phosphate	....	2,5	16,5 O. L. + 26 P. A.	
——— carbonate	....	37,2	16,5 O. L. + 20,7 C. A.	
IV. CALCIUM	....	19		The Salts of Lime furnish precipitates of carbonate of lime by the carbonated alcalies; they afford no precipitate with caustic ammonia. Oxalic acid, and oxalate of ammonia, produce precipitates of oxalate of lime, which, at a red heat, affords quicklime.
——— oxide, or lime	1,5	26,5	19 C. + 7,5 O.	
——— ——— hydrate	....	35	26,5 O. C. + 8,5 W.	
——— chloride	....	52,5	19 C. + 33,5 C.	
——— muriate	....	61	26,5 O. C. + 34,5 M. A.	
——— chlorate	....	97,5	26,5 O. C. + 71 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
CALCIUM. iodide	....	136,7	19 C. + 117,7 I.	
——— oxyiodate	....	181,75	26,5 O. C. + 155,25 O. A.	
——— hydriodate	....	145,2	26,5 O. C. + 118,7 H. A.	
——— nitrate	1,6	77	26,5 O. C. + 50,5 N. A.	
——— sulphate	....	64	26,5 O. C. + 37,5 S. A.	
——— crystallized	....	81	64 dry sulphate + 17 water	
——— sulphuret	....	34	19 C. + 15 S.	
——— phosphuret	....	30	19 C. + 11 P.	
——— phosphate	....	52,5	26,5 O. C. + 26 P. A.	
——— biphosphate	....	78,5	26,5 O. C. + 52 P. A.	
——— carbonate	2,7	47,2	26,5 O. C. + 20,7 C. A.	
——— fluoride	3,	34	19 C. + 15 Fluorine ?	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Hydrofluoric acid	....	16	15 Fluorine + 1 hydrogen	
Fluoboric gas	32,68	to hydrog.	23,71 to atmospheric air.	
V. BARIUM	....	65		The Soluble Barytic Salts furnish white precipitates of carbonate of baryta, by the alcaline sub-carbonates. Sulphuric acid and the soluble sulphates occasion white precipitates of sulphate of baryta in the solution of the earth. They are poisonous, and tinge flame yellow.
—— oxide	....	72,5	65 B. + 7,5 O,	
—— hydrate	....	81	72,5 O. B. + 8,5 W.	
—— chloride	....	98,5	65 B. + 33,5 C.	
—— chlorate	....	143,5	72,5 O. B. + 71 C. A.	
—— iodide	....	182,7	65 B. + 117,7 I.	
—— oxiodate				
—— hydriodate	....	191,2	72,5 O. B. + 118,7 H. A,	
—— nitrate	....	123	72,5 O. B. + 50,5 N. A.	
—— sulphuret	....	80	65 B. + 15 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
BARIUM. sulphite	....	102,5	72,5 O. B. + 30 S'. A.	
—— sulphate........	4,4	110	72,5 O. B. + 37,5 S. A.	
—— phosphuret	....	76	65 B. + 11 P.	
—— phosphite	....	91	72,5 O. B. + 18,5 P. A.	
—— phosphate........	1,28	98,5	72,5 O. B. + 26 P. A.	
—— carbonate	4,2	93,2	72,5 O. B. + 20,7 C. A.	
VI. STRONTIUM........	....	44,5		The Salts of Strontium furnish white precipitates with the alcaline subcarbonates, and with sulphuric acid and sulphates; they tinge flame of a fine red; they are not poisonous. They are decomposed by baryta, which has a stronger attraction for acids than strontia; they are more soluble than barytic salts, but pure strontia is less soluble than baryta.
—— oxide	....	52	44,5 S. + 7,5 O.	
—— —— hydrate	....	60,5	52 O. S. + 8,5 W.	
—— chloride	....	78	44,5 S. + 33,5 C.	
—— muriate	....	86,5	52 O. S. + 34,5 M. A.	
—— nitrate........	....	102,5	52 O. S. + 50,5 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
STRONTIUM. sulphuret	....	59,5	44,5 S. + 15 Sul.	
——— sulphate	3,9	89,5	52 O. S. + 37,5 S. A.	
——— phosphate		78	52 O. S. + 26 P. A.	
——— carbonate	3,6	72,7	52 O. S. + 20,7 C. A.	
VII. MAGNESIUM	....	11		The salts of magnesia are decomposed by solution of potassa, and by its subcarbonate; the precipitate does not re-dissolve in excess of the alcalies, but readily dissolves in excess of sulphuric acid. The salts of magnesia are not precipitated by a solution of bicarbonate of potassa (cold), nor by subcarbonate of ammonia; but if heat be applied, carbonic acid escapes, and the earth is precipitated in the state of subcarbonate. The salts of mag-
——— oxide	2,3	18,5	11 M. + 7,5 O.	
——— hydrate	....	27	18,5 O. M. + 8,5 W.	
——— chloride	....	44,5	11 M. + 33,5 C.	
——— muriate	....	53	18,5 O. M. + 34,5 M. A.	
——— chlorate	....	89,5	18,5 O. M. + 71 C. A.	
——— hydriodate	....	137,2	18,5 O. M. + 118,7 H. A.	
——— nitrate	....	69	18,5 O. M. + 50,5 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
MAGNESIUM. sulphite				nesia are only partially decomposed by ammonia, which forms triple salts with the earth and acid. Oxalate of ammonia does not precipitate magnesia.
——— sulphate	1,66	56	18,5 O M. + 37,5 S. A.	
——— carbonate	....	39,2	18,5 O. M. + 20,7 C. A.	
——— bicarbonate	....	59,9	18,5 O. M. + 41,4 C. A.	
VIII. MANGANESE	6,85	53,5		The Salts of Manganese are not precipitated by hydriodic acid. They furnish white precipitates with the alcalies, which blacken by exposure to air. They are precipitated white by prussiate of potassa, and yellow by hydrosulphuret of ammonia.
——— 1. oxide	....	61	53,5 M. + 7,5 O.	
——— 2. oxide	....	68,5	53,5 M. + 15 O.	
——— peroxide	....	83,5	53,5 M. + 30 O.	
——— chloride	....	87	53,5 M. + 33,5 C.	
——— nitrate	....	111,5	61 O. M. + 50,5 N. A.	
——— sulphuret				
——— sulphate	....	98,5	61 O. M. + 37,5 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
MANGANESE. red sulphate	....	143,5	68,5 O. M. + 75 S. A.	
——— phosphuret	....	64,5	53,5 M. + 11 P.	
——— phosphate	....	87	61 O. M. + 26 P. A.	
——— carbonate	....	81,7	61 O. M. + 20,7 C. A.	
IX. IRON	7,78	52		The Solutions of Iron are known by affording a purple or black precipitate to infusion of galls, which is an extremely delicate test of the presence of the metal, provided any earthy or alcaline salt be present. They give no precipitate with hydriodic acid.
— 1. oxide	....	67	52 I. + 15 O.	
— 2. oxide	....	74,5	52 I. + 22,5 O.	
— 1. chloride	....	119	52 I. + 67 C.	
— 2. chloride	....	152,5	52 I. + 100,5 C.	
— muriate	....	136	67 O. I. + 69 M. A.	
— oxymuriate	....	178	74,5 O. I. + 103,5 M. A.	
— chlorate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Iron. iodide	....	287,4	52 I. + 235,4 Iod.	The pure salts containing the black oxide give a white or very pale blue precipitate with prussiate of potassa; while those containing the brown oxide furnish a dark blue precipitate, (Prussian blue). I have preferred the number 52 instead of 26 as the representative of iron, from the convenience of its application to most of the compounds.
—— nitrate	....	168	67 O. I. + 101 N. A.	
—— oxynitrate	....	226	74,5 O. I. + 151,5 N. A.	
—— sulphuret	....	82	52 I. + 30 S.	
—— bisulphuret	....	112	52 I. + 60 S.	
—— sulphate	....	142	67 O. I. + 75 S. A.	
———— crystallized.	1,83	261	142 dry + 119 W. (14 props.)	
—— oxysulphate	....	187	74,5 O. I. + 112,5 S. A.	
—— hydrosulphuret				
—— phosphuret	....	74	52 I. + 22 P.	
—— phosphate	....	119	67 O. I. + 52 P. A.	
—— oxyphosphate	....	152,5	74,5 O. I. + 78 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
IRON. carburet				
—— carbonate	....	108,4	67 O. I. + 41,4 C. A.	
X. ZINC	7	33		The Solutions of Zinc are not precipitated by hydriodic acid. Potassa, soda, and ammonia, form white precipitates redissoluble in excess either of acid or alcali. Hydrosulphuret of ammonia produces a yellowish white precipitate ; and the soluble phosphates, borates, and carbonates, all form white precipitates.
—— oxide	....	40,5	33 Z. + 7,5 O.	
—— chloride	....	66,5	33 Z. + 33,5 C.	
—— muriate	....	75	40,5 O. Z. + 34,5 M. A.	
—— iodide	....	150,7	33 Z + 117,7 I.	
—— hydriodate	....	159,2	40,5 O. Z. + 118,7 H. A.	
—— nitrate	....	91	40,5 O. Z. + 50,5 N. A.	
—— sulphuret	....	48	33 Z. + 15 S.	
—— sulphate	1,9	78	40,5 O. Z. + 37,5 S. A.	
—— hydrosulphuret				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
ZINC. phosphuret	....	44	33 Z. + 11 P.	
— phosphate	....	66,5	40,5 O. Z. + 26 P. A.	
— carbonate	....	61,2	40,5 O. Z. + 20,7 C. A.	
XI. TIN	7,30	55		The Hydriodic Acid affords a fine orange precipitate with solution of muriates of tin, provided there be no excess of acid. Hydrosulphuret of ammonia produces a precipitate of a deep orange colour.
— 1. oxide	....	62,5	55 T. + 7,5 O.	
— 2. oxide	....	70	55 T. + 15 O.	
— 1. chloride	....	88,5	55 T. + 33,5 O.	
— 2. chloride	....	122	55 T. + 67 C.	
— muriate	....	97	62,5 O. T. + 34,5 M. A.	
— oxymuriate	....	139	70 O. T. + 69 M. A.	
— iodide	....	172,7	55 I. + 117,7 I.	
— nitrate	....	113	62,5 O. T. + 50,5 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
TIN. sulphuret	....	70	55 T. + 15 S.	
—— bisulphuret	....	85	55 T. + 30 S.	
—— sulphate	....	100	62,5 O. T. + 37,5 S. A.	
—— hydrosulphuret				
—— phosphuret	....	65	55 T. + 10 P.	
XII. CADMIUM	8,63	82,5		Cadmium is readily soluble in muriatic acid. Its neutral solutions are precipitated yellow by sulphuretted hydrogen, and furnish a metallic precipitate upon immersed zinc.
——— oxide	....	90	82,5 C. + 7,5 O.	
——— chloride	....	116	82,5 C. + 33,5 Chlor.	
——— nitrate	....	140,5	90 O. C. + 50,5 N. A.	
——— sulphate	....	127,5	90 O. C. + 37,5 S. A.	
——— phosphate	....	116	90 O. C. + 26 P. A.	
——— carbonate	....	110,7	90 O. C. + 2,7 C. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
XIII. COPPER	8,8	60		The salts of this metal are distinguished by their blue and green colours; their solutions afford blue precipitates of hydrated oxide with the alcalies, and these redissolve in excess of ammonia, producing a deep blue solution. A plate of iron precipitates metallic copper; prussiate of potassa affords a fine brown precipitate; hydrosulphuret of ammonia one of a dirty brown; hydriodic acid produces an insoluble iodide of an ash grey colour.
—— 1. oxide	....	67,5	60 C. + 7,5 O.	
—— 2. oxide	....	75	60 C. + 15 O.	
—— 1. chloride	....	93,5	60 C. + 33,5 C.	
—— 2. chloride	....	127	60 C. + 67 C.	
—— iodide	....	177,7	60 C. + 117,7 I.	
—— submuriate?	....	184,5	75 O. C. + 34,5 M. A.	
—— muriate	....	144	75 O. C. + 69 M. A.	
—— chlorate				
—— nitrate	2,17	176	75 O. C. + 101 N. A.	The nitrate is erroneously described in the text as consisting of 75 oxide + 50,5 acid, which is the composition of the subnitrate. The salts of copper containing the protoxide have hitherto been but imperfectly described.
—— ammoniuret				
—— sulphuret	....	75	60 C. + 15 S.	
—— bisulphuret	....	90	60 C. + 30 S.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
COPPER. sulphite	....	97,5	67,5 O. C. + 30 S. A.	
—— sulphate (dry)	....	150	75 O. C. + 75 S. A.	
—— sulphate crystallized	2,19	235	75 O. C. + 75 S. A. + 85 water.	
—— hydrosulphuret				
—— phosphuret	....	71	60 C. + 11 P.	
—— phosphate	....	93,5	67,5 O. C. + 26 P. A.	
—— oxyphosphate	....	125	75 O. C. + 50 P. A.	
—— carbonate	....	95,7	75 O. C. + 20,7 C. A.	
XIV. LEAD	11,35	97		The soluble Salts of Lead furnish colourless solutions of a sweetish taste, precipitated white by sulphate and prussiate of potassa, and by infusion of galls; brownish black by sulphuretted hydrogen; and brown by hydrosulphuret of
—— 1. oxide	....	104,5	97 L. + 7,5 O.	
—— 2. oxide	....	108,25	97 L. + 11,25 O.	
—— 3. oxide	....	112	97 L. + 15 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
LEAD. chloride	....	130,5	97 L. + 33,5 C.	ammonia. Hydriodic acid affords a fine yellow precipitate of iodide of lead. The alcalies produce white precipitates, *easily soluble* in excess of potassa or soda, but *insoluble* in excess of ammonia. Zinc precipitates metallic lead. The insoluble salts of lead treated by the blow-pipe on charcoal, afford a globule of lead.
—— chlorate	....	175,5	104,5 O. L. + 71 C. A.	
—— iodide	....	214,7	97 L. + 117,7 I.	
—— nitrate	....	155	104,5 O. L. + 50,5 N. A.	
—— sulphuret	....	112	97 L. + 15 S.	
—— sulphate	....	142	104,5 O. L. + 37,5 S. A.	
—— hydrosulphuret				
—— phosphuret	....	108	97 L. + 11 P.	
—— phosphate	....	130,5	104,5 O. L. + 26 P. A.	
—— carbonate	....	125,2	104,5 O. L. + 20,7 C. A.	
XV. ANTIMONY	6,70	45		The soluble binary salts of the protoxide of antimony are precipitated white by water; the precipitate is a subsalt. Sul-
——— 1. oxide	....	52,5	45 A. + 7, 5 O.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS;
ANTIMONY. 2 oxide........	....	60	45 A. + 15 O.	phuretted hydrogen, and hydrosulphuret of ammonia, give an orange precipitate, and a plate of iron or zinc throws down the metal in the form of a black powder.
——— chloride........	....	78,5	45 A. + 33,5 C.	
——— iodide	....	162,7	45 A. + 117,7 I.	
——— muriate........				
——— sulphuret	....	60	45 A. + 15 S.	
——— sulphate				
——— hydrosulphuret				
——— phosphuret	....	56	45 A. + 11 P.	
——— phosphate........	....	78,5	52,5 O. A. + 26 P. A.	
XVI. BISMUTH........	9,80	66,5		The Salts of Bismuth are precipitated white by water—brownish black by sulphuretted hydrogen—yellowish white by prussiate of potassa, and hydriodic acid affords a deep brown iodide of bismuth.
——— oxide........	....	74	66,5 B. + 7,5 O.	
——— chloride	....	100	66,5 B. + 33,5 C.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
BISMUTH nitrate	....	124,5	74 O. B. + 50,5 N. A.	
——— sulphuret	....	81,5	66,5 B. + 15 S.	
——— sulphate	....	111,5	74 O. B. + 37,5 S. A.	
XVII. COBALT	8	43		
——— 1. oxide	....	50,5	43 C. + 7,5 O.	Nearly all the Salts of Cobalt are of a red colour, when in dilute solution, but green when concentrated; potassa, soda, and ammonia, produce in them blue precipitates of hydrated oxide, which is soluble in excess of ammonia, producing a red solution. Hydrosulphuret of ammonia gives a black precipitate. Prussiate of potassa a pale green. Carbonates, phosphates, and arseniates, produce red precipitates. Hydriodic acid does not precipitate the salts of cobalt.
——— 2. oxide	....	58	43 C. + 15 O.	
——— chloride	....	76,5	43 C. + 33,5 C.	
——— muriate	....	85	50,5 O. C. + 34,5 M. A.	
——— sulphuret	....	58	43 C. + 15 S.	
——— sulphate crystallized	....	147,5	50,5 O. C. + 37,5 S. A. + 59,5 Water.	
——— phosphuret	....	54	43 C. + 11 P.	
——— phosphate	....	76,5	50,5 O. C. + 26 P. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
XVIII. URANIUM	9	60		Of the salts of Uranium the greater number are soluble, and of a greenish yellow colour; they form yellow precipitates with the alcalies, and afford a reddish yellow iodide with hydriodic acid. Prussiate of potassa forms a precipitate of a rich brown colour, and hydrosulphuret of ammonia one nearly black.
——— 1. oxide	....	67,5	60 U. + 7,5 O.	
——— 2. oxide..............	....	75	60 U. + 15 O.	
XIX. TITANIUM				The Salts of Titanium are colourless, and afford white precipitates with the alcalies. Prussiate of potassa gives a green precipitate, and infusion of galls a red one. Hydrosulphuret of ammonia gives a green precipitate.
XX. CERIUM	....	86,2		
——— 1. oxide................	....	101,2	86,2 C. + 15 O.	
——— 2. oxide	....	108,5	86 C. + 22,5 O.	
XXI. TELLURIUM	6,10	36,5		
——— oxide	....	44	36,5 T. + 7,5 O.	
——— chloride	....	70	36,5 T. + 33,5 C.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
XXII. SELENIUM				
XXIII. ARSENIC	8,3	44		Hydriodic Acid produces a precipitate of white oxide of arsenic, when added to arsenite of potassa, and hydriodate of potassa is formed. Arsenite of potassa gives a white precipitate with hydrosulphuret of ammonia; a white precipitate soon becoming yellow and brown with nitrate of silver; a grey precipitate with nitrate, and a white with oxynitrate of mercury; a white with nitrate of lead; a pale green with nitrate of nickel; pale pink by nitrate of cobalt; apple green with nitrate of copper; white with the muriate and oxymuriate of tin; dingy green with the muriate and oxymuriate of iron; white with sulphate of zinc; bright yellow with nitrate of uranium.
——— 1. oxide (arsenious acid)	3,7	59	44 A. + 15 O.	
——— 2. oxide (arsenic acid)..	....	66,5	44 A. + 22,5 O.	
——— chloride	....	111	44 A. + 67 C.	
——— muriate?	....	127	59 O. A. + 68 M. A.	
——— iodide	....	397,1	44 A. + 353,1 I.	
——— hydruret				
——— arseniuretted hydrogen				
——— sulphuret	....	59	44 A. + 15 S.	
——— bisulphuret	....	74	44 A. + 30 S.	
——— sulphate				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Arseniate of ammonia	....	82,5	66,5 A. A. + 16 A.	The Arseniate of Potassa produces a reddish precipitate in nitrate of silver; straw-coloured with nitrate, and yellow with oxynitrate of mercury; white with nitrate of lead; pale green with nitrate of nickel; pale blue with nitrate of copper; pink with nitrate of cobalt; white with muriate of tin; no precipitate with oxymuriate of tin; pale sea-green with muriate and oxymuriate of iron; straw colour with nitrate of uranium; and white with sulphate of zinc.
——— silver	....	176,5	66,5 A. A. + 110 O. S.	
——— mercury	....	264	66,5 A. A. + 197,5 O. M.	
——— lead	....	171	66,5 A. A. + 104,5 O. L.	
——— nickel	....	102	66,5 A. A. + 35,5 O. N.	
XXIV. MOLYBDENUM	7,40	44		
——— 1. oxide	....	51,5	44 M. + 7,5 O.	
——— 2. oxide	....	59	44 M. + 15 O.	The compounds of the arsenic and arsenious acids are decomposed when heated with charcoal, and exhale an alliaceous smell.
——— 3. oxide	....	66,5	44 M. + 22,5 O.	
——— sulphuret	....	74	44 M. + 30 S.	
XXV. CHROME	5, 9	28,5		Chromic Acid and Chromate of Soda produce insoluble precipitates in solutions of silver,

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
CHROME. 1. oxide	....	36	28,5 + 7,5	mercury, lead, copper, iron, and uranium ; the colours are crimson, red, yellow or orange, apple green, brown, and yellow. No precipitate is formed in solutions of nickel, zinc, tin, cobalt, gold, or platinum.
——— 2. oxide (chromic acid)	....	43,5	28,5 + 15	
XXVI. TUNGSTEN	17,5	90		
——— Tungstic acid	....	112,5	90 T. + 22,5 O.	
XXVII. COLUMBIUM	....	139		
——— oxide	....	146,5	139 C. + 7,5 O.	
XXVIII. NICKEL	8,5	28		The Salts of Nickel furnish green solutions, of a sweetish acrid flavour ; ammonia furnishes green precipitates, redissoluble in excess of alcali, and forming triple salts. Prussiate of potassa forms a greenish precipitate; hydrosulphuret of ammonia gives a black precipitate; hydriodic acid forms a pea-green iodide.
——— oxide	....	35,5	28 N. + 7,5 O	
——— hydrate				
——— chloride	....	61,5	28 N. + 33,5 C.	
——— nitrate	....	86	35,5 O. N. + 50,5 N. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
NICKEL. ammoniuret				
——— sulphuret	....	43	28 N. + 15 S.	
——— sulphate (dry)........	....	73	35,5 O. N. + 37,5 S. A.	
——— phosphuret	....	39	28 N. + 11 P.	
——— carbonate	....	56,2	35,5 O. N. + 20,7 C. A.	
XXIX. MERCURY....................	13,50	190		The Mercurial Salts are volatilized by heat. They are precipitated yellowish by prussiate of potassa; deep brown by hydrosulphuret of ammonia; and copper separates pure mercury. The salts, with the protoxide, furnish black precipitates with the alcalies, and white with muriatic acid. The salts with the peroxide furnish to the fixed alcalies reddish precipitates, and white with ammonia.
——— protoxide............	....	197,5	190 M. + 7,5 O.	
——— peroxide	....	205	190 M. + 15 O.	
——— chloride	....	223,5	190 M. + 33,5 C.	
——— bichloride............	....	257	190 M. + 67. C.	
——— muriate?				
——— chlorate............	Chlorate of Mercury is yellow and insoluble. Oxychlorate furnishes crystals.			

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
MERCURY. iodide	....	307,7	190 M. + 117,7 I.	Hydriodic Acid furnishes a yellow precipitate in solutions of protoxide, and a red precipitate with the peroxide. These are the protiodide and periodide of mercury. Phosphoric Acid produces a white insoluble precipitate in nitrate of mercury, but no precipitate in the oxynitrate.
——— periodide	....	425,4	190 M. + 235,4	
——— hydriodate	....	316,2	197,5 O. M. + 118.7 H. A.	
——— nitrate	....	248	197,5 O. M. + 50,5 N. A.	
——— oxynitrate	....	306	205 O. M. + 101 N. A.	
——— sulphuret	....	205	190 M. + 15 S.	
——— bisulphuret	....	220	190 M. + 30 S.	
——— sulphite	....	227,5	197,5 O. M. + 30 S. A.	
——— sulphate	....	235	197,5 O. M. + 37,5 S. A.	
——— oxysulphate	....	280	205 O. M. + 75 S. A.	
——— superoxysulphate				
——— suboxysulphate	....	242,5	205 O. M. + 37,5 S. A.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
MERCURY. hydrosulphuret				
——— phosphuret				
——— phosphate	....	223,5	197,5 O. M. + 26 P. A.	
——— oxyphosphate	....	257	205 O. M. + 52 P. A.	
——— carbonate	....	218,2	197,5 O. M. + 20,7 C. A.	
——— cyanuret	....	238,8	190 M. + 48,8 C.	
XXX. OSMIUM				
XXXI. IRIDIUM	18			
XXXII. RHODIUM	10,6			
XXXIII. PALLADIUM	11			
XXXIV. SILVER	10,50	102,5		The salts of silver are reduced upon charcoal by the blow-pipe. The soluble salts are precipitated by the alcalies, which
——— oxide	....	110	102,5 S. + 7,5 ox.	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
SILVER. chloride	....	136	102,5 S. + 33,5 C.	furnish dark olive precipitates; by sulphuretted hydrogen and hydrosulphuret of ammonia, nearly black; by infusion of galls, yellow brown; by prussiate of potassa white.. Muriatic acid, and the muriates, give white precipitates of chloride of silver. Sulphate of iron, and a plate of copper, throw down metallic silver.
—— chlorate	A detonating salt.			
—— iodide, —— hydriodate	Hydriodic acid throws down iodide of silver from the nitrate, at first white, but becoming *very* soon yellow, then grey and blackish.			
—— nitrate	....	160,5	110 O. S. + 50,5 N. A.	
—— ammoniuret	Liquid ammonia easily dissolves the oxide of silver. When the solution is evaporated, a grey compound remains, which leaves metallic silver when heated. Sometimes it detonates.			
—— sulphuret	....	117,5	102,5 S. + 15 Sul.	
—— sulphite	forms a white and difficultly soluble salt.			
—— sulphate	....	147,5	110 O. S. + 37, 5 S. A.	
—— hydrosulphuret				
—— phosphuret				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
SILVER. phosphate	....	136	110 O. S. + 26 P. A.	
—— carbonate	....	130,7	110 O. S. + 20,7 C. A.	
—— cyanuret	....	151,3	102,5 O. S. + 48,8 C.	
—— hydrocyanate				
—— borate	Boracic acid produces no precipitate in solutions of silver, but borate of soda throws down a white *borate of silver*.			
XXXV. GOLD	19,30	97		The salts of gold are yellow and soluble in water. Potassa and soda produce in them yellow precipitates. Sulphuretted hydrogen and hydrosulphuret of ammonia occasion black precipitates: phosphuretted hydrogen, a purple precipitate: a plate of tin or muriate of tin, a purple powder. Sulphate of iron separates minutely-divided metallic gold. Tincture of galls gives a brown precipitate. Prussiate of potassa occasions no precipitate.
—— peroxide	....	104,5	97 G. + 7,5 ox.	
—— chloride	....	130,5	97 G. + 33,5 C.	
—— muriate	....	139	104,5 ox. G. + 34,5 M. A.	
—— chlorate				
—— iodide / —— hydriodate	Hydriodic acid produces an insoluble yellow precipitate in dilute muriate of gold, which is the iodide of gold. Heat separates the iodine.			

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
GOLD. nitrate	....	155	104,5 ox. G. + 50,5 N. A.	
—— sulphuret	....	127	97 G. + 30 S.	
—— sulphite	Sulphurous acid produces a metallic precipitate in solution of gold.			
—— sulphate				
—— phosphuret	....	108	97 G. + 11 P.	
—— phosphite	Neither these acids, nor their neutral salts, occasion any precipitate in solution of muriate of gold.			
—— phosphate				
—— carbonate				
—— cyanuret				
XXXVI. PLATINUM				The solutions of these salts are deep or brownish yellow. They afford no precipitate with solutions of soda, of sulphate of iron, or of prussiate of potassa. The addition of the lat-
—— protoxide				
—— peroxide				

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
PLATINUM. chloride		—	—	ter produces a fine green solution. Potassa and ammonia, and many of their salts, occasion yellow precipitates. Sulphuretted hydrogen occasions a black precipitate. Infusion of galls gives a dingy brown precipitate.
——— muriate		—	—	
——— iodide............	Hydriodic acid precipitates a dingy brown iodide of platinum, decomposed by heat.			
——— hydriodate				
——— nitrate		—	—	The analysis of these compounds are, at present, too much at variance to enable us, with sufficient precision, to ascertain the representative number of Platinum.
——— ammoniuret		—	—	
——— ammonio-muriate		—	—	
——— sulphuret		—	—	
——— sulphate		—	—	
——— hydrosulphuret....	Hydrosulphuret of ammonia produces a brown precipitate in muriate of platinum. This is probably a sulphuretted hydrosulphuret.			
——— phosphuret		—	—	

Metals and their Combinations (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
PLATINUM. phosphate	A soluble salt, obtained by dissolving oxide of platinum in phosphoric acid.			
XXXVII. SILICIUM	....	15		
Silica	2,6	30	15 S. + 15 O.	Of the following bodies such combinations only are here set down as have been examined with sufficient precision. Their distinctive characters are given at length in the text.
Silicated fluoric acid	3,574	=sp. gr. to	atmospheric air.	
———————	49,2	=sp. gr to	hydrogen.	
———————	110,78	grs. = weight	of 100 C. I.	
XXXVIII. ALUMIUM	....	16,5		
Alumina..................	....	24	16,5 A. + 7,5 O.	
——— sulphate............	....	61,5	24 O. A. + 37,5 S. A.	
XXXIX. ZIRCONIUM	....	35		
Zirconia..................	....	42,5	35 Z. + 7,5 O.	

Metals and their Combinations (continued)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
XL. GLUCINUM	....	20		
Glucina	2,97	27,5	20 G.+7,5 O.	
XLI. YTTRIUM	....	30		
Yttria	....	37,5	30 Y.+7,5 O.	
XLII. THORINUM				

III. *Vegetable Acids.*

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
I. TARTARIC ACID	1,5	62,5		The ultimate components of tartaric acid, are 3 hydrogen = 3 4 carbon = 22,8 5 oxygen = 37,5 63,3
Tartrate of potassa	....	107,5	62,5 acid + 45 potassa.	
Bitartrate of ditto	....	170	125 T. A. + 45 potassa.	
Tartrate of soda	....	92	62,5 T. A. + 29,5 soda.	

Vegetable Acids, (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Tartrate of lime	....	89	62,5 T. A. + 26,5 lime.	The number 62,5 is deduced from Berzelius, analysis of tartrate of lead.
——— baryta	....	135	62,5 T. A. + 72,5 baryta.	
——— stronthia	....	114,5	62,5 T. A. + 52 stronthia.	
——— magnesia	....	81	62,5 T. A. + 18,5 magnesia.	
——— lead	....	167	62,5 T. A. + 104,5 ox. lead.	
II. OXALIC ACID	....	35,5		
Oxalate of ammonia	....	51,5	35,5 O. A. + 16 ammonia.	The representative number of oxalic acid is deduced from the composition of oxalate of lead.
——— potassa	....	80,5	35,5 O. A. + 45 potassa.	
Binoxalate of ditto	....	116	71 O. A. + 45 potassa.	
Quadroxalate of ditto	....	187	142 O. A. + 45 potassa.	
Oxalate of Soda	....	65	35,5 O. A. + 29,5 soda.	
——— lime	....	62	35,5 O. A. + 26,5 lime.	

Vegetable Acids, (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Oxalate of baryta	....	108	35,5 O. A. + 72,5 baryta.	
——— strontia	....	87,5	35,5 O. A. + 52 strontia.	
——— magnesia	....	54	35,5 O. A. + 18,5 magnesia.	
——— lead	....	140	35,5 O. A. + 104,5 ox. lead.	
III. CITRIC ACID	....	55,5		
Citrate of potassa	....	100,5	55,5 C. A. + 45 potassa.	The ultimate elements of citric acid are, 3 hydrogen = 3 4 oxygen = 30 4 carbon = 2,82 —— 55,8
——— soda	....	85	55,5 C. A. + 29,5 soda.	
——— lime	....	82	55,5 C. A. + 26,5 lime.	
——— baryta	....	128	55,5 C. A. + 72,5 baryta.	
——— strontia	....	107,5	55,5 C. A. + 52 strontia.	
——— magnesia	....	74	55,5 C. A. + 18,5 magnesia.	
——— lead	....	160	55,5 C. A. + 104,5 ox. lead.	

Vegetable Acids, (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
IV. MALIC ACID........................	....	66		The number 66 is deduced from Braconnot's analysis of the malate of lead.
Malate of baryta	....	138,5	66 M. A. + 72,5 baryta.	
——— lead	....	170,5	66 M. A. + 104,5 ox. lead.	The ultimate components of gallic acid are, 3 hydrogen = 3 6 carbon = 34,2 3 oxygen = 22,5 ——— 59,7
V. GALLIC ACID	....	60		
Gallate of lead	....	164,5	60 G. A. + 104,5 ox. lead.	The number 60 is deduceded from the gallate of lead.
VI. BENZOIC ACID	0,65?	112		According to Berzelius the ultimate components of benzoic acid are, 6 hydrogen = 6 15 carbon = 85,5 3 oxygen = 22,5 ——— 114
Benzoate of ammonia	....	128	112 B. A. + 16 ammonia.	
——— lead	....	216,5	112 B. A. + 104,5 ox. lead.	
VII. ACETIC ACID	....	48		
Acetate of ammonia	....	64	48 A. A. + 16 ammonia.	The number 112 is taken from the benzoate of lead.
——— potassa....................	....	93	48 A. A. + 45 potassa.	
——— soda	2,1	77,5	48 A. A. + 29,5 soda.	

Vegetable Acids, (continued.)

SUBSTANCES	Specific Gravity	Representative Number	COMPOSITION	REMARKS
Acetate of lime	1,00	74,5	48 A. A. + 26,5 lime.	The ultimate component parts of the acetic acid are, 3 hydrogen = 3 4 carbon = 22,8 3 oxygen = 22,5 48,3
——— baryta	....	120,5	48 A. A. + 72,5 baryta.	
——— strontia	....	100	48 A. A. + 52 strontia.	
——— magnesia	1,37	66,5	48 A. A. + 18,5 magnesia.	
——— zinc	....	88,5	48 A. A. + 40,5 ox. zinc.	
——— copper	....	123	48 A. A. + 75 ox. copper.	
——— lead	2,34	152,5	48 A. A. + 104,5 ox. lead.	
Subacetate ditto	....	361,5	48 A. A. + 313,5 ox. lead.	
Acetate mercury	....	245,5	48 A. A. + 197,5 ox. mercury	
IV. *Animal Acids.*				
I. SACCHOLACTIC ACID	....	97		The numbers of the saccholactic and formic acids are taken from their compounds with oxide of lead.
II. URIC ACID	....	33?		
III. * FORMIC ACID	....	35		

* The formic acid is omitted in the text. It is obtained from Ants.

ENGLISH WEIGHTS AND MEASURES.

Troy Weight.

Pound.		Ounces.		Drms.		Scruples.		Grains.		Grammes.
1	=	12	=	96	=	288	=	5760	=	372,96
		1	=	8	=	24	=	480	=	31,08
				1	=	3	=	60	=	3,885
						1	=	20	=	1,295
								1	=	0,06475

Avoirdupois Weight.

Pound.		Ounces.		Drms.		Grains.		Grammes.
1	=	16	=	256	=	7000	=	453,25
		1	=	16	=	437,5	=	28,328
				1	=	27,34375	=	1,7705

Measures.

Gal.		Pints.		Ounces.		Drms.		Cub. Inch.		Litres.
1	=	8	=	128	=	1024	=	231	=	3,78515
		1	=	16	=	128	=	28,875	=	0,47398
				1	=	8	=	1,8047	=	0,02957
						1	=	0,2256	=	0,00396

N. B.—The English ale-gallon contains 282 cubical inches. The wine gallon contains 58176 Troy grains; and the wine pint 7272 Troy grains.

NEW FRENCH WEIGHS AND MEASURES.

Calculated by Dr. DUNCAN, *jun.*

1.—MEASURES OF LENGTH: *the Metre being at 32°, and the Foot at 62°.*

		English inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	,03937						
Centimetre	=	,39371						
Decimetre	=	3,93710						
Metre*	=	39,37100						
Decametre	=	393,71000	=	0	0	10	2	9,7
Hecatometre	=	3937,10000	=	0	0	109	1	1
Kilometre	=	39371,00000	=	0	4	213	1	10,2
Myriometre	=	393710,00000	=	6	1	156	0	6

2.—MEASURES OF CAPACITY.

English.

		Cubic inches.		Tons.	Hogs.	Wine G.	Pints.
Millilitre	=	,06103					
Centilitre	=	,61028					
Decilitre	=	6,10280					
Litre	=	61,02800	=	0	0	0,	2,1133
Decalitre	=	610,28000	=	0	0	2,	5,1352
Hecatolitre	=	6102,80000	=	0	0	26,419	
Kilolitre	=	61028,00000	=	1	0	12,19	
Myriolitre	=	610280,00000	=	10	1	58,9	

3.—MEASURES OF WEIGHT.

Avoirdupois.

		English grains.		Poun.	Oun.	Dram.
Milligramme	=	,0154				
Centigramme	=	,1544				
Decigramme	=	1,5444				
Gramme	=	15,4440				
Decagramme	=	154,4402	=	0	0	5,65
Hecatogramme	=	1544,4023	=	0	3	8,5
Kilogramme	=	15444,0234	=	2	3	5
Myriogramme	=	154440,2344	=	22	1	2

* Lately ascertained by Captain Kater to be 39,37079 inches.—*Phil. Trans.* 1818.

ABLE *of the* QUANTITY *of* OIL *of* VITRIOL (sp. gr. 1,8485,) *and of* DRY SULPHURIC ACID, *in* 100 PARTS *by* WEIGHT *of* DILUTED ACID, *at* DIFFERENT DEN-SITIES. *By* DR. URE.

(Journal of Science, &c. iv. 122.)

quid	Sp. Gr.	Dry	Liq.	Sp. Gr.	Dry	Liq.	Sp. Gr.	Dry
00	1,8485	81,54	66	1,5503	53,82	32	1,2334	26,09
99	1,8475	80,72	65	1,5390	53,00	31	1,2260	25,28
98	1,8460	79,90	64	1,5280	52,18	30	1,2184	24,46
97	1,8439	79,09	63	1,5170	51,37	29	1,2108	23,65
96	1,8410	78,28	62	1,5066	50,55	28	1,2032	22,83
95	1,8376	77,46	61	1,4960	49,74	27	1,1956	22,01
94	1,8336	76,65	60	1,4860	48,92	26	1,1876	21,20
93	1,8290	75,83	59	1,4760	48,11	25	1,1792	20,38
92	1,8233	75,02	58	1,4660	47,29	24	1,1706	19,57
91	1,8179	74,20	57	1,4560	46,48	23	1,1626	18,75
90	1,8115	73,39	56	1,4460	45,66	22	1,1549	17,94
89	1,8043	72,57	55	1,4360	44,85	21	1,1480	17,12
88	1,7962	71,75	54	1,4265	44,03	20	1,1410	16,31
87	1,7870	70,94	53	1,4170	43,22	19	1,1330	15,49
86	1,7774	70,12	52	1,4073	42,40	18	1,1246	14,68
85	1,7673	69,31	51	1,3977	41,58	17	1,1165	13,86
84	1,7570	68,49	50	1,3884	40,77	16	1,1090	13,05
83	1,7465	67,68	49	1,3788	39,95	15	1,1019	12,23
82	1,7360	66,86	48	1,3697	39,14	14	1,0953	11,41
81	1,7245	66,05	47	1,3612	38,32	13	1,0887	10,60
80	1,7120	65,23	46	1,3530	37,51	12	1,0809	9,78
79	1,6993	64,42	45	1,3440	36,69	11	1,0743	8,97
78	1,6870	63,60	44	1,3345	35,88	10	1,0682	8,15
77	1,6750	62,78	43	1,3255	35,06	9	1,0614	7,34
76	1,6630	61,97	42	1,3165	34,25	8	1,0544	6,52
75	1,6520	61,15	41	1,3080	33,43	7	1,0477	5,71
74	1,6415	60,34	40	1,2999	32,61	6	1,0405	4,89
73	1,6321	59,52	39	1,2913	31,80	5	1,0336	4,08
72	1,6204	58,71	38	1,2826	30,98	4	1,0268	3,26
71	1,6090	57,89	37	1,2740	30,17	3	1,0206	2,446
70	1,5975	57,08	36	1,2654	29,35	2	1,0140	1,63
69	1,5868	56,26	35	1,2572	28,54	1	1,0074	0,8154
68	1,5760	55,45	34	1,2490	27,72			
67	1,5648	54,63	33	1,2409	26,91			

TABLE *shewing the* PROPORTION *of* REAL *or* DRY NITRIC ACID *in* 100 PARTS *of the* LIQUID ACID, *at successive* SPECIFIC GRAVITIES. *By* DR. URE.

(Journal of Science, iv. 297.)

Specific Gravity	Acid in 100	Specific Gravity	Acid in 100	Specific Gravity	Acid in 100
1,5000	79,700	1,3783	52,602	1,1833	25,504
1,4980	78,903	1,3732	51,805	1,1770	24,707
1,4960	78,106	1,3681	51,068	1,1709	23,910
1,4940	77,309	1,3630	50,211	1,1648	23,113
1,4910	76,512	1,3579	49,414	1,1587	22,316
1,4880	75,715	1,3529	48,617	1,1526	21,519
1,4850	74,918	1,3477	47,820	1,1465	20,722
1,4820	74,121	1,3427	47,023	1,1403	19,925
1,4790	73,324	1,3376	46,226	1,1345	19,128
1,4760	72,527	1,3323	45,429	1,1286	18,331
1,4730	71,730	1,3270	44,632	1,1227	17,534
1,4700	70,933	1,3216	43,835	1,1168	16,737
1,4670	70,136	1,3163	43,038	1,1109	15,940
1,4640	69,339	1,3110	42,241	1,1051	15,143
1,4600	68,542	1,3056	41,444	1,0993	14,346
1,4570	67,745	1,3001	40,647	1,0935	13,549
1,4530	66,948	1,2947	39,850	1,0878	12,752
1,4500	66,155	1,2887	39,053	1,0821	11,955
1,4460	65,354	1,2826	38,256	1,0764	11,158
1,4424	64,557	1,2765	37,459	1,0708	10,361
1,4385	63,760	1,2705	36,662	1,0651	9,564
1,4346	62,963	1,2644	35,865	1,0595	8,767
1,4306	62,166	1,2583	35,068	1,0540	7,970
1,4269	61,369	1,2523	34,271	1,0485	7,173
1,4228	60,572	1,2462	33,474	1,0430	6,376
1,4189	59,775	1,2402	32,677	1,0375	5,579
1,4147	58,978	1,2341	31,880	1,0320	4,782
1,4107	58,181	1,2277	31,083	1,0267	3,985
1,4065	57,384	1,2212	30,286	1,0212	3,188
1,4023	56,587	1,2148	29,489	1,0159	2,391
1,3978	55,790	1,2084	28,692	1,0106	1,594
1,3945	54,993	1,2019	27,895	1,0053	0,797
1,3882	54,196	1,1958	27,098		
1,3833	53,399	1,1895	26,301		

TABLE *of the* QUANTITY *of* REAL *or* DRY MURIATIC ACID *in* 100 PARTS *of the* LIQUID ACID, *at successive* SPECIFIC GRAVITIES. *By* DR. URE.

(Thomson's Annals of Philosophy, x. 371.)

Specific Gravity	Acid in 100	Specific Gravity	Acid in 100	Specific Gravity	Acid in 100
1,1920	28,30	1,1272	18,68	1,0610	9,05
1,1900	28,02	1,1253	18,39	1,0590	8,77
1,1881	27,73	1,1233	18,11	1,0571	8,49
1,1863	27,45	1,1214	17,83	1,0552	8,21
1,1845	27,17	1,1194	17,55	1,0533	7,92
1,1827	26,88	1,1173	17,26	1,0514	7,64
1,1808	26,60	1,1155	16,98	1,0495	7,36
1,1790	26,32	1,1134	16,70	1,0477	7,07
1,1772	26,04	1,1115	16,41	1,0457	6,79
1,1753	25,75	1,1097	16,13	1,0438	6,51
1,1735	25,47	1,1077	15,85	1,0418	6,23
1,1715	25,19	1,1058	15,56	1,0399	5,94
1,1698	24,90	1,1037	15,28	1,0380	5,66
1,1679	24,62	1,1018	15,00	1,0361	5,38
1,1661	24,34	1,0999	14,72	1,0342	5,09
1,1642	24,05	1,0980	14,43	1,0324	4,81
1,1624	23,77	1,0960	14,15	1,0304	4,53
1,1605	23,49	1,0941	13,87	1,0285	4,24
1,1587	23,20	1,0922	13,58	1,0266	3,96
1,1568	22,92	1,0902	13,30	1,0247	3,68
1,1550	22,64	1,0883	13,02	1,0228	3,39
1,1531	22,36	1,0863	12,73	1,0209	3,11
1,1510	22,07	1,0844	12,45	1,0190	2,83
1,1491	21,79	1,0823	12,17	1,0171	2,55
1,1471	21,51	1,0805	11,88	1,0152	2,26
1,1452	21,22	1,0785	11,60	1,0133	1,98
1,1431	20,94	1,0765	11,32	1,0114	1,70
1,1410	20,66	1,0746	11,04	1,0095	1,41
1,1391	20,37	1,0727	10,75	1,0076	1,13
1,1371	20,09	1,0707	10,47	1,0056	0,85
1,1351	19,81	1,0688	10,19	1,0037	0,56
1,1332	19,53	1,0669	9,90	1,0019	0,28
1,1312	19,24	1,0649	9,62	1,0000	0,00
1,1293	18,96	1,0629	9,34		

TABULAR VIEW OF THE COMPOSITION OF MINERAL WATERS.

One Pint (Wine Measure) contains the following Ingredients:

	WATERS	GASES: Nitrogen C. I.	GASES: Carbonic Acid, C. I.	GASES: Sulphuretted Hydrogen C. I.	CARBONATES: Carbonate of Soda, grains	CARBONATES: Carbonate of Magnesia, grains	CARBONATES: Carbonate of Lime, grains	SULPHATES: Sulphate of Soda, grains	SULPHATES: Sulphate of Magnesia, grains	SULPHATES: Sulphate of Lime, grains	MURIATES: Muriate of Soda, grains	MURIATES: Muriate of Magnesia, grains	MURIATES: Muriate of Lime	Oxide of Iron	Silica	Temperature	Total of Saline Contents.	AUTHORITY
CARBONATED	Seltzer	......	17,	......	4,	5,	3,	......	......	......	17,	......	......	....	....	Cold	29,	Bergman.
	Pyrmont	......	26,	......	......	10,	4,5	......	5,5	8,5	1,5	......	......	0,6	....	do.	30,6	Ditto.
	Spa	......	13,	......	1,5	4,5	1,5	......	......	......	0,2	......	......	0,6	....	do.	8,3	Ditto.
	Carlsbad	......	5,	......	5,	......	1,5	8,5	......	......	4,5	......	......	a trace	0,3	165°	19,8	Klaproth.
	Pouges	......	30,	......	10,	1,2	12,	......	......	......	2,2	......	......	2,5	0,5	Cold	28,4	Hassenfratz.
	Saint Parize	......	22,	......	......	0,5	11,5	......	......	13,	......	......	......	....	....	do.	25,	Ditto.
SULPHUREOUS	Harrogate	0,8	1,	2,3	......	0,7	2,5	......	1,3	......	77,	11,	1,5	....	....	do.	94,	Garnet.
	Moffatt	0,5	0,6	1,2	......	......	......	......	......	......	4,5	......	......	....	....	do.	4,5	Ditto.
	Aix la Chapelle	......	......	5,5	12,	......	4,2	......	......	......	5,	......	......	....	....	143°	21,2	Bergman.
	Cheltenham Sulphur Spring	......	1,5	2,5	......	......	......	23,5	5,	1,2	35,	......	......	0,3	....	Cold	65,	Parkes & Brande
SALINE	Seidlitz	......	......	......	......	2,5	0,8	......	180,	5,	......	4,5	......	....	....	do.	192,8	Bergman.
	Cheltenham pure Saline	......	......	......	......	......	......	15,	11,	4,5	50,	......	......	....	....	do.	80,5	Parkes & Brande
	Bristol	......	3,5	......	......	......	1,5	1,5	......	1,5	0,5	1,	......	....	....	74°	6,	Carrick.
	Buxton	0,2	......	......	......	......	1,3	......	......	0,3	0,2	......	......	0,03	....	82°	1,83	Pearson.
	Bath	......	1,2	......	......	......	0,8	1,5	......	9,	3,3	......	......	a trace	0,2	116°	14,6	Phillips.
	Scarborough	......	......	......	......	......	a trace	20,	......	9,	......	......	......	ditto	....	Cold	29,	Saunders.
	Barege	......	......	uncertain	2,5	......	ditto	......	......	a trace	0,5	......	......	....	....	120	3,	Ditto.
	Plombieres	......	......	......	2,2	......	0,3	2,3	......	......	1,5	......	......	....	0,3	?	66,	Vauquelin.
	Kilburn	......	3,5	8,5 ?	......	0,5	1,	12,	37,	5,5	2,5	5,5	0,2	a trace	....	Cold	64,2	Schmeisser.
	Lemington New Bath	0,4	a trace	a trace	......	......	......	19,	......	14,	53,	1,5	......	0,8	....	do.	88,3	Lambe.
	Lemington Old Bath	0,3	......	ditto	......	......	......	7,5	7,	18,	41,	......	......	....	....	do.	73,5	Ditto.
CHALYBEATE	Tunbridge	0,50	1,	a trace of oxygen	......	......	0,03	......	......	0,17	0,30	0,03	0,05	0,28	....	do.	0,86	Scudamore.
	Cheltenham Chalybeate	......	2,5	......	0,5	......	......	22,7	6,	2,5	41,3	......	......	0,8	....	do.	73,8	Parkes & Brande
	Brighton	......	2,2	......	......	......	......	......	......	4,	3,	0,75	......	1,4	0,14	do.	9,29	Marcet.

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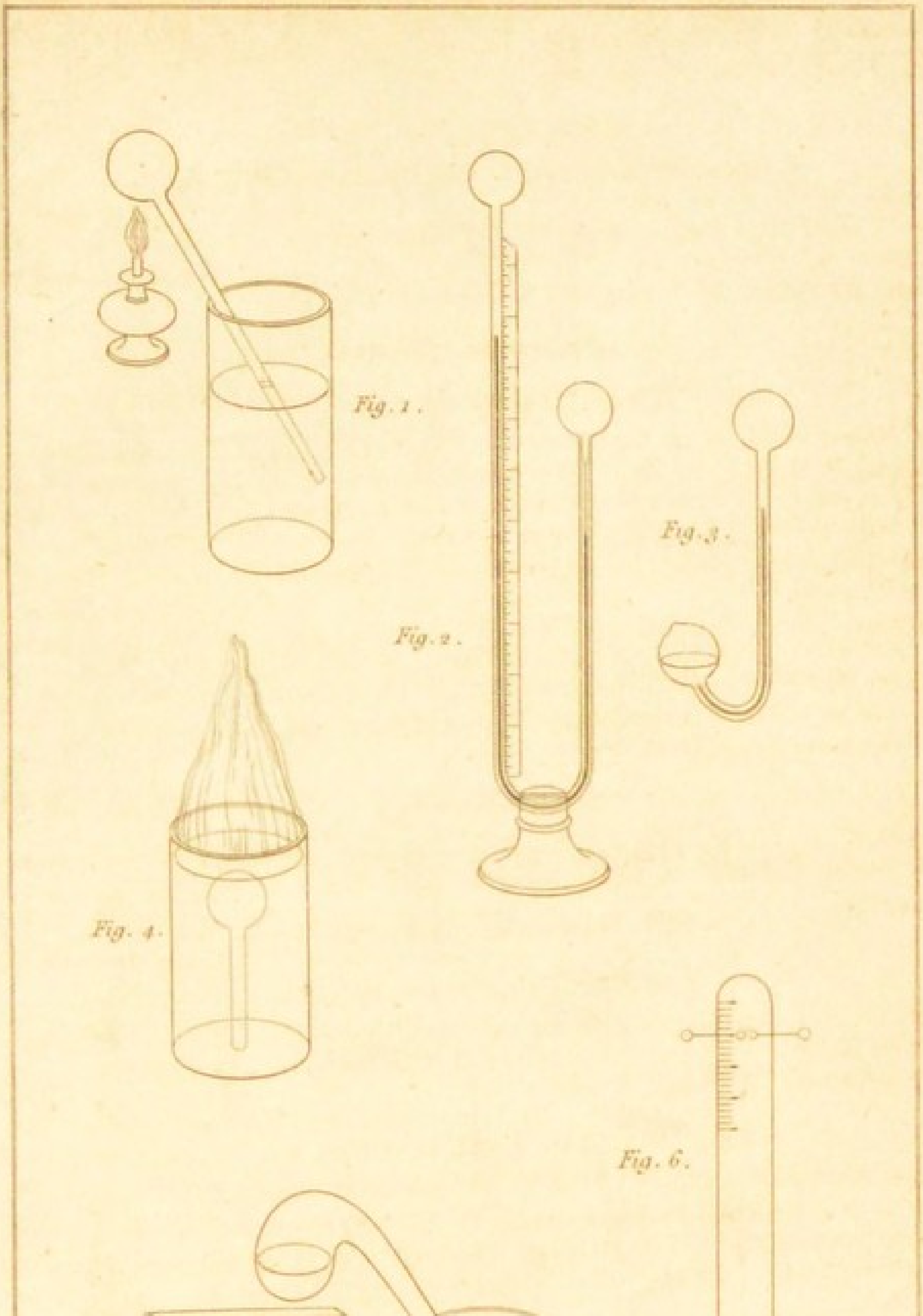

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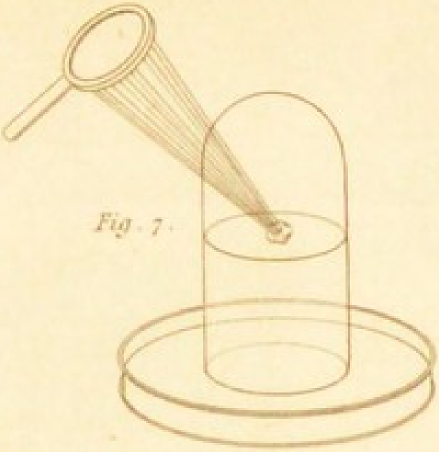

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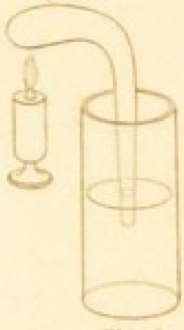

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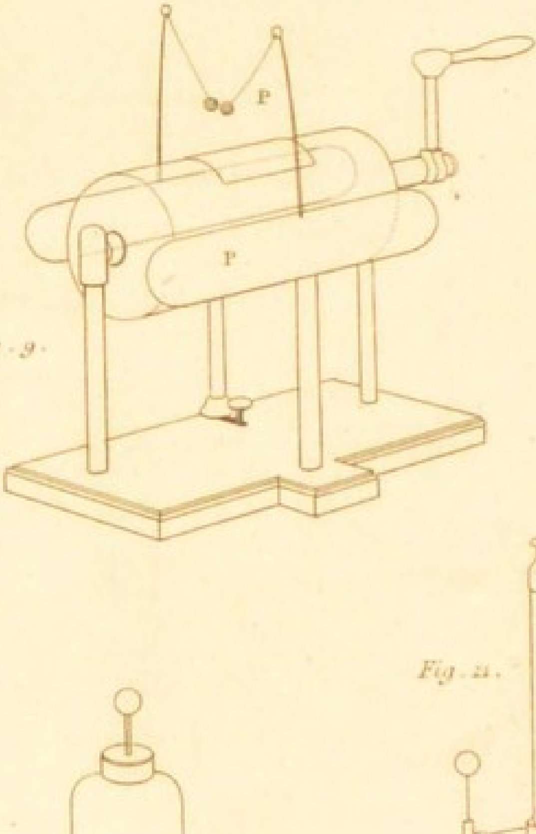

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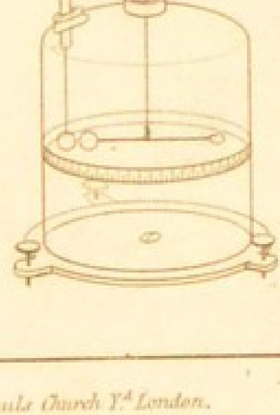

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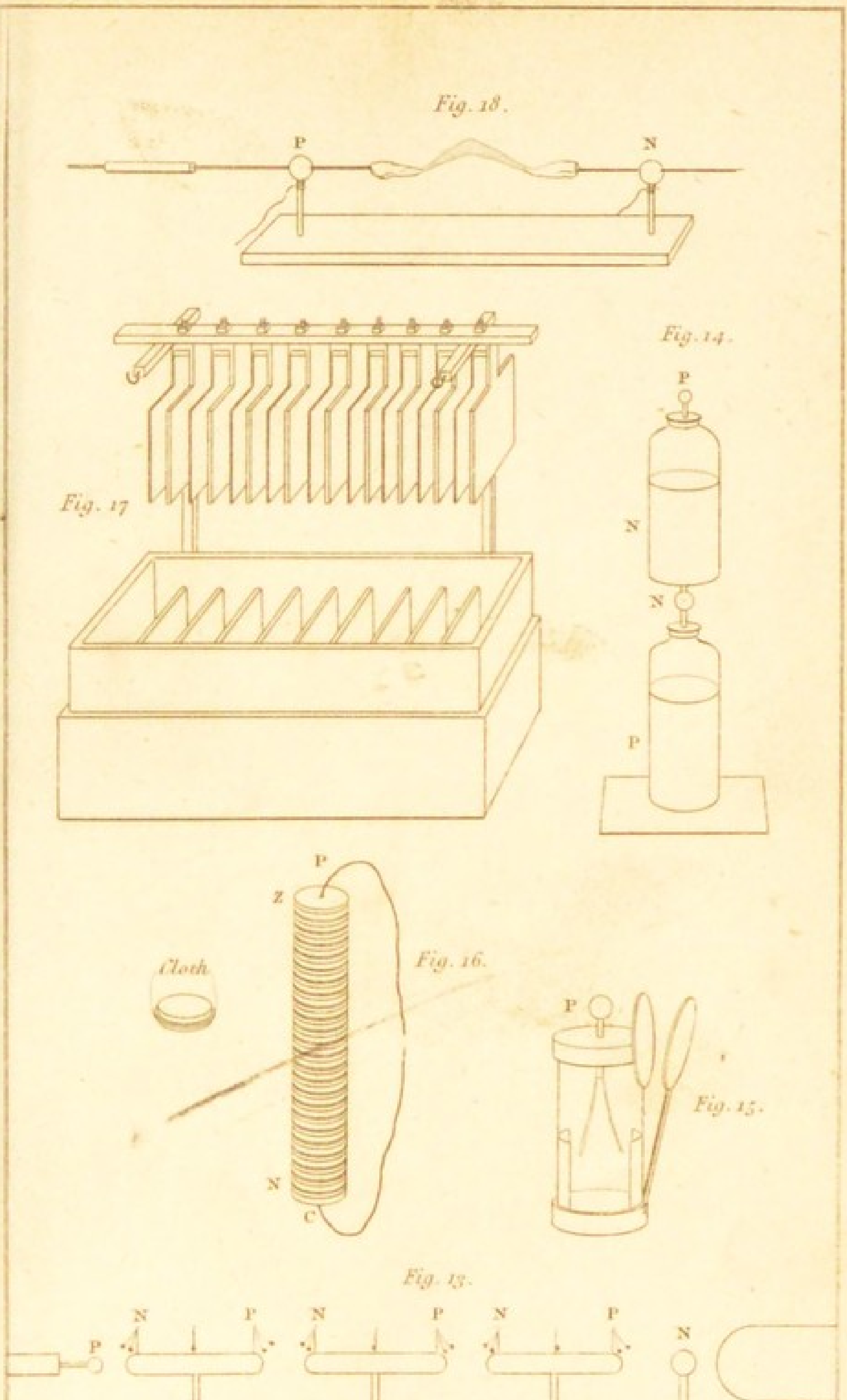

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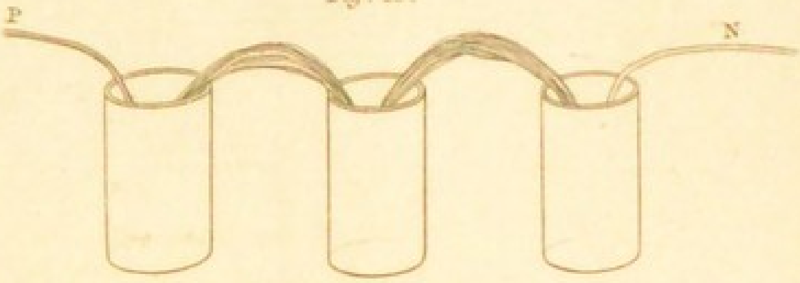

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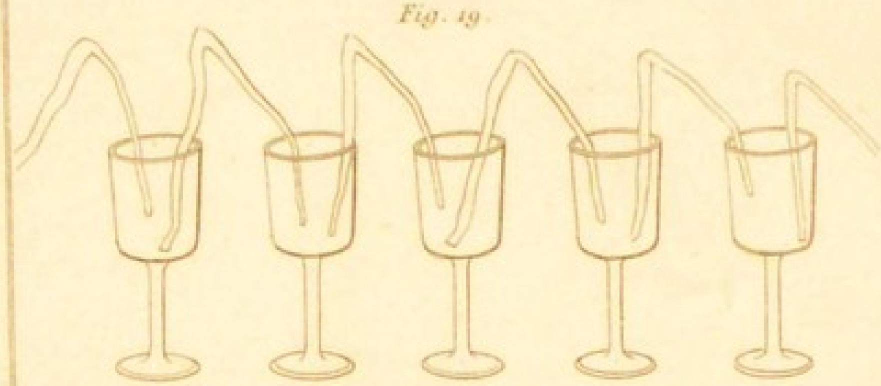

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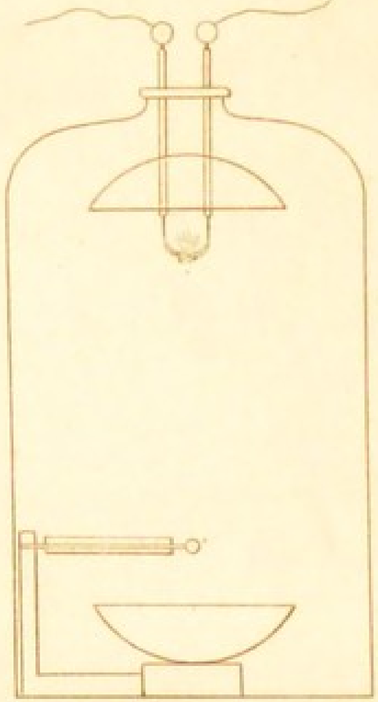

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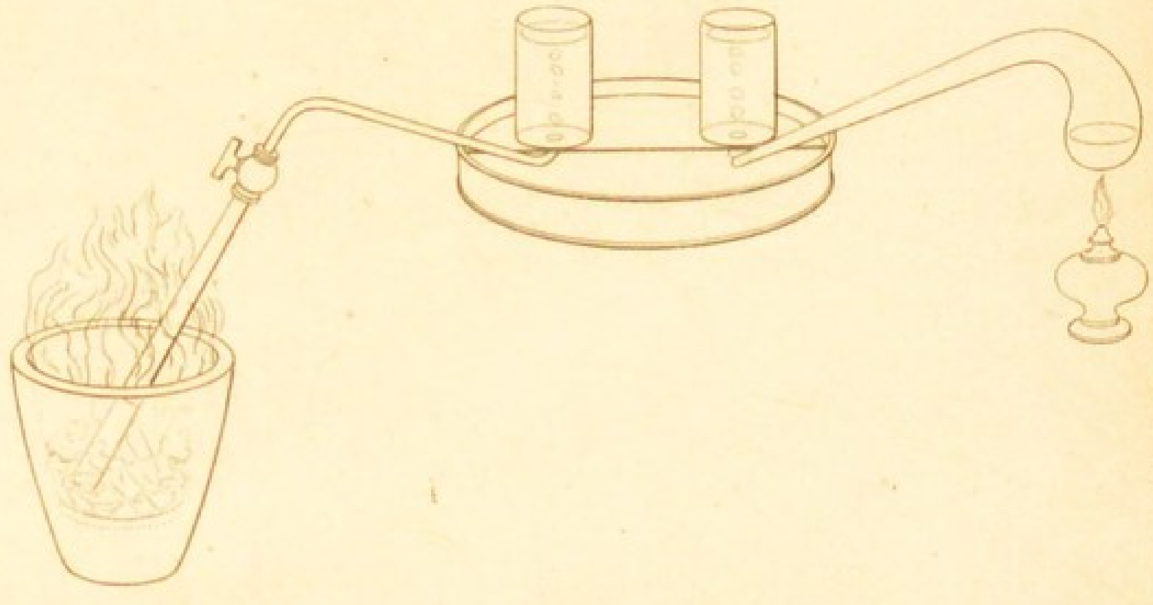

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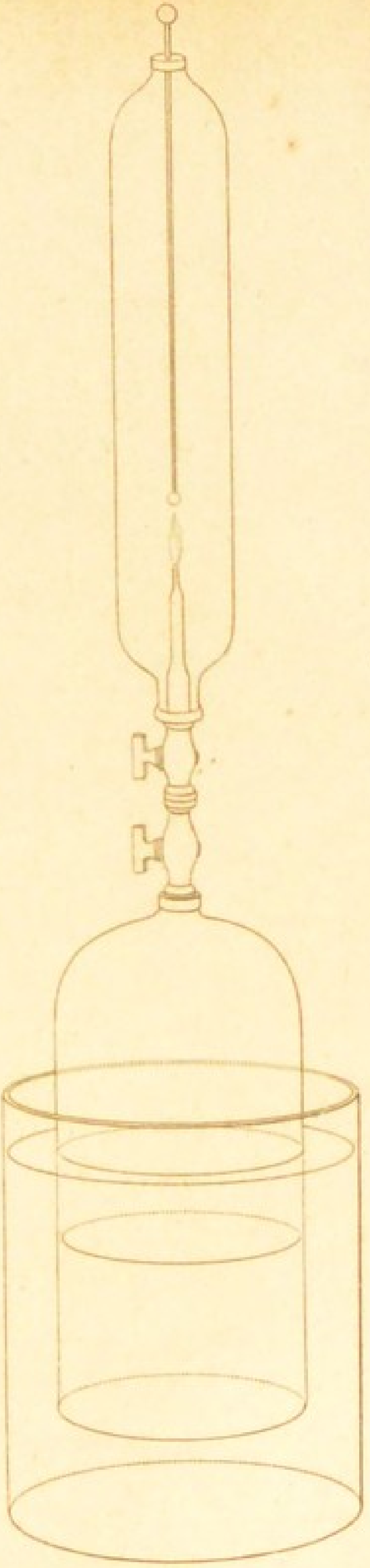

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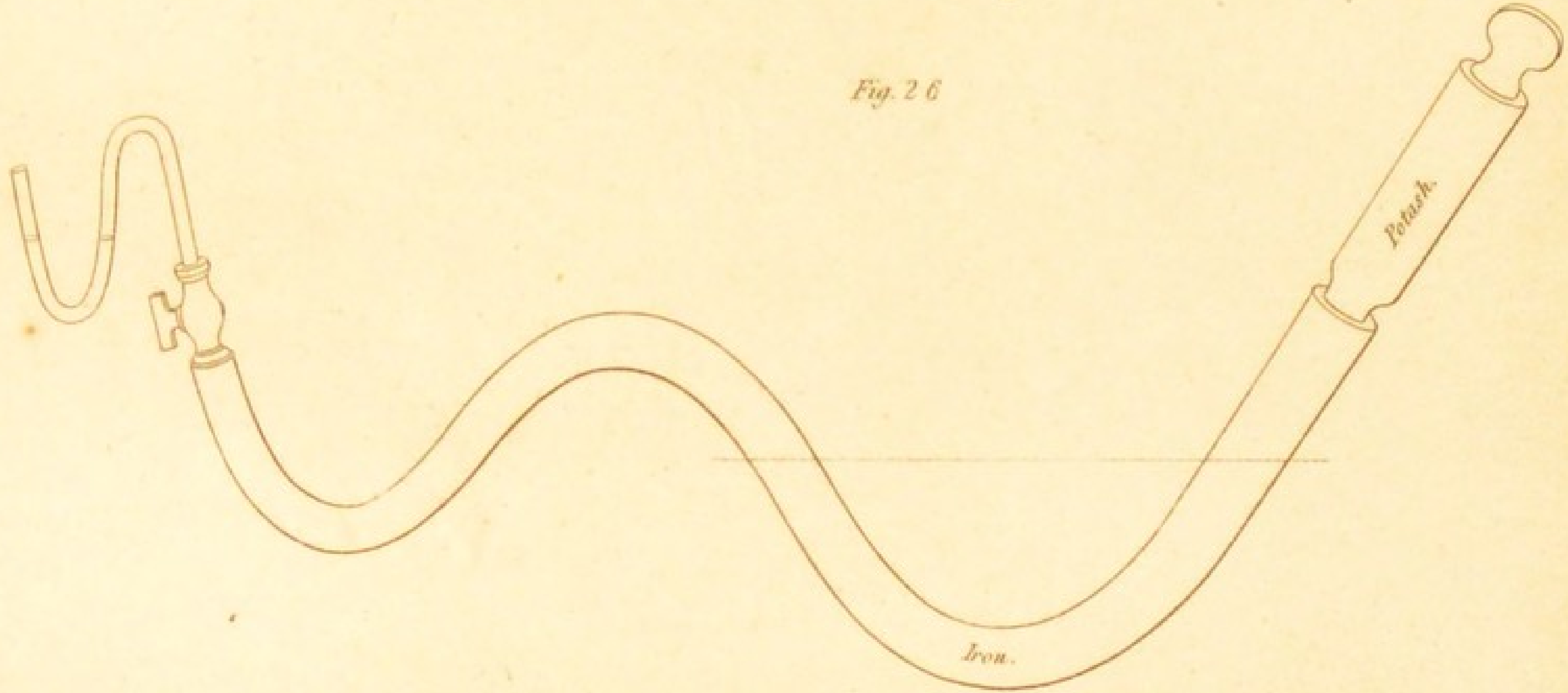

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