

The elements of experimental chemistry.

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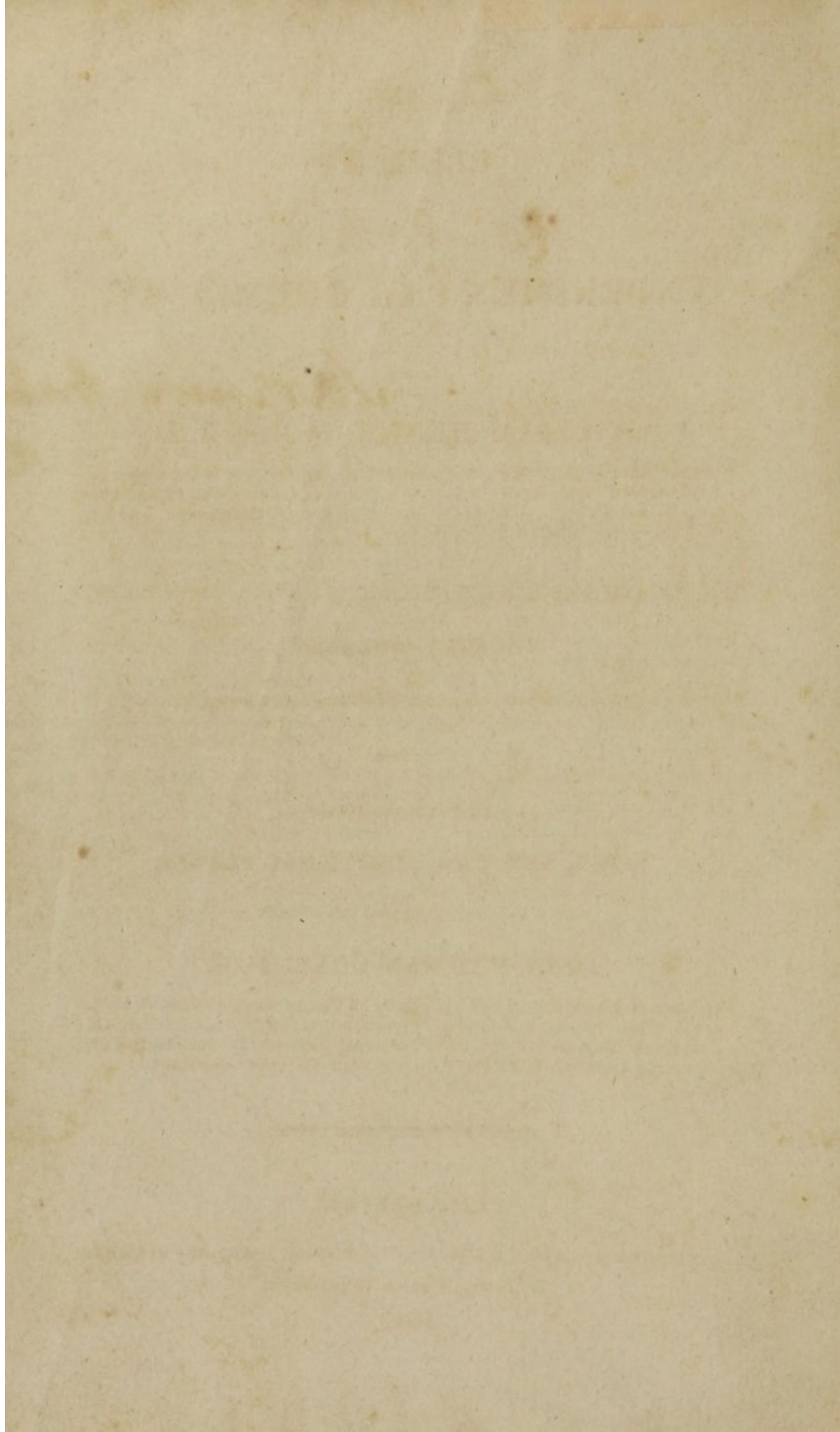


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THE
ELEMENTS
OF
EXPERIMENTAL CHEMISTRY,

BY *Stevenson Archer*
WILLIAM HENRY, M.D. F.R.S.

Member of the Roy. Med. and Wernerian Societies of Edinburgh; the Medico-Chirurgical and Geological Societies of London; the Physical Soc. of Jena; Vice Pres. of the Lit. and Phil. Soc. of Manchester; and Physician to the Manchester Infirmary.

1822

THE FOURTH AMERICAN, FROM THE SEVENTH LONDON EDITION,
GREATLY ENLARGED;

AND ILLUSTRATED WITH NINE PLATES, ENGRAVED BY LOWRY.



TO WHICH ARE ADDED,

NOTES, AND TWO ADDITIONAL PLATES,

BY

JOHN REDMAN COXE, M. D.

Professor of Chemistry in the University of Pennsylvania; Member of the Am. Phil. Society, and of the Batavian Society of Sciences at Haarlem; Ordinary Member of the Royal Medical Society of Copenhagen; and Foreign Member of the Royal Society of Sciences at Copenhagen.



PHILADELPHIA:

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1817.

District of Pennsylvania, to wit:

BE IT REMEMBERED, That, on the nineteenth day of September, in the forty-second year of the Independence of the United States of America, A. D. 1817, John Redman Coxe, M. D. of the said District, hath deposited in this office the title of a book, the right whereof he claims as proprietor, in the words following, to wit :

“The Elements of Experimental Chemistry, by William Henry, M. D. F. R. S. Member of the Roy. Med. and Wernerian Societies of Edinburgh; the Medico-Chirurgical and Geological Societies of London; the Physical Soc. of Jena; Vice Pres. of the Lit. and Phil. Soc. of Manchester, and Physician to the Manchester Infirmary. The fourth American, from the Seventh London Edition, greatly enlarged; and illustrated with nine Plates, engraved by Lowry. To which are added, Notes, and two additional Plates, by John Redman Coxe, M. D. Professor of Chemistry, in the University of Pennsylvania, Member of the Am. Phil. Society, and of the Batavian Society of Sciences at Haarlem, Ordinary Member of the Royal Medical Society of Copenhagen, and Foreign Member of the Royal Society of Sciences at Copenhagen.”

In conformity to the act of the Congress of the United States, intituled, “An act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies, during the times therein mentioned.” And also to the act, entitled, “An act supplementary to an act, entitled, ‘An act for the encouragement of learning, by securing the copies of maps, charts, and books, to the authors and proprietors of such copies during the times therein mentioned,’ and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints.”

D. CALDWELL,
Clerk of the District of Pennsylvania.

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TO THE

AMERICAN EDITION.

IN the present unsettled state of chemistry, when new discoveries are delapidating the fair fabric which Lavoisier and his colleagues had erected on the ruins of the Phlogistic School ; an apology is scarcely necessary for those deviations that may appear in the notes of the American Editor, (to this edition of Dr. Henry's Elements,) from those doctrines to which we have been long accustomed to bow with respectful homage. The want of a proper text book, to aid in the lectures delivered in the University of Pennsylvania, has long been felt; and nothing but that unsettled state, adverted to above, has prevented such a work from making its appearance. Dr. Henry's Elements has hitherto supplied its place ; and from the intrinsic merits of the work, it has, it is believed, (especially as improved by the notes of Professor Silliman,) been generally adopted in the different Colleges and Universities of the United States. It would have been highly gratifying to the Editor of the present edition, could he have had the advantage of those notes ; but as this could not be expected, and as the seventh edition of the English copy, from which this is printed, embraces all, or most of the new discoveries, to the end of 1815, it was judged proper merely to add a few notes, which might, in some degree, approximate it to the purpose intended.

That great changes must ensue from the recent discoveries in the theoretical part of the science, can scarcely be doubted. The idea of oxygen as an exclusive acidifying principle, is not now entertained by the French themselves ; and if the Scavans of that school admit the inadequacy of the Lavoisierian doctrines in this and other respects, we cannot feel ourselves obliged to support what they have thus abandoned. Whether the old phlogistic doctrines, modified, and embodied on what appears true in those of its antagonist, will again resume a place in the schools of chemistry, remains to be ascertained by the progress of research. It is the opinion of the Editor, so far as he is enabled to form one, that, sooner or later, this must be the case : nor can he perceive any difficulty which such a conjunction can pos-

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sibly increase ; on the contrary, he believes that a doctrine more reasonable and satisfactory than either, alone, must result therefrom. Indeed, so long as we actually remain ignorant of what is, and what is not a simple body, so long will it be impossible to erect a theory which shall be permanent. Each day successively demonstrating our errors on this fundamental point, will necessarily render it expedient to alter the superstructure. Our theories are more properly to be regarded as hypotheses ; and are useful, merely from enabling us to classify the numerous facts which are established ; but which, without such a classification, must become a burden to the most retentive memory. Had Lavoisier lived, he must have submitted to the progress of science, and have acknowledged, that however beautiful might be the hypothesis he constructed thirty years ago, yet that, like the fashion of the day, it could no longer be regarded as binding upon his successors.

Dr. Murray has well observed, that “the simplicity of the substances assumed as the basis of arrangement, can never be demonstrated. They are regarded as simple, only because we are unable to decompose them ; but this may arise, not from their real simplicity, but from the imperfection of our knowledge, and of our instruments of analysis. As the science advances, their composition is accordingly in general discovered ; and whenever this happens, the basis of the classification is subverted, and a new class of substances, supposed to be simple, is again formed ; of the simplicity of which, however, there is no better proof than of the former : the progress of discovery, probably, will prove them to be compounds, and the whole system must be again changed. This must continue until the ultimate principles of bodies are discovered—a period from which chemistry is undoubtedly far distant.” And these observations, which are intended by him to show the difficulty of a proper classification, are equally cogent, when applied to the theories which have been attempted to be established. In short, the more the subject is contemplated, so much more hopeless appears the practicability of supporting, for a length of time, any hypothesis whatsoever, in chemical science ; since it must inevitably yield to each addition, which time and investigation shall bring with them.

Philadelphia, September 12th, 1817.

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TO THE

SEVENTH ENGLISH EDITION.

THE publication of this edition of the *ELEMENTS OF CHEMISTRY* has been delayed, by circumstances in which the reader can take no interest, long after the period when a new impression had been called for by the public. During the interval which has elapsed since the foregoing edition, the progress of Chemistry has been marked, not only by the discovery of a great number of new facts, but by important changes in the general principles of the science. It has been necessary, therefore, to revise the whole work with the greatest care; to make large additions to most of the sections; and to introduce several entirely new ones. These alterations I have been enabled to effect, without materially increasing the bulk of the volumes, by the enlargement of the page, and by the rejection of every thing, which recent experience has corrected or rendered doubtful.

Though no pains have been spared to render the work a faithful abstract of the present state of Chemistry, yet it is probable that errors and omissions will, after all, be discovered in it. In correcting these, I hope to be assisted by a continuance of those candid criticisms, both through public and private channels of communication, to which I have already been much indebted.

Manchester, October, 1815.

INTRODUCTION.*

It has so long been a custom to preface a course of lectures with the history of the science which is their subject, that it may be necessary to state, briefly, the reasons that have induced me to depart from this established usage.

The history of chemistry may either be merely a history of the science, that is, a view of the progressive development of the facts and doctrines of which the science is composed; or it may comprehend, also, the biography of chemists. The detail of the progress of discovery, however, concerning particular objects of chemical research, would certainly be premature, at a period, when the student may be supposed to be ignorant of the external forms, and even of the existence, of no inconsiderable part of them. Respecting chemists themselves, little can be said that can contribute to information or amusement; for their lives, devoted to the abstract pursuits of science, have seldom been productive of events, that are suited to awaken or gratify general curiosity. Our interest, indeed, respecting philosophers, is seldom excited, unless by a knowledge of the additions which they have made to the facts or theories of a science; and with these a lecturer may fairly presume, however the fact may really be, that his hearers, at the commencement of a course, are wholly unacquainted. On these grounds, therefore, I hope to be excused for devoting to other purposes the time, that would have been allotted to the history of the science. For this will be substituted a brief view of the nature and objects of chemistry; of its connexion with the arts and with other sciences; and an outline of the plan on which the following lectures will be conducted.

* The following discourse formed, originally, the introduction to a series of lectures delivered in Manchester, and was afterwards published under the title of "A General View of the Nature and Objects of Chemistry, and of its Application to Arts and Manufactures." As the readers of an elementary book may be presumed to require a similar plan of instruction, with the hearers of a popular course of lectures, I have thought it unnecessary to alter the form under which the essay first appeared, though a few passages are applicable chiefly to the persons to whom it was originally addressed.

Natural philosophy, in its most extensive sense, is a term comprehending every science, that has for its objects the properties and affections of matter. But it has attained, by the sanction of common language, a more limited signification ; and chemistry, though strictly a branch of natural philosophy, is generally regarded as a distinct science. Between the two it may, perhaps, be difficult to mark out precisely the line of separation : but, an obvious character of the facts of natural philosophy is, that they are always attended with sensible motion ; and the determination of the laws of motion is peculiarly the office of its cultivators. Chemical changes, on the other hand, of the most important kind, often take place without any apparent motion, either of the mass, or of its minute parts ; and where the eye is unable to perceive that any change has occurred. The laws of gravitation, of central forces, and all the other powers that fall under the cognizance of the natural philosopher, produce, at most, only a change of place in the bodies that obey their influence. But, in chemical changes, we may always observe an important difference in the properties of things ; their appearances and qualities are completely altered, and their individuality destroyed. Thus, two highly corrosive substances, by uniting chemically together, may become mild and harmless ; the combination of two colourless substances may present us with a compound of brilliant complexion ; and the union of two fluids, with a compact and solid mass.

Chemistry, therefore, may be defined, that science, the object of which is to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies.*

From this definition, it may readily be conceived, how wide is the range of chemical inquiry ; and, by applying it to the various events that daily occur in the order of nature, we shall be enabled to separate them with accuracy, and to allot, to the sciences of natural philosophy and chemistry, the proper objects of the cultivation of each. Whenever a change of place is a necessary part of any event, we shall call in the aid of the former. When this condition may be dispensed with, we shall resort to chemistry for the light of its principles. But it will be often found, that the concurrence of the two sciences is essential to the full explanation of phenomena. The water of the ocean, for example, is raised into

* The reader, who wishes to examine other definitions of chemistry, will find a variety of them, collected by Dr. Black, in the first volume of his "Lectures."

the atmosphere by its chemical combination with the matter of heat; but the clouds, that are thus formed, maintain their elevated situation by virtue of a specific gravity inferior to that of the lower regions of the air,—a law, the discovery and application of which are due to the natural philosopher, strictly so called.

It has not been unusual to consider chemistry, under the twofold view of a science and of an art. This arrangement, however, appears to have had its origin in an imperfect discrimination between two objects, that are essentially distinct. Science consists of assemblages of facts, associated together in classes, according to circumstances of resemblance or analogy. The business of its cultivators is, first, to investigate and establish individual truths, either by the careful observation of natural appearances, or of new and artificial combinations of phenomena produced by the instruments of experiment. The next step is the induction, from well ascertained facts, of general principles or laws, more or less comprehensive in their extent, and serving, like the classes and orders of natural history, the purposes of an artificial arrangement. Of such a body of facts and doctrines, the science of chemistry is composed. But the employment of the artist consists merely in producing a given effect, for the most part by the sole guidance of practice or experience. In the repetition of processes, he has only to follow an established rule; and, in the improvement of his art, he is benefited generally by fortuitous combinations, to which he has not been directed by any general axiom. An artist, indeed, of enlarged and enlightened mind, may avail himself of general principles, and may employ them as an useful instrument in perfecting established operations: but the art and the science are still marked by a distinct boundary. In such hands, they are auxiliaries to each other; the one contributing a valuable accession of facts; and the other, in return, imparting fixed and comprehensive principles, which simplify the processes of art, and direct to new and important practices.

The possession of the general principles of chemistry enables us to comprehend the mutual relation of a great variety of events, that form a part of the established course of nature. It unfolds the most sublime views of the beauty and harmony of the universe; and develops a plan of vast extent, and of uninterrupted order, which could have been conceived only by perfect wisdom, and executed by unbounded power. By withdrawing the mind, also, from pursuits and amusements that excite the imagination, its investigations may tend, in common with the rest of the physical sci-

ences, to the improvement of our intellectual and moral habits; to strengthen the faculty of patient and accurate thinking; and to substitute placid trains of feeling, for those which are too apt to be awakened by the contending interests of men in society, or the imperfect government of our own passions.

The class of natural events, that call for the explanation of chemical science, is of very considerable extent; and the natural philosopher (using this term in its common acceptation) is wholly incompetent to unfold their connexion. He may explain, for example, on the principles of his own science, the annual and diurnal revolutions of the Earth, and part of the train of consequences depending on these rotations. But here he must stop; and the chemist must trace the effects, on the Earth's surface, of the caloric and light derived from the sun; the absorption of caloric by the various bodies on which it falls; the consequent fluidity of some, and volatilization of others; the production of clouds, and their condensation in the form of rain; and the effects of this rain, as well as of the sun's heat, on the animal, vegetable, and mineral kingdoms. In these minuter changes, we shall find, there is not less excellence of contrivance, than in the stupendous movements of the planetary system. And they interest us even more nearly; because, though not more connected with our existence or comfort, yet they are more within our sphere of observation; and an acquaintance with their laws admits of a more direct application to human affairs.

There is another branch of knowledge (that of natural history), which is materially advanced by the application of chemical science. The classifications of the naturalist are derived from an examination and comparison of the external forms, both of animate and inanimate bodies. He distributes the whole range of nature into three great and comprehensive kingdoms,—the animal, the vegetable, and the mineral. Each of these, again, is subdivided into several less extensive classes; and individual objects are referred to their place in the system, by the agreement of their characters, with those assigned to the class, order, and genus. In the different departments of natural history, these resemblances vary in distinctness, in facility of observation, and in certainty of description. Thus, the number and disposition of the parts of fructification in vegetables afford marks of discrimination, which are well defined, and easily ascertained. But minerals, that are not possessed of a regularly crystallized form, are distinguished by outward qualities that scarcely admit of being accurately convey-

ed by language ; such as minute shades of colour ; or trifling differences of hardness, transparency, &c. To the evidence of these loose and varying characters, that of the chemical composition of minerals has within the few past years been added ; and mineralogy has been advanced, from a confused assemblage of its objects, to the dignity of a well methodized and scientific system. In the example of crystallized bodies, the correspondence between external form and chemical composition, has been most successfully traced by the genius of Haüy ; whose method of investigation has enabled him, in numerous instances, to anticipate, from physical characters, the results of the most skilful and laborious analysis.

It is unnecessary to pursue this part of the subject to a greater extent ; because, to all who have been in the habit of philosophical investigation, the connexion between the sciences must be sufficiently apparent ; and because there is another ground, on which chemistry is more likely to claim, with success, the respect and attention of the great mass of mankind. This is, its capacity of ministering to our wants and our luxuries, and of instructing us to convert to the ordinary purposes of life, many substances which nature presents in a rude and useless form. The extraction of metals from their ores ; the conversion of the rudest materials into the beautiful fabrics of glass and porcelain ; the production of wine, ardent spirits, and vinegar ; and the dyeing of linen and woollen manufactures,—are only a few of the arts that are dependent on chemistry for their improvement, and even for their successful practice.

It cannot, however, be denied, that all the arts which have been mentioned were practised in times when the rank of chemistry, as a science, was extremely degraded ; and that they are the daily employment of unlettered and ignorant men. But to what does this confession amount ? and how far does it prove the independence of the above arts on the science of chemistry ?

The skill of an artist is compounded of knowledge and of manual dexterity. The latter, it is obvious, no science can teach. But the acquirement of experience, in other words, a talent for accurate observation of facts, and the habit of arranging facts in the best manner, may be greatly facilitated by the possession of scientific principles. Indeed, it is hardly possible for any one to frame rules for the practice of a chemical art, or to profit by the rules of others, who is unacquainted with the general doctrines of the science. For, in all rules, it is implied, that the promised effect

will only take place, when circumstances are precisely the same, as in the case under which the rule was formed. To ensure an unerring uniformity of result, the substances, employed in chemical processes, must be of uniform composition and excellence; or, when it is not possible to obtain them thus unvaried, the artist should be able to judge precisely of the defect, that he may proportion his agents according to their qualities. Were chemical knowledge more generally possessed, we should hear less of failures and disappointments in chemical operations; and the artist would commence his proceedings, not, as at present, with distrust and uncertainty, but with a well grounded expectation of success.

It will scarcely be contended, that any one of the arts has hitherto attained the extent of its possible perfection. In all, there is yet a wide scope for improvement, and an extensive range for ingenuity and invention. But from what class of men are we to expect useful discoveries? Are we to trust, as hitherto, to the favour of chance and accident; to the fortuitous success of those who are not guided in their experiments, by any general principles? Or shall we not rather endeavour to inform the artist, and induce him to substitute, for vague and random conjecture, the torch of induction and of rational analogy? In the present imperfect state of his knowledge, the artist is even unable fully to avail himself of those fortunate accidents, by which improvements sometimes occur in his processes; because, to the eye of common observation, he may have acted agreeably to established rules, and have varied in circumstances which he can neither perceive nor appreciate. The man of science, in these instances, sees more deeply, and, by availing himself of a minute and accidental difference, contributes at once to the promotion of his own interest, and to the advancement of his art.

But it is the union of theory with practice that is now recommended. And "when theoretical knowledge and practical skill are happily combined in the same person, the intellectual power of man appears in its full perfection, and fits him equally to conduct, with a masterly hand, the details of ordinary business, and to contend successfully with the untried difficulties of new and perplexing situations. In conducting the former, mere experience may frequently be a sufficient guide; but experience and speculation must be combined to prepare us for the latter."* "Expert

* Stewart's Elements of the Philosophy of the Human Mind, chap. iv. sect. 7.

men," says Lord Bacon, "can execute and judge of particulars one by one ; but the general counsels, and the plots, and the marshalling of affairs, come best from those that are learned."

This recommendation to artists, of the acquirement of scientific knowledge, is happily sanctioned by the illustrious success, in our own days, of the application of theory to the practice of certain arts. Few persons are ignorant of the benefits, that have resulted to the manufactures of this country, from the inventions of Mr. Watt and Mr. Wedgwood ; both of whom have been not less benefactors of philosophy than eminent for practical skill. The former, by a clear insight into the doctrine of latent heat, resulting, in a great measure, from his own acuteness and patience of investigation, and seconded by an unusual share of mechanical skill, has perhaps brought the steam-engine to its acme of perfection. Mr. Wedgwood, aided by the possession of extensive chemical knowledge, made rapid advances in the improvement of the art of manufacturing porcelain ; and, besides raising himself to great opulence and distinction, has created for his country a source of most profitable and extensive industry. In an art, also, which is nearly connected with the manufactures of our own town, and the improvement of which must, therefore, "come home to our business and bosoms," we owe unspeakable obligations to two speculative chemists,—to Scheele, who first discovered the oxygenized muriatic acid ; and to Berthollet, who first instructed us in its application to the art of bleaching.

Examples, however, may be urged against indulgence in theory ; and instances are not wanting, in which the love of speculative refinement has withdrawn men entirely from the straight path of useful industry, and led them on gradually to the ruin of their fortunes. But from such instances, it would be unfair to deduce a general condemnation of theoretical knowledge. It would be the common error of arguing against things that are useful, from their occasional abuse.—In truth, projects which have, for their foundation, a dependence on chemical principles, may be undertaken with a more rational confidence, than such as have in view the accomplishment of mechanical purposes ; because, in chemistry, we are better able, than in mechanics, to predict, from an experiment on a small scale, the probable issue of more extensive attempts. No one, from the successful trial of a small machine, can affirm, with unerring certainty, that the same success will attend one on a greatly enlarged plan ; because the amount of the resistances, that are opposed to motion, increases often in a *ratio* greater than, from

theory, could ever have been foreseen : but the same law, by which the mineral alkali is extracted from a pound of common salt, must equally operate on a thousand times the quantity ; and, even when we augment our proportion in this immense degree, the chemical affinities, by which so large a mass is decomposed, are exerted only between very small particles. The failures of the mechanic, therefore, arise from the nature of things ; they occur, because he has not in his power the means of foreseeing and calculating the causes that produce them. But, if the chemist fail in perfecting an economical scheme on a large scale, it is either because he has not sufficiently ascertained his facts on a small one, or has rashly embarked in extensive speculations, without having previously ensured the accuracy of his estimates.

The benefits which we are entitled to expect from the efforts of the artist and the man of science, united in one person, and at the same time tempered and directed by prudential wisdom, affect not only individual but national prosperity. To the support of its distinction, as a commercial nation, this country is to look for the permanency of its riches, its power, and, perhaps, even of its liberties ; and this preeminence is to be maintained, not only by local advantages, but on the more certain ground of superiority in the productions of its arts. Impressed with a full conviction of this influence of the sciences, a neighbouring and rival people offer the most public and respectful incitements to the application of theory in the improvement of the chemical arts ; and, with the view of promoting this object, national institutions have been formed among them, which have been already, in several instances, attended with the most encouraging success. It may be sufficient, at present, to mention, as an example, that France, during a long war, supplied, from her own native resources, her enormous, and, perhaps, unequalled consumption of nitre.

The general uses of chemistry have been thus fully enlarged upon, because it is a conviction of the utility of the science, that can alone recommend it to attentive and persevering study. It may now be proper to point out, in detail, a few of its more striking applications.

I. The art which is, of all others, the most interesting, from its subserviency to wants that are interwoven with our nature, is AGRICULTURE, or the art of obtaining, from the earth, the largest crops of useful vegetables at the smallest expense.

The vegetable kingdom agrees with the animal one, in the pos-

session of a living principle. Every individual of this kingdom is regularly organized, and requires for its support an unceasing supply of food, which is converted, as in the animal body, into substances of various forms and qualities. Each plant has its periods of growth, health, disease, decay, and death; and is affected, in most of these particulars, by the varying condition of external circumstances. A perfect state of agricultural knowledge would require, therefore, not only a minute acquaintance with the structure and economy of vegetables, but with the nature and effects of the great variety of external agents, that contribute to their nutriment, or influence their state of health and vigour. It can hardly be expected, that the former attainment will ever be generally made by practical farmers; and it is in bringing the agriculturist acquainted with the precise composition of soils and manures, that chemistry promises the most solid advantages. Indeed, any knowledge that can be acquired on this subject, without the aid of chemistry, must be vague and indistinct, and can neither enable its possessor to produce an intended effect with certainty, nor be communicated to others in language sufficiently intelligible. Thus we are told, by Mr. Arthur Young, that, in some parts of England, any loose clay is called marl, in others marl is called chalk, and in others clay is called loam. From so confused an application of terms, all general benefits of experience in agriculture must be greatly limited.

Chemistry may, to agriculturalists, become a universal language, in which the facts, that are observed in this art, may be so clothed, as to be intelligible to all ages and nations. It would be desirable, for example, when a writer speaks of clay, loam, or marl, that he should explain his conception of these terms, by stating the chemical composition of each substance expressed by them. For, all the variety of soils and manures, and all the diversified productions of the vegetable kingdom, are capable of being resolved, by chemical analysis, into a small number of elementary ingredients. The formation of a well refined language, expressing the proportion of these elements in the various soils and manures, now so vaguely characterized, would give an accuracy and precision, hitherto unknown, to the experience of the tillers of the earth.

It has been said, by those who contend for pure empiricism in the art of agriculture, that it has remained stationary, notwithstanding all improvements in the sciences, for more than two thousand years. "To refute this assertion," says Mr. Kirwan, "we need

only compare the writings of Cato, Columella, or Pliny, with many modern tracts, or still better, with the modern practice of our best farmers."—"If the exact connexion of effects with their causes," he adds, "has not been so fully and extensively traced in this as in other subjects, we must attribute it to the peculiar difficulty of the investigation. In other subjects, exposed to the joint operation of many causes, the effect of each, singly and exclusively taken, may be particularly examined, and the experimenter may work in his laboratory, with the object always in his view. But the secret processes of vegetation take place in the dark, exposed to the various and indeterminable influences of the atmosphere, and require, at least, half a year for their completion. Hence the difficulty of determining on what peculiar circumstance success or failure depends; for, the diversified experience of many years alone can afford a rational foundation for solid, specific conclusions."*

II. To those who study **MEDICINE** as a branch of general science, or with the more important view of practical utility, chemistry may be recommended with peculiar force and propriety.—The animal body may be regarded as a living machine, obeying the same laws of motion as are daily exemplified in the productions of human art. The arteries are long, flexible, and elastic canals, admitting, in some measure, the application of the doctrine of hydraulics; and the muscles are so many levers, of precisely the same effect with those which are employed to gain power in mechanical contrivances. But there is another view, in which, with equal justice, the living body may be contemplated. It is a laboratory, in which are constantly going forward processes of various kind, dependent on the operation of chemical affinities. The conversion of the various kinds of food into blood, a fluid of comparatively uniform composition and qualities; the production of animal heat by the action of the air on that fluid, as it passes through the lungs; and the changes, which the blood afterwards undergoes in its course through the body,—are all, exclusively, subjects of chemical inquiry. To these, and many other questions of physiology, chemistry has of late years been applied with the most encouraging success; and it is to a long continued prosecution of the same plan, that we are to look for a system of physiological science, which shall derive new vigour and lustre from the passing series of years.

* See Kirwan on Manures.

It must be acknowledged, however, as has been observed by Sir H. Davy,* that "the connection of chemistry with physiology has given rise to some visionary and seductive theories; yet even this circumstance has been useful to the public mind, in exciting it by doubt, and in leading it to new investigations. A reproach, to a certain degree just, has been thrown upon those doctrines known by the name of the chemical physiology; for, in the applications of them, speculative philosophers have been guided rather by the analogies of words than of facts. Instead of endeavouring slowly to lift up the veil, which conceals the wonderful phenomena of living nature; full of ardent imaginations, they have vainly and presumptuously attempted to tear it asunder."

III. There is an extensive class of arts, forming, when viewed collectively, a great part of the objects of human industry, which do not, on a loose and hasty observation, present any general principle of dependency or connexion. But they appear thus disunited, because we have been accustomed to attend only to the productions of these arts, which are, in truth, subservient to widely different purposes. Who would conceive, for instance, that iron and common salt; the one a metal, the use of which results from its hardness, ductility and malleability; the other a substance, chiefly valuable from its acting as a preservative and seasoner of food,—are furnished by arts alike dependent on the general principles of chemistry? The application of science, in discovering the principles of these arts, constitutes what has been termed **ECONOMICAL CHEMISTRY**; amongst the numerous objects of which, the following stand most distinguished:

1st. *Metallurgy*, or the art of extracting metals from their ores, comprehending that of *Assaying*, by which we are enabled to judge, from the composition of a small portion, of the propriety of working large and extensive strata. To the metallurgist, also, belong the various modifications of the metals when obtained, and the union of them together, in different proportions, so as to afford compounds adapted to particular uses.—Throughout the whole of this art, much practical knowledge may be suggested by attention to the general doctrines of chemistry. The artist may receive useful hints respecting the construction of furnaces for the fusion of ores and metals; the employment of the proper fluxes; the utility of the admission or exclusion of air; and the conversion of

* In his excellent "Discourse, Introductory to a Course of Lectures," &c. London. Johnson. 1802.

the refuse of his several operations to useful purposes. When the metals have separated from their ores, they are to be again subjected to various chemical processes. Cast or pig iron is to be changed into the forms of wrought or malleable iron and of steel. Copper, by combination with zinc or tin, affords the various compounds of brass, pinchbeck, bell-metal, gun-metal, &c. Even the art of printing owes something of its present unexampled perfection to the improvement of the metal of types.

2d. Chemistry is the foundation of those arts that furnish us with *saline substances*, an order of bodies highly useful in the business of common life. Among these, the most conspicuous are, sugar in all its various forms; the vegetable and mineral alkalis, known in commerce by the names of potash, pearlash, and barilla; common salt; green and blue vitriol, and alum; nitre or saltpetre; sugar of lead; borax; and a long catalogue, which it is needless to extend farther.

3d. The manufacturer of *glass*, and of various kinds of *pottery* and *porcelain*, should be thoroughly acquainted with the nature of the substances he employs: with their fusibility, as affected by difference of proportion, or by the admixture of foreign ingredients; with the means of regulating and measuring high degrees of heat; with the principles on which depend the hardness of his products, and their fitness for bearing the vicissitudes of heat and cold; and with the chemical properties of the best adapted colours and glazings. Even the humble art of making bricks and tiles has received, from the chemical knowledge of Bergman, the addition of several interesting facts.

4th. The preparation of various kinds of *fermented liquors*, of wine, and ardent spirits, is intimately connected with chemical principles. Malting, the first step in the production of some of these liquors, consists in the conversion of part of the grain into saccharine matter, essential in most instances to the success of the fermentative change. To acquire a precise acquaintance with the circumstances, that favour or retard the process of fermentation, no small share of chemical knowledge is required. The brewer should be able to ascertain, and to regulate exactly, the strength of his infusions, which will vary greatly when he has seemingly followed the same routine. He should be aware of the influence of minute changes of temperature in retarding or advancing fermentation; of the means of promoting it by proper ferments; and of the influence of the presence or exclusion of atmospherical air.

A complete acquaintance with the chemical principles of his art, can hardly fail to afford him essential aid in its practice.

The production of ardent spirits is only a sequel of the vinous fermentation, and is, therefore, alike dependent on the doctrines of chemistry.

5th. The arts of *bleaching*, *dyeing* and *printing*, are, throughout, a tissue of chemical operations. It is not unusual to hear the new mode of bleaching distinguished by the appellation of the chemical method; but it is, in truth, not more dependent on the principles of this science, than the one which it has superseded, nor than the kindred arts of dyeing and printing. In the instances of bleaching, the obligation due to the speculative chemist is universally felt and acknowledged. But the dyer and the printer have yet to receive from the philosopher some splendid invention, which shall command their respect, and excite their attention to chemical science. From purely speculative men, however, much less is to be expected, than from men of enlightened experience, who endeavour to discover the design and reason of each step in the processes of their arts, and fit themselves for more effectual observation of particular facts, by diligently possessing themselves of general truths.

The objections of inquiry that present themselves to the dyer and printer, are of considerable number and importance. The preparation of goods for the reception of colouring matter; the application of the bases, or means of fixing fugitive colours; the improvement of colouring ingredients themselves; and the means of rendering them permanent, so that they shall not be affected by soap, or by the accidental contact of acids or other corrosive bodies; are among the subjects of chemical investigation. It is the business of the dyer, therefore, to become a chemist; and he may be assured that, even if no brilliant discovery should be the reward of the acquisition, he will yet be better fitted by it for conducting common operations, with certain and unvaried success.

6th. The *tanning and preparation of leather* are processes strictly chemical, which were involved in mystery, till they were reduced to well established principles by the researches of Seguin, and by the subsequent experiments of Davy. In this, as in most other examples, the application of science to the practical improvement of an art, has to encounter the obstacles of ignorance and prejudice. But the interests of men are sure finally to prevail; and the most bigotted attachment to established forms must give place to the clearly demonstrated utility of new practices. Such a demonstration is generally furnished by some artist of more enlightened views

than his neighbours, who has the spirit to deviate from ordinary rules; and thus becomes (not unfrequently with some personal sacrifice) a model for the imitation of others, and an important benefactor of mankind.

Many other chemical arts might be enumerated; but enough, I trust, has been said, to evince the connexion between practical skill and the possession of scientific knowledge. I shall now proceed to develop the plan, on which the following course of instruction will be conducted.

There are two methods of delivering the general doctrines of chemistry, and the facts connected with them. The one consists in a historical detail of the gradual progress of the science; and, in pursuing this plan, we follow the natural progress of the human mind, ascending from particular facts to the establishment of general truths. But a strong objection to its adoption is, that we are thus led into a minuteness of detail, which is ill suited to the plan of elementary instruction. In the other mode of arrangement, we neglect wholly the order of time in which facts were discovered, and class them under general divisions, so framed as to assist the mind in apprehending and retaining the almost infinite variety of particular truths.

In a classification of the objects of chemistry, we may either begin with those substances, which are deemed to be simple, and proceed gradually to the more complicated; or we may take bodies, as they are usually presented to us, and arrange them according to the resemblances of their external characters; making the development of their composition a subordinate part of the plan. To the former, or synthetic method, there is this strong objection; that as we are probably still very remote from a knowledge of the true elements of matter, it must be liable, in the progress of science, to frequent and fundamental changes. It has been found necessary, for example, in consequence of Sir H. Davy's discoveries, to remove the fixed alkalis and the earths from the class of simple to that of compound bodies. Besides, it may be urged, where are we to place those substances, which have hitherto resisted all attempts at their analysis, and yet have a close resemblance, in natural characters, to the bodies with which they are now associated? For these reasons it appears to me, that one arrangement is preferable to another, on no other ground, than as it is better adapted for communicating a knowledge of the subject; for all must be equally remote from that perfection, which cannot be considered as attained, till the science of chemistry is no longer capable of improvement.

The order, which I have adopted as most eligible, is to commence with those facts, which lead most directly to the establishment of general principles. Attraction or affinity, as the great cause of all chemical changes, and as admitting of illustration by phenomena that are sufficiently familiar, has a primary claim to consideration. Next to that of attraction, the influence of Heat, over the forms and properties of bodies, is the most generally observed fact; and as heat is a power, which is constantly opposed to that of affinity, there is the more propriety in contrasting their operation. With heat, Light also, as a repulsive agent, is frequently associated, and electricity belongs to the same class of powers. But as the action of electricity consists, chiefly, in effecting the disunion of chemical compounds, I have removed it from that place in the system, which seems naturally to belong to it. For before we can understand the general laws of electro-chemical agency, it is necessary to know something of oxygen and a few of the inflammable bodies; nor can the theory of the excitation of galvanic electricity be made at all intelligible, without this previous knowledge.

The phenomena of heat, and the laws deduced from them, conduct us naturally to the great source of that fluid, which will be traced to a class of bodies, agreeing, in mechanical properties, with the air of our atmosphere, and called *airs* or *gases*. These gases, we shall find, consist partly of gravitating matter, and partly of an extremely subtile fluid, which impresses on our organs the sensation of heat, and is called *caloric*.* When the ponderable ingredients, usually called the *bases*, of these gases, combine together, or with other bodies, caloric is given out and new compounds are generated. It is on the possession or absence of the property of decomposing one of them, oxygen gas, that a comprehensive division has been made of bodies into *combustible* and *incombustible*. The latter, however, it appears probable, are such, only in consequence of being already combined with oxygen. Hence we might divide all the variety of substances into oxygen and inflammable matter; and of these, the last mentioned, it appears not improbable from Sir H. Davy's discoveries, will turn out to be universally metallic.

The next class of bodies, that claim our attention, includes those compounds, which are formed either by the union of the simple gases or of their bases. Thus oxygen and nitrogen gases compose atmospheric air; and hydrogen and oxygen, water. Nitrogen

* Light and electricity are probably, also, constituents of the gases.

and hydrogen, by their union, afford ammonia; and with this fluid the fixed alkalis are naturally associated. The detail of properties belonging to the alkalis and earths, is, indeed, a necessary preliminary to that of the acids, the most important quality of which is, that they constitute, with the alkalis and earths, the extensive class of neutral salts. The consideration of the bases of the alkalis and earths has been made to follow that of the bodies themselves, because these bases are the products of refined and complicated operations, which could scarcely have been otherwise understood. The fixed alkalis, also, precede the volatile ones, on account of the singular effects of potassium on ammonia.

The next class of compounds is, that of acids. With each of these I have connected the history of its base, when known; for as several of these bodies have lost, in consequence of Sir H. Davy's discoveries, their title to be considered as elementary, it becomes merely a question of convenience where they should be placed. In treating of the acids, their relation will be traced to those bodies only which have already been described; for it would be unseasonable to detail their action on metals, till that class of substances has been specifically discussed.

Having dismissed the consideration of such elementary bodies as are distinguished by affording acids when combined with oxygen, of the properties of acids thus generated, and of the compounds afforded by the union of acids with alkalis; an important division of elementary substances will next claim our attention, *viz.* the metals.

This class of bodies, it is usual to introduce at a much earlier period: but I have adopted a different order, from the consideration, that, with the previous knowledge of the constitution and qualities of acids, the history of the metals may be made much more complete; and, especially, that all the various modes and phenomena of their combinations with oxygen may be more distinctly explained. The more complex productions of the vegetable and animal kingdoms will be the last step in our progress through the science.

For the exclusive adoption of the new doctrines of chemistry, and of the nomenclature connected with them, no apology can now be necessary. From those who have been in the habit of teaching chemistry, both before and since the revolution in this science, we have the strongest testimony, that the labour of acquiring a knowledge of it is diminished beyond all comparison.—“I have adopted the

new nomenclature," says Mr. Chaptal, "in my lectures and writings, and I have not failed to perceive how very advantageous it is to the teacher; how much it relieves the memory; how greatly it tends to produce a taste for chemistry; and with what facility and precision the ideas and principles concerning the nature of bodies fix themselves in the minds of the auditors." We have the approbation, also, of the most distinguished metaphysicians of the age, of the connexion of new doctrines with a new and more accurate language. "The new nomenclature of chemistry," it is observed by Mr. Dugald Stewart, in his *Elements of the Philosophy of the Human Mind*, "seems to furnish a striking illustration of the effect of appropriate and well-defined expressions, in aiding the intellectual powers; and the period is probably not far distant, when similar innovations will be attempted in other sciences."

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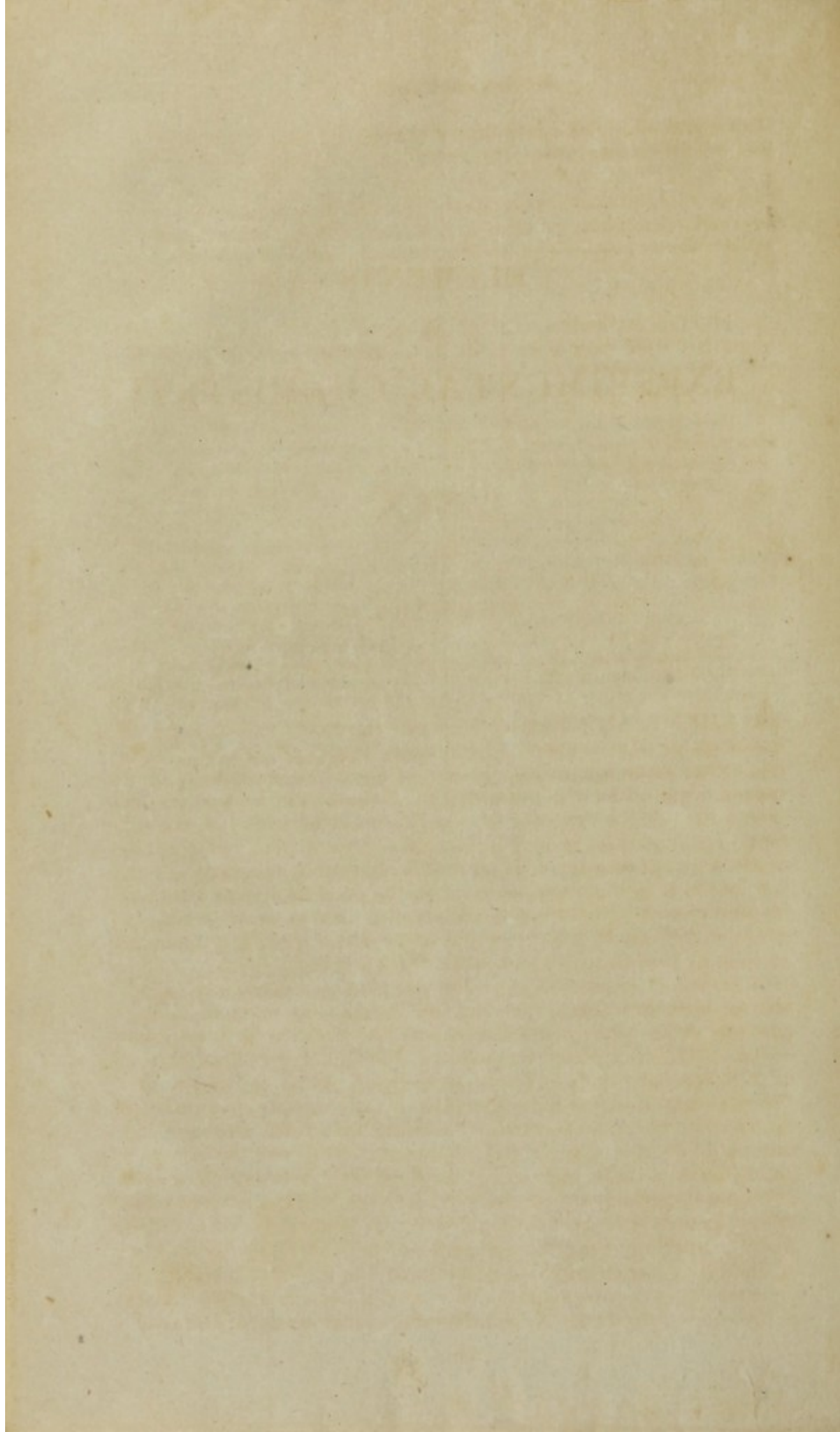
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ERRATUM FROM THE ENGLISH EDITION.

Dele the description of Fig. 44; as that figure should have been erased from the plate, the article to which it refers not having been retained in this edition.



ELEMENTS OF EXPERIMENTAL CHEMISTRY.

PART I.

CHAPTER I.

OF A CHEMICAL LABORATORY AND APPARATUS.

A CHEMICAL laboratory, though extremely useful, and even essential, to all who embark extensively in the practice of chemistry, either as an art, or as a branch of liberal knowledge, is by no means required for the performance of those simple experiments, which furnish the evidence of the fundamental truths of the science. A room that is well lighted, easily ventilated, and destitute of any valuable furniture, is all that is absolutely necessary for the purpose. It is even advisable, that the construction of a regular laboratory should be deferred, till the student has made some progress in the science; for he will then be better qualified to accommodate its plan to his own peculiar views and convenience.

It is scarcely possible to offer the plan of a laboratory, which will be suitable to every person, and to all situations; or to suggest any thing more than a few rules that should be generally observed. Different apartments are required for the various classes of chemical operations. The principal one may be on the ground-floor; twenty-five feet long, fourteen or sixteen wide, and open to the roof, in which there should be contrivances for allowing the occasional escape of suffocating vapours. This will be destined chiefly for containing furnaces, both fixed and portable. It should be amply furnished with shelves and drawers, and with a large table in the centre, the best form of which is that of a double cross. Another apartment may be appropriated to the minuter operations of chemistry; such as those of precipitation on a small scale, the processes that require merely the heat of a lamp, and experiments on the gases. In a third, of a smaller size, may be deposited accu-

rate balances, and other instruments of considerable nicety, which would be injured by the acid fumes that are constantly spread through a laboratory.

The following are the principal instruments that are required in chemical investigations ; but it is impossible, without entering into very tedious details, to enumerate all the apparatus that should be in possession of a practical chemist.

I. FURNACES. These may be formed either of solid brick-work, or of such materials as admit of their removal from place to place.*

The directions generally laid down in elementary books of chemistry, for the construction of **FIXED FURNACES**, appear to me deficient in precision, and such as a workman would find it difficult to put in practice. I have, therefore, given plans and sections, in the last two plates, of the various kinds of furnaces : and, in the Appendix, minute instructions will be found for erecting them.†

The furnaces of most general utility are, 1st, the *Wind Furnace*, in which an intense heat is capable of being excited for the fusion of metals, &c. In this furnace, the body submitted to the action of heat, or the vessel containing it, is placed in contact with the burning fuel. Fig. 60 exhibits one of the most common construction. Fig. 61 is the section of a wind furnace ; the plan of which was obligingly communicated to me by Mr. Knight, of Fosterlane, London, to whom, also, I am indebted for that represented, fig. 62. The wind furnace of Mr. Chenevix is shown by fig. 74. 2dly, The *Evaporating Furnace* is formed of iron plates, joined together by rabbeting, and placed over horizontal returning flues of brick. Figs. 64 and 65, are two views of this furnace, as recommended by Mr. Knight. When evaporation is performed by the naked fire, the vessel may be placed on the top of the furnace, fig. 60 or 61 ; and when effected through the intervention of a water bath, a shallow kettle of water, in which is placed the evaporating dish and its contents, may be set in the same situation. For the purposes of evaporating liquids, and drying precipitates on a small scale, at a temperature not exceeding 212° Fahrenheit, a convenient apparatus is represented by fig. 27. 3dly, The plan of a *Reverberatory Furnace* is exhibited by figs. 66, 67, and 68. 4thly, The *Furnace for Distilling by a Sand Heat* is constructed by setting upon the top of the brick-work, fig. 60, the iron pot, fig. 71 ; a door being made in the side of the furnace for introducing fuel. Distillation by the naked fire is performed with the wind furnace, figs. 62, 63.

* The best arrangement that can be made of a series of Furnaces for a Chemical Laboratory, is probably that of Mr. Allen, a plate and description of which is given in the 2d vol. of Aiken's Chemical Dictionary. Another, not very dissimilar, is described in Parke's Chemical Catechism, 6th London Edition, as taken from the Laboratory of the Surry Institution, and which that author conceives to be one of the most complete experimental Laboratories in Great Britain. C.

† See the Description of the 7th and 8th plates in the Appendix.

5thly, The *Cupelling*, or *Enamelling Furnace*, is shown by figs. 69, 70.

Portable furnaces, however, are amply sufficient for all the purposes of the chemical student, at the outset of his pursuit. The one which I prefer is that shown by figs. 58 and 59. It was originally contrived, I believe, by Mr. Schmeisser*; and is made, with considerable improvements, and sold by Mr. Knight. Its size is so small, that it may be set on a table, and the smoke may be conveyed by an iron pipe, into the chimney of the apartment. In the furnace, as it is usually sold, the chimney, adapted for distillation with a sand heat, passes directly through the sand-bath, the form of which is necessarily altered, from the common to a very inconvenient one. I have found it a great improvement to make the aperture for the chimney at *k*. This allows us to have a sand-bath of the usual shape, as shown by fig. 59; or even to place evaporating dishes, or a small boiler, on the top of the furnace. The aperture may be closed by a stopper, when we dispose the furnace as shown by fig. 28. Dr. Black's furnace is generally made of a larger size, and is adapted to operations on a more considerable scale. (See figs. 72 and 73.) Both these furnaces are constructed of thin iron plates, and are lined with fire-clay. They will be minutely described in the references to the plates.

For the purpose of exciting a sudden heat, and of raising it to great intensity, nothing can be better adapted than a very simple, cheap, and ingenious furnace, contrived by Mr. Charles Aikin, fig. 55. It is formed out of pieces of black-lead melting pots, in a manner to be afterwards described; and is supplied with air by a pair of double bellows, *d*. By a slight alteration, this furnace may occasionally be employed for the operation of cupelling. (See fig. 57.)

II. For containing the materials, which are to be submitted to the action of heat in a wind furnace, vessels called CRUCIBLES are employed. They are most commonly made of a mixture of fire clay and sand, occasionally with the addition of plumbago, or black lead. The Hessian crucibles are best adapted for supporting an intense heat without melting; but they are liable to crack when suddenly heated or cooled. The porcelain ones, made by Messrs. Wedgwood, are of much purer materials, but are still more apt to crack on sudden changes of temperature; and, when used, they should, therefore, be placed in a common crucible of larger size, the interval being filled with sand. The black-lead crucibles resist very sudden changes of temperature and may be repeatedly used; but they are destroyed when some saline substances (such as nitre) are melted in them, and are consumed by a current of air. For certain purposes, crucibles are formed of pure silver, or platinum. Their form varies considerably, as will appear from inspecting plate vi. figs. 49, 50, 51, and 54. It is necessary, in all cases, to raise them from the bars of the grate, by a stand, fig. 53, *a* or *b*. For

* See his Mineralogy, Tab. iii. and iv.

the purpose of submitting substances to the continued action of a red heat, and with a considerable surface exposed to the air, the hollow arched vessel, with a flat bottom, fig. 52, termed a *muffle*, is commonly used. In fig. 69, *d, e*, the muffle is shown, placed in a furnace for use.

III. EVAPORATING VESSELS should always be of a flat shape, so as to expose them extensively to the action of heat. (See a section of one, fig. 12.) They are formed of glass, of earthen ware, and of various metals. Those of glass are with difficulty made sufficiently thin, and are often broken by changes of temperature; but they have a great advantage in the smoothness of their surface, and in resisting the action of most acid and corrosive substances. Evaporating vessels of porcelain, or Wedgwood's ware, are next in utility, are less costly, and less liable to be cracked. They are made both of glazed and unglazed ware. For ordinary purposes the former are to be preferred; but the unglazed should be employed when great accuracy is required, since the glazing is acted on by several chemical substances. Evaporating vessels of glass, or porcelain, are generally bedded, up to their edge, in sand (see fig. 65); but those of various metals are placed immediately over the naked fire. When the glass or porcelain vessel is very thin, and of small size, it may be safely placed on the ring of the brass stand, plate i. fig. 13, and the flame of an Argand's lamp, cautiously regulated, may be applied beneath it. A lamp thus supported, so as to be raised or lowered, at pleasure, on an upright pillar, to which rings, of various diameters, are adapted, will be found extremely useful; and, when a strong heat is required, it is advisable to employ a lamp, provided with double concentric wicks.

IV. In the process of evaporation, the vapour for the most part is allowed to escape; but of certain chemical processes, the collection of the volatile portion is the principal object. This process is termed, DISTILLATION. It is performed in vessels of various forms and materials. The common still is so generally known, that a representation of it in the plates was deemed unnecessary*. It consists of a vessel, generally of copper, shaped like a tea-kettle, but without its spout and handle. Into the opening of this vessel, instead of a common lid, a hollow moveable head is affixed, which ends in a narrow, open pipe. The pipe is received into another tube of lead, which is twisted spirally, and fixed in a wooden tub, so that it may be surrounded by cold water. (Fig. 40, *dd*.) When the apparatus is to be used, the liquid intended to be distilled is poured into the body of the still, and the head is fixed in its place, the pipe which terminates it, being received into the leaden worm. The liquid is raised into vapour, which passes into the worm, is there condensed by the surrounding cold water, and flows out at the lower extremity.

The common still, however, can only be employed for volatilizing

* See Aikin's Chem. Dict. pl. ii. fig. 31.

substances that do not act on copper, or other metals, and is, therefore, limited to very few operations. The vessel, fig. 2, is of glass, or earthen ware, and is also intended for distillation. It is termed an *alembic*, and consists of two parts; the body *a* for containing the materials, and the head, *b*, by which the vapour is condensed; the pipe, *c*, conveying it to a receiver. Vessels, termed *retorts*, however, are more generally used. Fig. 1, *a* shows the common form, and fig. 13, *a* represents a stoppered, or tubulated retort. Retorts are made of glass, of earthen ware, or of metal. When a liquid is to be added at distant intervals during the process, the best contrivance is that shown fig. 26, *a*, consisting of a bent tube, with a funnel at the upper end. When the whole is introduced at first, it is done either through the tubulure, or, if into a plain retort, through the funnel, fig. 10.

To the retort, a *receiver* is a necessary appendage; and this may either be plain, fig. 1, *b*, or tubulated, as shown by the dotted lines at *c*. To some receivers a pipe is added (fig. 13, *b*), which may enter partly into a bottle beneath. This vessel, which is principally useful for enabling us to remove the distilled liquid, at different periods of the process, is termed a *quilled receiver*. For some purposes, it is expedient to have the quilled part accurately ground to the neck of the bottle, *c*, which should then be furnished with a tubulure, or second neck, having a ground stopper, and should be provided, also, with a bent tube, to be occasionally applied, for conveying away any gases that may be produced. The condensation of the vapour is much facilitated, by lengthening the neck of the retort with an *adopter*, (fig. 11,) the wider end of which slips over the retort neck, while its narrow extremity is admitted into the mouth of the receiver. (See fig. 63.)

Heat may be applied to the retort in several modes. When the vessel is of earthen ware, and when the distilled substance requires a strong heat to raise it into vapour, the naked fire is applied, as shown fig. 63. Glass retorts are generally placed in heated sand (fig. 59); and, when of a small size, the flame of an Argand's lamp, cautiously regulated, may be conveniently used (fig. 13).

In several instances, the substance raised by distillation is partly a condensable liquid, and partly a gas, which is not condensed till it is brought into contact with water. To effect this double purpose, a series of receivers, termed *Woulfe's Apparatus*, is employed. The first receiver (*b*, fig. 30) has a right-angled glass tube, open at both ends, fixed into its tubulure; and the other extremity of the tube is made to terminate beneath the surface of distilled water, contained, as high as the horizontal dotted line, in the three-necked bottle *c*. From another neck of this bottle, a second pipe proceeds, which ends, like the first, under-water, contained in a second bottle *d*. To the central neck a straight tube, open at both ends, is fixed, so that its lower end may be a little beneath the surface of the liquid. Of these bottles any number may be employed that is thought necessary.

The materials being introduced into the retort, the arrangement completed, and the joints secured in the manner to be presently

described, the distillation is begun. The condensable vapour collects in a liquid form in the balloon *b*, while the evolved gas passes through the bent pipe, beneath the surface of the water in *c*, which continues to absorb it till saturated. When the water of the first bottle can absorb no more, the gas passes, uncondensed, through the second right-angled tube, into the water of the second bottle, which, in its turn, becomes saturated. Any gas that may be produced, which is not absorbable by water, escapes through the bent tube *e*, and may be collected, if necessary.

Supposing the bottles to be destitute of the middle necks, and, consequently, without the perpendicular tubes, the process would be liable to be interrupted by an accident: for if, in consequence of a diminished temperature, an absorption or condensation of gas should take place, in the retort *a*, and, of course, in the balloon *b*, it must necessarily ensue that the water of the bottles *c* and *d* would be forced, by the pressure of the atmosphere, into the balloon, and possibly into the retort; but, with the addition of the central tubes, a sufficient quantity of air rushes through them to supply any accidental vacuum. This inconvenience, however, is still more conveniently obviated by Welthers's tube of safety (fig. 31. *b*), which supersedes the expediency of three-necked bottles. The apparatus being adjusted, as shown by the figure, a small quantity of water is poured into the funnel, so as to about half fill the ball *b*. When any absorption happens, the fluid rises in the ball, till none remains in the tube, when a quantity of air immediately rushes in. On the other hand, no gas can escape, because any pressure from within is instantly followed by the formation of a high column of liquid in the perpendicular part, which resists the egress of gas. This ingenious invention I can recommend, from ample experience of its utility.*

Very useful alterations in the construction of Woulfe's apparatus have been contrived also by Mr. Pepys and Mr. Knight. That of the former is shown (fig. 32), where the balloon *b* is surmounted by a vessel accurately ground to it, and furnished with a glass valve, resembling that affixed to Nooth's apparatus. This valve allows gas to pass freely into the vessel *c*, but prevents the water which it contains from falling into the balloon. Mr. Knight's improvement is described, and represented in a plate, in the *Philosophical Magazine*, vol. xx.†

* Although this apparatus is known always by the name of Woulfe's, there cannot be a doubt, that the invention originated with Glauber, who has given a representation of it in his works, and which is here introduced, as some reparation to the neglect he has received on this, as well as on some other occasions. Much however as his original contrivance has been improved by various chemists, none it is believed, has accomplished it so effectually as Mr. Wm. Hembel jr. of this City. A plan and description of his apparatus is also subjoined, for the information of those who pursue the practice of Chemistry. See Plate 10.—C.

† Another modification of this apparatus, by Mr. Murray, is represented in *Nich. Journ.* 8vo. vol. iii. or in *Murray's System of Chemistry*, vol. i. plate v. fig. 40. Fig. 41 of the same plate exhibits a cheap and simple form of this apparatus, contrived by the late Dr. Hamilton, and depicted originally in his translation of Berthollet on Dyeing. Mr. Burkitt's improvement of this apparatus may be seen in *Nicholson's Journal*, 4to. vol. v. 349.

When a volatile substance is submitted to distillation, it is necessary to prevent the escape of the vapour through the junctures of the vessels; and this is accomplished by the application of LUTES. The most simple method of confining the vapour, it is obvious, would be to connect the places of juncture accurately together by grinding; and accordingly the neck of the retort is sometimes ground to the mouth of the receiver. This, however, adds too much to the expence of apparatus to be generally practised.

When the distilled liquid has no corrosive property, (such as water, alcohol, ether, &c.), slips of moistened bladder, or of paper, or linen, spread with flour paste, white of egg, or mucilage of gum arabic, sufficiently answer the purpose. The substance which remains, after expressing the oil from bitter almonds, and which is sold under the name of almond-meal,* or powder, forms a useful lute, when mixed, to the consistency of glaziers' putty with water or mucilage. For confining the vapour of acid, or highly corrosive substances, the fat lute is well adapted. It is formed by beating perfectly dry and finely sifted tobacco pipe-clay, with painters' drying oil, to such a consistence that it may be moulded by the hand. The same clay, beat up with as much sand as it will bear, without losing its tenacity, with the addition of cut tow, or of horse-dung, and a proper quantity of water, furnishes a good lute, which has the advantage of resisting a considerable heat, and is applicable in cases where the fat lute would be melted or destroyed. Various other lutes are recommended by chemical writers; but the few that have been enumerated I find to be amply sufficient for every purpose.

On some occasions, it is necessary to protect the retort from too sudden changes of temperature, by a proper coating. For glass retorts, a mixture of common clay, or loam, with sand, and cut shreds of flax, may be employed. If the distillation be performed by a sand heat, the coating needs not to be applied higher than that part of the retort which is bedded in sand; but if the process be performed in a wind furnace (fig. 63), the whole body of the retort and that part of the neck also which is exposed to heat, must be carefully coated. To this kind of distillation, however, earthen retorts are better adapted; and they may be covered with a composition originally recommended by Mr. Willis. Two ounces of borax are to be dissolved in a pint of boiling water, and a sufficient quantity of slaked lime added, to give it the thickness of cream. This is to be applied by a painter's brush, and allowed to dry. Over this a thin paste is afterwards to be applied, formed of slaked lime and common linseed-oil, well mixed and perfectly plastic. In a day or two, the coating will be sufficiently dry to allow the use of the retort.

* Linseed meal, after the expression of the oil, is equally useful; and for the purpose of confining acid vapours, where the heat is not great, nothing is better than a simple luting of yellow bees-wax. It is easily applied in a state of liquefaction and quickly hardens. With it alone I have repeatedly distilled even the oxygenated muriatic acid. C.

For joining together the parts of iron vessels, used in distillation, a mixture of the finest China clay, with solution of borax, is well adapted. In all cases, the different parts of any apparatus made of iron should be accurately fitted by boring and grinding, and the above lute is to be applied to the part which is received into an aperture. This will generally be sufficient without any exterior luting; otherwise the lute of clay, sand, and flax, already described, may be used.

In every instance, where a lute or coating is applied, it is advisable to allow it to dry before the distillation is begun; and even the fat lute, by exposure to the air during one or two days after its application is much improved in its quality. The clay and sand lute is perfectly useless, except it be previously quite dry. In applying a lute, the part immediately over the juncture should swell outwards, and its diameter should be gradually diminished on each side. (See fig. 13, where the luting is shown, applied to the joining of the retort and receiver.)

Besides the apparatus already described, a variety of vessels and instruments are necessary, having little resemblance to each other, in the purposes to which they are adapted. Glass vessels are required for effecting *solution*, which often requires the application of heat, and sometimes for a considerable duration. In the latter case, it is termed *digestion*, and the vessel, fig. 4, called a *matras*, is the most proper for performing it. When solution is required to be quickly effected, the bottle, fig. 5, with a rounded bottom, may be used; or a common Florence oil flask serves the same purpose extremely well, and bears, without cracking, sudden changes of temperature. For *precipitations*, and separating liquids from precipitates, the decanting-jar (fig. 14,) will be found useful; or, if preferred, it may be shaped as in fig. 26, *f*. Liquids, of different specific gravities, are separated by the vessel, fig. 3; the heavier fluid being drawn off through the cock *b*, and air being admitted by the removal of the stopper *a*, to supply its place. Glass rods, of various lengths, and spoons of the same material, or of porcelain, are useful for stirring acid and corrosive liquids; and a stock of cylindrical tubes, of various sizes, is required for occasional purposes. It is necessary also to be provided with a series of glass measures, graduated into drachms, ounces and pints.

For the drying of precipitates, and other substances, by a heat not exceeding 212° , a very useful apparatus is sold in London. It is represented, supported by the ring of a lamp-stand, by fig. 27. The vessel *a* is of sheet-iron or copper japanned and hard-soldered; *c* is a conical vessel of very thin glass, having a rim, which prevents it, when in its place, from entirely slipping into *a*; and *d* is a moveable ring, which keeps the vessel *c* in its place. When the apparatus is in use, water is poured into *a* about as high as the dotted line; the vessel *c*, containing the substance to be dried, is immersed in the water, and secured by the ring *d*; and the whole apparatus set over an Argand's lamp. The steam escapes

by means of the chimney *b*, through which a little hot water may be occasionally poured to supply the waste by evaporation. By changing the shape of *c* to the segment of a sphere, still retaining the rim, I have found it a most convenient vessel for evaporating fluids.

Accurate beams and scales, of various sizes, with corresponding weights, some of which are capable of weighing several pounds, while the smaller size ascertains a minute fraction of a grain, are essential instruments in the chemical laboratory. So also are mortars of different materials, such as of glass, porcelain, agate, and metal. Wooden stands, of various kinds, for supporting receivers, should be provided*. For purposes of this sort, and for occasionally raising to a proper height any article of apparatus, a series of blocks, made of well seasoned wood, eight inches (or any other number) square, and respectively eight, four, two, one, and half an inch in thickness, will be found extremely useful; since, by combining them in different ways, thirty-one different heights may be obtained.

The blow-pipe is an instrument of much utility in chemical researches. A small one, invented by Mr. Pepys, with a flat cylindrical box for condensing the vapour of the breath, and for containing caps, to be occasionally applied with apertures of various sizes, is perhaps the most commodious form†. One of a much smaller size, for carrying in the pocket, has been contrived by Dr. Wollaston, and, may be had from Mr. Knight, of Foster-Lane‡. A blow-pipe, which is supplied with air from a pair of double bellows, worked by the foot§, may be applied to purposes that require both hands to be left at liberty, and will be found useful in blowing glass, and in bending tubes. The latter purpose, however, may be accomplished by holding them over an Argand's lamp with double wicks. Occasionally, when an intense heat is required, the flame of the blow-pipe, instead of being supported by the mouth, may be kept up by a stream of oxygen gas, expelled from a bladder or from a gas-holder||.

In the course of this work, various other articles of apparatus will be enumerated, in detailing the purposes to which they are adapted, and the principles on which they are constructed. It must be remembered, however, that it is no part of my object to describe every ingenious and complicated invention, which has been employed in the investigation of chemical science: but merely to assist the student in attaining apparatus for general and ordinary purposes. For such purposes, and even for the prosecution of new and important inquiries, very simple means are sufficient; and some of the most interesting chemical facts may be exhibited with the aid merely of Florence flasks, of common vials, and of wine

* See Aikin's Chem. Dict. pl. iv. fig. 59, *c*.

† See Aikin's Chem. Dict. pl. vii. fig. 71, 72, 73.

‡ It is described in Nich. Journ. xv. 284.

§ Phil. Mag. xliii. 280.

|| See a representation of the apparatus for this purpose, in the Chemical Conversations, pl. ix.

glasses. In converting these to the purposes of apparatus, a considerable saving of expense will accrue to the experimentalist; and he will avoid the encumbrance of various instruments, the value of which consists in show, rather than in real utility.

In the selection of experiments, I shall generally choose such as may be undertaken by persons not possessed of an extensive chemical apparatus. On some occasions, however, it may be necessary, in order to complete the series, that others should be included, requiring, for their performance, instruments of considerable nicety. The same experiment may, perhaps, in a few instances, be repeatedly introduced in illustration of different principles, but this repetition will be avoided as much as possible. Each experiment will be preceded by a brief enunciation of the general truth which it is intended to illustrate.

CHAPTER II.

OF CHEMICAL AFFINITY.

ALL bodies, composing the material system of the universe, have a mutual tendency to approach each other, whatsoever may be the distances at which they are placed. The operation of this force extends to the remotest parts of the planetary system, and is one of the causes that preserves the regularity of their orbits. The smaller bodies, also, that are under our more immediate observation, are influenced by the same power, and fall to the Earth's surface, when not prevented by the interference of other forces. From these facts, the existence of a property has been inferred, which has been called *attraction*, or more specifically the *attraction of gravitation*. Its nature is entirely unknown to us; but some of its laws have been investigated, and successfully applied to the explanation of phenomena. Of these, the most important are, that the force of gravity acts on bodies directly in proportion to the quantity of matter in each; and that it decreases in the reciprocal proportion of the squares of the distances.

From viewing bodies in the aggregate, we may next proceed to contemplate them as composed of minute particles. Of the nature of these particles, we have no satisfactory evidence. It is probable that they consist of solids, which are incapable of mechanical division, but are still possessed of the dimensions of length, breadth, and thickness. In simple bodies, the particles must be all of the same nature, or *homogenous*. In compound bodies, we are to understand, by the term *particles*, the smallest parts into which bodies can be resolved without decomposition. The word *atom* has of late been revived, to denote both these kinds of particles; and we may, therefore, speak with propriety of *simple atoms* and of *compound atoms*. When two atoms of different kinds unite to form a third or compound atom, we may term

the two first *component atoms*; and if these have not been decomposed, they may be called *elementary atoms*.

The atoms or particles of bodies are also influenced by the force of attraction, but not unless when placed in apparent contact. Hence a distinction has been made between gravitation, and that kind of attraction, which is effective only at insensible distances. The latter has been called *contiguous attraction* or *affinity*; and it has been distinguished, as it is exerted between particles of matter, of the same kind, or between particles of a different kind.

By the *affinity of aggregation*, the *cohesive affinity*, or, more simply, *cohesion*, is to be understood that force or power, by which particles or atoms of matter of the same kind attract each other, the only effect of this affinity being an aggregate or mass. Thus a lump of copper may be considered as composed of an infinite number of minute particles or integrant parts, each of which has precisely the same properties, as those that belong to the whole mass. These are united by the force of cohesion. But if the copper be combined with another metal (such as zinc), we obtain a compound (brass), the constituent parts of which, copper and zinc, are combined by the power of chemical affinity. In simple bodies, therefore, cohesion is the only force exerted between their particles. But in compound bodies, we may distinguish the force, with which the component atoms are united, from that which the compound atoms exert towards each other; the former being united by chemical affinity, and the latter by the cohesive attraction.

SECTION I.

Of Cohesion, Solution, and Crystallization.

THE cohesive affinity is a property, which is common to a great variety of bodies. It is most strongly exerted in solids; and in these it is proportionate to the mechanical force required for effecting their disunion. In liquids, it acts with considerably less energy; and in aëriiform bodies we have no evidence that it exists at all; for their particles, as will afterwards be shown, are mutually repulsive, and, if not held together by pressure, would probable separate to immeasurable distances. Its force is not only different among different bodies, but in various states of the same body. Thus in the cohesion of certain metals (steel for instance,) important changes are produced by the rate of cooling, by hammering, and by other mechanical operations. Water, also, in a solid state, has considerable cohesion, which is much diminished when it becomes liquid, and is entirely destroyed when it is changed into vapour.

The most important view, in which the chemist has to consider cohesion, is that of a force either counteracting or modifying chemical affinity; for the more strongly the particles of any body are united by this power, the less are they disposed to enter into com-

bination with other bodies. In many cases, a very powerful affinity between two substances may be rendered wholly inefficient, by the strong cohesion of one or both them. Hence it has been received as an axiom, that *the affinity of composition is inversely proportionate to the cohesive affinity*. To the language, however, in which this axiom is expressed, it has been justly objected, that it implies an accuracy of proportion between the forces of cohesion and of chemical affinity, which cannot be proved to exist; since all that can truly be affirmed is, in general terms, that the affinity of composition is less effective, as the attraction of cohesion is greater.

The cohesion of bodies may be overcome, 1stly, by mechanical operations, as by rasping, grinding, pulverising, and other modes of division, which are generally employed as preliminary steps to chemical processes. In some instances, even a minuter division of bodies is necessary, than can be accomplished by mechanical means; and recourse is then had to precipitation. Silica, for example, in the state of rock crystal, may be boiled for a long time in liquid potash, without any appearance of chemical action. It may even be bruised to powder, without being rendered sensibly soluble. But when first precipitated from a state of chemical solution, it is readily dissolved by that menstruum.

2dly, Cohesion may be counteracted by heat, applied so as to melt one or both of the bodies, if fusible; or to raise them into vapour, if volatile. Lead and sulphur contract no union, till one or both of them is melted by heat. Arsenic and sulphur are united most effectually, by bringing them into contact, when both are in a state of vapour.

3dly, Cohesion may be counteracted by *solution*; and this is so general a condition of chemical union, that it was formerly received as an axiom, that *bodies do not act on each other, unless one or both are in a state of solution*; a principle to which the progress of chemical science has since discovered many exceptions.

The term *solution* is applied to a very extensive class of phenomena. When a solid disappears in a liquid, or when a solid or liquid is taken up by an aëriform body, if the compound exhibit perfect transparency, we have, in each instance, an example of solution. The expression is applied, both to the *act* of combination, and to the *result* of the process. When common salt, such as is used in cookery, is agitated with water, it disappears; in other words, its solution takes place; and we also term the liquid which is obtained, *a solution of salt in water*. This is one of the simplest cases that can be adduced, of the efficiency of chemical affinity; for solution is always the result of an affinity between the fluid and the solid which is acted upon, sufficient in force to overcome the cohesion of the solid. This affinity continues to act, until, at length, a certain point is attained, where the affinity of the solid and fluid for each other is overbalanced by the cohesion of the solid, and the solution cannot be carried further. The point is called *saturation*, and the fluid obtained is termed a *saturated solution*.

With respect to common salt, water acquires no increase of its

solvent power by the application of heat.* But there are various salts with which water may be saturated at the common temperature of the atmosphere, and will yet be capable of dissolving a still farther quantity by an increase of its temperature. When a solution, thus charged with an additional quantity of salt, is allowed to cool, the second portion of salt is deposited in a form resembling its original one.

To recover a salt from its solution, if its solubility does not vary with the temperature of the solvent, as in the instance of common salt, it is necessary to expel a portion of the fluid by heat. This constitutes the process of *evaporation*. If the evaporation be carried on very slowly, so that the particles of the solid may approach each other in the way best adapted to them, we obtain solid figures, of a regular shape, called *crystals*. The crystallization of a solid may also take place from that state of fluidity which is produced by heat. Thus, several of the metals crystallize on cooling from a melted state; and some volatile bodies, as arsenic, assume, when condensed from the state of vapour, the shape of regular crystals.

In the act of separating from the water in which they were dissolved, the crystals of almost all salts carry with them a quantity of water, which is essential to the regularity of their form, and cannot be expelled without reducing them to shapeless masses.† It is termed their *water of crystallization*. Its proportion varies in different salts; in some it is extremely small; in others it constitutes the principal part of the salt, and is even so abundant as to liquefy them on the application of heat, producing what is called the *watery fusion*. The water of crystallization is retained also in different salts with very different degrees of force. Some crystals, which lose their watery ingredient by mere exposure to the atmosphere, are said to *effloresce*. Others, on the contrary, not only hold their water of crystallization very strongly, but even attract more; and, on exposure to the atmosphere, become liquid, or *deliquiate*. The property itself is called *deliquescence*.

When two salts are contained in the same solution, which vary in their degree of solubility, and which have no remarkable attraction for each other, they may be obtained separate. For by carefully reducing the quantity of the solvent by evaporation, the salt whose particles have the greatest cohesion, will crystallize first. If both salts are more soluble in hot than in cold water, the crystals will not appear till the liquid cools. But if one of them, like common salt, is equally soluble in hot and in cold water, crystals will appear, even during the act of evaporation. In this way we may completely separate nitre from common salt, the crystals of the latter being

* Although the difference of solubility of common salt in water, at 60° and at 212° is very trifling, it is nevertheless sufficiently obvious. At the former temperature it requires 2.8 times its weight, but only 2.76 at the latter. C.

† This is correct in a general point of view; nevertheless, it appears that sulphat of soda, under particular circumstances, may still retain its crystalline form, although deprived of its water of crystallization. C.

formed during evaporation; while those of nitre do not appear till some time after the fluid has cooled.

Salts, which are thus deposited in regular shapes, generally adhere to the surface of the vessel containing the solution, or to any substance, such as pieces of thread or of wood, introduced for the purpose of collecting them. But a still more effectual way of inducing crystallization is to immerse, in the solution, a crystal of the same kind with that which we expect to be formed. The crystal, thus exposed, receives successive additions to its several surfaces, and preserves its form, with a considerable addition to its magnitude. This curious fact was originally noticed by Le Blanc, who has founded on it a method of obtaining large and perfect crystals.*

In some instances, the affinity of a salt for its solvent is so powerful, that it will not separate from it in the form of crystals; but will yet crystallize from another fluid, which is capable of dissolving it, and for which it has a weaker affinity. Pot-ash, for instance, cannot be made to crystallize from its watery solution, but will yet separate in a regular form, from its solution in alcohol.

Every solid, that is susceptible of crystallization, has a tendency to assume a peculiar shape. Thus common salt, when most perfectly crystallized, forms regular cubes; nitre has the shape of a six-sided prism; and alum that of an octahedron. It had, indeed, been alleged, as an objection to the modern theory of crystallization, that minerals, differing essentially in their composition, have precisely the same primitive form; but this has been shown, by Dr. Wollaston, to be a mistake, and that, though the figures are similar, their angles, on admeasurement by a nice instrument, differ very appreciably†. The same solid, however, admits of variations of its crystalline figure. Calcareous spar, for example, forms six-sided prisms, and three or six-sided pyramids. These varieties are occasioned by accidental circumstances which modify the operation of the force of cohesion. The diversities of shape are, on first view, extremely numerous; and yet upon a careful examination and comparison, they are found to be reducible to a small number of simple figures.

The attempt to trace all the observed forms of crystals to a few simple or primary ones, seems to have originated with Bergman‡. In the instance of calcareous spar, this distinguished chemist demonstrated that its numerous modifications may possibly result from one simple figure, the rhomb, by the accumulation of which, in various ways, crystals of the most opposite forms may be generated. This theory he extended to crystals of every kind; and he accounted for the differences of their external figures, by varieties of their mechanical elements or minute molecules.

About the same period with Bergman, or immediately afterwards,

* Le Blanc's method was to employ the most perfect crystals for the process; but I have shewn experimentally, that an *imperfect* mass of Sulphat of Copper, may by proper attention be equally made to assume a perfect and regular form. C.

† Phil. Trans 1812.

‡ Bergman's Essays, vol. ii.

M. Romé de l'Isle pursued still farther the theory of the structure of crystals. He reduced the study of crystallography to principles more exact, and more consistent with observation. He classed together, as much as he was able, crystals of the same nature. From among the different forms belonging to the same species, he selected, for the primitive form, one which appeared to him to be the most proper, on account of its simplicity. Supposing this to be truncated in different manners, he deduced the other forms, and established a certain gradation, or series of passages, from the primitive form to complicated figures, which on first view would scarcely appear to have any connexion with it. To the descriptions and figures of the primitive forms, he added the mechanical measurement of the principal angles, and showed that these angles are constantly the same in each variety. It must be acknowledged, however, that the primitive forms, assumed by this philosopher, were entirely imaginary, and not the result of any experimental analysis. His method was to frame an hypothesis; and then to examine its coincidence with actual appearances. On his principles any form might have been the primitive one, and any other have been deduced from it.

It was reserved for the sagacity of the Abbé Hüay to unfold the true theory of the structure of crystals, and to support it both by experimental and mathematical evidence. By the mechanical division of a complicated crystal, he first obtains the simple form, and afterwards constructs, by the varied accumulation of the primitive figure, according to mathematical synthesis, all the observed varieties of that species.

Every crystal may be divided by means of proper instruments; and, if split in certain directions, presents plane and smooth surfaces. If split in other directions, the fracture is rugged, is the mere effect of violence, and is not guided by the natural joining of the crystal. This fact had been long known to jewellers and lapidaries; and an accidental observation of it proved, to the Abbé Haüy, the key of the whole theory of crystallization. By the skillful division of a six-sided prism of calcareous spar, he reduced it to a rhomb, precisely resembling that which is known under the name of Iceland crystal. Other forms of calcareous spar were subjected to the same operation; and however different at the outset, finally agreed in yielding, as the last product a rhomboidal solid. It was discovered also by Haüy, that if we take a crystal of another kind (the cubic fluor spar for instance), the nucleus, obtained by its mechanical division, will have a different figure, *viz.* an octahedron. Other crystallized bodies produce still different forms; which are not, however, very numerous. Those which have hitherto been discovered, are reducible to six; the parallelopipedon, which includes the cube, the rhomb, and all the solids which are terminated by six faces, parallel two and two; the tetrahedron; the octahedron; the regular hexahedral prism; the dodecahedron with equal and similar rhomboidal planes; and the dodecahedron with triangular planes.

The solid of the primitive form or nucleus of a crystal, obtained

by mechanical division, may be subdivided in a direction parallel to its different faces. All the sections thus produced being similar, the resulting solids are precisely similar in shape to the nucleus, and differ from it only in size, which continues to decrease as the division is carried farther. To this division, however, there must be a limit, beyond which we should come to particles so small, that they could no longer be divided. At this term, therefore, we must stop: and to these last particles, the result of an analysis of the primitive nucleus, and similar to it in shape, Haüy has given the name of the *integrant molecule*. If the division of the nucleus can be carried on in other directions than parallel to its faces, the integral molecule may then have a figure different from that of the nucleus. The forms, however, of the integrant molecule, which have hitherto been discovered, are only three; the tetrahedron, the simplest of pyramids; the triangular prism, the simplest of prisms: and the parallelepipedon, including the cube and rhomboid, the simplest of solids which have their faces parallel two and two. With respect to octahedral crystals, there is a difficulty, whether the octahedron, or tetrahedron, is to be adopted as the primitive form; and, whichever be chosen, since neither of them can fill space without leaving vacuities, it is not easy to conceive any arrangement, by which the particles will remain at rest. To obviate this difficulty, Dr. Wollaston has suggested that, in such instances, the elementary particles may be perfect spheres; and by the due application of spheres to each other, he has shown, that a variety of crystalline forms may be produced.*

The primitive form, and that of the integral molecule having been experimentally determined by the dissection of a crystal, the next step is to discover the law, according to which these molecules are arranged, in order to produce, by their accumulation around the primitive figure, the great variety of secondary forms. What is most important in the discoveries of Haüy, and what constitutes in fact the essence of his theory, is the determination of these laws, and the precise measurement of their action. He has shown that all the parts of a secondary crystal, superadded to the primitive nucleus, consist of laminæ, which decrease gradually by the subtraction of one or more layers of integrant molecules; so that theory is capable of determining the number of these ranges, and, by a necessary consequence, the exact form of the secondary crystal.

By the developement of these laws of decrement, Haüy has shown how, from variations of the arrangement of the integrant molecules, a great variety of secondary figures may be produced. Their explanation, however, would involve a minuteness of detail, altogether unsuitable to the purpose of this work; and I refer, therefore, for a very perspicuous statement of them to the first and ninth volumes of the *Philosophical Magazine*.

* Phil. Trans. 1813.

SECTION II.

Of Chemical Affinity, and the General Phenomena of Chemical Action.

CHEMICAL affinity, like the cohesive attraction, is effective only at insensible distances; but it is distinguished from the latter force, in being exerted between the particles of bodies of *different kinds*. The result of its action is not a mere aggregate, having the same properties as the separate parts, and differing only by its greater quantity or mass, but a new compound, in which the properties of the components have either entirely or partly disappeared, and in which new qualities are also apparent. The combinations effected by chemical affinity are permanent, and are destroyed only by the interference of a more powerful force, either of the same or of a different kind.

As a general exemplification of chemical action, we may assume that which takes place between potash and sulphuric acid. In their separate state, each of these bodies is distinguished by striking peculiarities of taste, and by other qualities. The alkali, on being added to blue vegetable infusions, changes their colour to green; and the acid turns them red. But, if we add the one substance to the other, very cautiously and in small quantities, examining the effect of each addition, we shall at length attain a certain point, at which the liquid will possess neither acid nor alkaline qualities; the taste will be converted into a bitter one; and the mixture will produce no effect on blue vegetable colours. Here then, the qualities of the constituent parts, or at least some of their most important ones, are destroyed by combination. When opposing properties thus disappear, the bodies combined have been said to *saturate* each other; and the precise term, at which this takes place, has been called the *point of saturation*. It is advisable, however, to restrict this expression to weaker combinations, where there is no remarkable alteration of qualities, as in cases of solution; and to apply, to those results of more energetic affinities, which are attended with loss of properties, the term *neutralization*.

At the same time that the properties of bodies disappear on combination, other new qualities, both sensible and chemical, are acquired; and the affinities of the components for other substances become in some cases increased, in others, diminished in energy. Sulphur, for example, is destitute of taste, smell, or action on vegetable colours; and oxygen gas is, in these respects, equally inefficient. But the compound of sulphur and oxygen is intensely acid; the minutest portion instantly reddens blue vegetable infusions; and the acid is disposed to enter into combination with a variety of bodies, for which its components evinced no affinity. Facts of this kind sufficiently refute the opinion of the older chemists, that the properties of compounds are *intermediate* between those of their component parts; for in instances like the foregoing

the compound has qualities, not a vestige of which can be traced to either of its elements.

It is not, however, in all cases, that the change of properties is so distinct and appreciable by the senses, as in the instances which have been just now described. In some examples of chemical union, the change is scarcely perceptible to the eye or the taste, when the chemist is nevertheless certain that combination must have taken place. This occurs chiefly in the mixture of saline solutions with each other, where a complete exchange of principles ensues, without any evident change of properties. Examples of this kind cannot, however, be understood till the subject of complex affinity has been first elucidated.

The existence of chemical affinity, between any two bodies is inferred, therefore, from their entering into chemical combination; and that this has happened, a change of properties may be considered as a sufficient proof, even though the change may not be very obvious, and may require accurate examination to be perceived at all.

The proof, which establishes the nature of chemical compounds, is of two kinds, *synthesis* and *analysis*. Synthesis consists in effecting the chemical union of two or more bodies; and analysis in separating them from each other, and exhibiting them in a separate state. When we have a compound of two or more ingredients, which are themselves compounded also, the separation of the compounds from each other may be called the *proximate analysis* of the body; and the farther separation of these compounds into their most simple principles, its *ultimate analysis*. Thus the proximate analysis of sulphate of potash consists in resolving it into potash and sulphuric acid; and its ultimate analysis is effected by decomposing the potash into potassium and oxygen, and the sulphuric acid into oxygen and sulphur.

When the analysis of any substance has been carried as far as possible, we arrive at its most simple principles, or *elements*, by which expression we are to understand, not a body that is *incapable* of further decomposition, but only one which *has not yet been decomposed*.* The progress of chemical science, for several centuries past, has consisted in carrying still farther the analysis of bodies, and in proving those to be compounded, which had before been considered as elementary.

Beside the alteration of properties, which usually accompanies chemical action, there are certain other phenomena, which are generally observed to attend it.

1st. In almost every instance of chemical union, the *specific gravity* of the compound is greater than might have been inferred from that of its components; and this is true both of weaker and more energetic combinations. When equal weights of water and sulphuric acid are made to combine, the specific gravity of the

* The term above applied of *most simple principles* or Elements, is evidently erroneous, unless it can be absolutely shewn that no further decomposition is capable of being effected. C.

resulting liquid is not the mean, but considerably greater than the mean. The law extends also to solids. But though general, it is not universal; for in a very few instances chiefly of æriform fluids, condensation does not attend chemical union. And in the combination of one or two bodies the reverse even takes place, the compound being specifically lighter than might have been expected, from the specific gravity of its elements, and their proportion to each other.

2dly. When bodies combine chemically, it may be received as a general fact, that their temperature changes. Equal weights of oil of vitriol and water, both at the temperature of 50° of Fahrenheit, are heated, by sudden mixture, to considerably above 212° . In other examples, a contrary effect takes place, and a diminished temperature, or, in other words, a production of cold, is observed. This is all that it is at present necessary to state on the subject, which will be more fully considered when we come to treat of caloric.

3dly. The *forms of bodies* are often materially changed by chemical combination. Two solids may, by their union, become fluid; or two fluids may become solid. Solids are also often changed into æriform fluids; and, in many instances, the union of two airs, or gases, is attended with their sudden conversion into the solid state. By long exposure of quicksilver to a moderate heat, we change it from a brilliant liquid into a reddish scaly solid; and by heating this solid in a retort, we obtain an æriform fluid, or gas, in considerable quantity, and recover the quicksilver in its original form.

4thly. Change of *colour* is a frequent, but not universal concomitant of chemical action. In some cases, brilliant colours are destroyed, as when oxymuriatic acid is made to act on solution of indigo. In other instances two substances, which are nearly colourless, form, by their union, a compound distinguished by beauty of colour; as when liquid potash is added to very dilute syrup of violets. Certain colours appear also to belong essentially to chemical compounds, and to be characteristic of them. Thus 100 parts of quicksilver, and 4 of oxygen, invariably give a black compound; and the same quantity, with 8 parts of oxygen, a red compound.

SECTION III.

Of the Proportions in which Bodies combine; and of the Atomic Theory.

IN the chemical combination of bodies with each other, a few leading circumstances deserve to be remarked.

1st. Some bodies unite in all proportions; for example, water and sulphuric acid, or water and alcohol.

2dly. Other bodies combine in all proportions, as far as a certain point, beyond which combination no longer takes place. Thus water will take up successive portions of common salt, until at length

it becomes incapable of dissolving any more. In cases of this sort, as well as in those included under the first head, combination is weak and easily destroyed, and the qualities which belonged to the components in their separate state continue to be apparent in the compound.

3dly. There are many examples in which bodies unite in one proportion only; and in all such cases the proportion of the elements of a compound must be uniform for the species. Thus hydrogen and oxygen unite in no other proportions, than those constituting water, which, by weight, are very nearly $11\frac{1}{2}$ of the former to $88\frac{1}{2}$ of the latter, or 1 to $7\frac{1}{2}$. In cases of this sort, the combination is generally energetic; and the characteristic qualities of the components are no longer observable in the compound.

4thly. Other bodies unite in several proportions; but those proportions are definite, and, in the intermediate ones, no combination ensues. Thus 100 parts by weight of charcoal combine with $132\frac{1}{2}$ of oxygen, or with 265, but with no intermediate quantity; 100 parts of manganese combine with 14 of oxygen, or with 28, or with 42, or with 56, and with those proportions only.

Now it is remarkable, that when one body enters into combination with another, in several different proportions, the numbers indicating the greater proportions are exact simple multiples of that denoting the smallest proportion. In other words, if the smallest proportion in which B combines with A, be denoted by 10, A may combine with twice 10 of B, or with three times 10, and so on; but with no intermediate quantities. There cannot be a more striking instance of this law than that above mentioned, of the compounds of manganese with oxygen; in which the oxygen of the three last compounds may be observed to be a multiplication of that of the first (14) by the numbers 2, 3, and 4. Examples, indeed, of this kind have, of late, so much accumulated, that the law of simple multiples bids fair to become universal, with respect at least to chemical compounds, the proportions of which are definite.

Facts of this kind are not only important in themselves, but also on account of the generalizations that have been deduced from them; for on them Mr. Dalton has founded what may be termed the *Atomic Theory of the chemical Constitution of Bodies*. Till this theory was proposed, we had no adequate explanation of the uniformity of the proportions of chemical compounds; or of the nature of the cause which renders combination, in other proportions, impossible. In this place I shall offer only a brief illustration of the theory; for in the course of the work I shall have occasion to apply it to the explanation of a variety of phenomena.

Though we appear, when we effect the chemical union of bodies, to operate on masses, yet it is consistent with the most rational view of the constitution of bodies to believe, that it is only between their *ultimate particles*, or *atoms*, that combination takes place. By the terms *atoms*, it has been already stated, we are to understand the smallest parts of which bodies are composed. An atom, therefore, must be mechanically indivisible, and of course a fraction of an atom cannot exist. Whether the atoms of different bodies be of the same

size, or of different sizes, we have no sufficient evidence. The probability is, that the atoms of different bodies are of unequal sizes;* but it cannot be determined whether their sizes bear any regular proportion to their weights. We are equally ignorant of their shape; but it is probable, though not essential to the theory, that they are spherical. This, however, requires a little qualification. The atoms of all bodies probably consist of a solid corpuscle, forming a nucleus, and of an atmosphere of heat, by which that corpuscle is surrounded; for absolute contact is never supposed to take place between the atoms of bodies. The figure of a simple atom may readily, therefore, be conceived to be spherical. But in compound atoms, consisting of a single central atom, surrounded by other atoms of a different kind, it is obvious, that the figure (contemplating the solid corpuscles only) cannot be spherical; yet, if we include the atmosphere of heat, the figure of a compound atom may be spherical, or some shape approaching to a sphere.

Taking for granted that combination takes place between the atoms of bodies only, Mr. Dalton has deduced, from the relative weights in which bodies unite, the relative weights of their ultimate particles, or atoms. When only one combination of any two elementary bodies exists, he assumes, unless the contrary can be proved, that its elements are united atom to atom singly. Combinations of this sort he calls *binary*. But, if several compounds can be obtained from the same elements, they combine, he supposes, in proportions expressed by some simple multiple of the number of atoms. The following table exhibits a view of some of these combinations.

- 1 atom of A + 1 atom of B = 1 atom of C, binary.
- 1 atom of A + 2 atoms of B = 1 atom of D, ternary.
- 2 atoms of A + 1 atom of B = 1 atom of E, ternary.
- 1 atom of A + 3 atoms of B = 1 atom of F, quaternary.
- 3 atoms of A + 1 atom of B = 1 atom of G, quaternary.

A different classification of atoms has been proposed by Berzelius, viz. into, 1stly, *elementary* atoms; 2dly, *compound* atoms. The compound atoms he divides again into three different species, namely, 1st, atoms formed of only two elementary substances united, or *compound atoms of the first order*: 2dly, atoms composed of more than two elementary substances; and these, as they are only found in organic bodies, or bodies obtained by the destruction of organic matter, he calls *organic atoms*: 3dly, atoms formed by the union of two or more compound atoms; as for example, the salts; these he calls *compound atoms of the second order*.

If elementary atoms of different kinds were of the same size, the greatest number of the atoms of A that could be combined with

* If the atoms of bodies are really of unequal sizes, is it not evident that the larger may be divided (at least hypothetically), so as not to exceed the smaller in magnitude? Would it not seem therefore necessarily to follow, that the atoms of different bodies, must be of the same dimensions. C.

an atom of B would be 12; for this is the greatest number of spherical bodies that can be arranged in contact with a sphere of the same diameter. But this equality of size, though adopted by Berzelius, is not necessary to the hypothesis of Mr. Dalton; and is, indeed, supposed by him not to exist.

As an illustration of the mode in which the weight of the atoms of bodies is determined, let us suppose that any two elementary substances, A and B, form a binary compound; and that they have been proved experimentally to unite in the proportion, by weight, of 5 of the former to 4 of the latter; then, since, according to the hypothesis, they unite particle to particle, those numbers will express the relative weights of their atoms. But besides combining atom to atom singly, 1 atom of A may combine with 2 of B, or with 3, 4, &c. Or 1 atom of B may unite with 2 of A, or with 3, 4, &c. When such a series of compounds exists, the relative proportion of their elements ought necessarily, on analysis, to be proved to be 5 of A to 4 of B; or 5 to $(4+4=)$ 8; or 5 to $(4+4+4=)$ 12 &c.; or contrariwise, 4 of B to 5 of A; or 4 to $(5+5=)$ 10; or 4 to $(5+5+5=)$ 15. Between these there ought to be no intermediate compounds; and the existence of any such (as 5 of A to 6 of B, or 4 of B to $7\frac{1}{2}$ of A) would, if clearly established, militate against the hypothesis.

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

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

- | | |
|--|--------------|
| 1. In <i>water</i> , the hydrogen is to the oxygen as | 1 to 7.5. |
| 2. In <i>olefiant gas</i> , the hydrogen is to the carbon as | 1 to 5.65. |
| 3. In <i>carbonic oxide</i> the oxygen is to the carbon as | 7.5 to 5.65. |

Whether, therefore, we determine the weight of the atom of carbon, from the proportion in which it combines with hydrogen, or with oxygen, we arrive at the same number 5.65; an agreement which, at it occurs in various other instances, can scarcely be an accidental coincidence. In a similar manner, 7.5 is deducible, as representing the atom of oxygen, both from the combination of that base with hydrogen and with carbon; and 1 is inferred to be

the relative weight of the atom of hydrogen from the two principal compounds into which it enters.

In selecting the body, which should be assumed as unity, Mr. Dalton has been induced to fix on hydrogen, because it is that body which unites with others in the smallest proportion. Thus, in water, we have 1 of hydrogen by weight to $7\frac{1}{2}$ of oxygen; in ammonia, 1 of hydrogen to 5 of nitrogen; in carburetted hydrogen, 1 of hydrogen to 5.65 of carbon; and in sulphuretted hydrogen, 1 of hydrogen to 15 of sulphur. Taking for granted that all these bodies are binary compounds, we have the following scale of numbers, expressive of the relative weights of the atoms of their elements.

Hydrogen	1
Oxygen	7.5
Nitrogen	5.0?
Carbon	5.65
Sulphur	15.0

Drs. Wollaston and Thomson, and Professor Berzelius, on the other hand, have assumed oxygen as the decimal unit, chiefly with a view to facilitate the estimation of its numerous compounds with other bodies. This, perhaps, is to be regretted, even though the change may be in some respects eligible, because it is extremely desirable that chemical writers should employ an universal standard of comparison for the weights of the atoms of bodies. It is easy, however, to reduce their numbers to Mr. Dalton's by the rule of proportion. Thus as 10 (the number of Drs. Wollaston and Thomson for oxygen) is to 1.32 (their number for hydrogen) so very nearly is 7.5 (Mr. Dalton's number for oxygen) to 1 (his number for hydrogen).

Sir H. Davy has assumed, with Mr. Dalton, the atom of hydrogen as unity;* but that philosopher, and Berzelius also, have modified the theory, by taking for granted that water is a compound of one proportion (atom) of oxygen, and two proportions (atoms) of hydrogen. This is founded on the supposition, that equal measures of different gases contain equal numbers of atoms; and on

* The Atomic Theory, although highly ingenious, and in all probability correct in its general outlines, is however as yet, not sufficiently matured, to enable us fully to found our speculations thereon. And the difficulties of the subject are by no means lessened to the student, by finding some of the principal chemists of the day assuming oxygen as the decimal unit for their estimations of its compounds; whilst others of equal celebrity have fixed on hydrogen for the same intention; the difficulty is still further increased by their different sentiments, as to the number of atoms in which the above two bodies combine to form water. I should myself consider hydrogen as the most appropriate decimal unit, because it is the lightest of substances which we can appreciate by weight; and I should conclude, that since oxygen and hydrogen have no other known combination than as water, that such union is by an atom of each, since that is the smallest possible proportion in which they can unite. For the most complete exposition of the doctrine of definite proportions, and of the Atomic Theory, the reader is referred to the papers of Dr. Thomson in his *Annals of Philosophy*. I cannot however doubt, that they will be greatly modified, before they can be considered as approximating to perfection.—C.

the fact, that two measures of hydrogen gas and one of oxygen gas, are necessary to form water. And as, in water, the hydrogen is to the oxygen by weight as 1 to 7.5, two atoms of hydrogen must, on this hypothesis, weigh 1, and one atom of oxygen 7.5, or if we denote the atom of hydrogen by 1, we must express that of oxygen by 15. It is objectionable, however, to this modification of the atomic theory, that it contradicts a fundamental proposition of Mr. Dalton, the consistency of which with mechanical principles he has fully shown; namely, that when one combination only of two elements exists, it must be presumed, unless the contrary can be proved, to be a binary one.

It is easy to determine, in the manner already explained, the relative weights of the atoms of two elementary bodies, which unite only in one proportion. But when one body unites, in different proportions, with another, it is necessary, in order to ascertain the weight of its atom, that we should know the smallest proportion in which the former combines with the latter. Thus, if we have a body A, 100 parts of which by weight combine with not less than 30 of oxygen, the relative weight of its atom will be to that of oxygen as 100 to 30; or, reducing these numbers to their lowest terms, as 25 to 7.5; and the number 25 will, therefore express the relative weight of the atom of A. But if, in the progress of science, it should be found, that 100 parts of A are capable of uniting with 15 parts of oxygen, then the relative weight of the atom of A must be doubled, for, as 100 to 15, so is 50 to 7.5. This example will serve to explain the changes that have been made, in assigning the weights of the atoms of certain bodies; changes, which, it may be observed, always consist either in a multiplication, or division, of the original weight, by some simple number.

There are (it must be confessed) a few cases, in which one body combines with another in different proportions; and yet the greater proportions are not multiples of the less, by any entire number. For example, we have two oxides of iron, the first of which consists of 100 iron and about 30 oxygen; the second of 100 iron and about 45 oxygen. But the numbers 30 and 45 are to each other as 1 to $1\frac{1}{2}$. It will, however, render these numbers (1 and $1\frac{1}{2}$) consistent with the law of simple multiples, if we multiply each of them by 2, which will change them to 2 and 3; and if we suppose that there is an oxide of iron (though it has not yet been obtained experimentally), consisting of 100 iron and 15 oxygen; for the multiplication of this last number by 2 and 3, will then give us the known oxides of iron.

In some cases, where we have the apparent anomaly of 1 atom of one substance, united with $1\frac{1}{2}$ of another, it has been proposed, by Dr. Thomson*, to remove the difficulty, by multiplying both numbers by 2; and by assuming that, in such compounds, we have 2 atoms of the one combined with 3 atoms of the other. Such combinations, it is true, are exceptions to a law deduced by Berzelius; *that, in all inorganic compounds, one of the constituents is in*

* Thomson's Annals, v. 187.

the state of a single atom. But they are in no respect inconsistent with the views of Mr. Dalton; and are, indeed expressly admitted by him to be compatible with his hypothesis, as well as confirmed by experience.*

Several objections have been proposed to the theory of Mr. Dalton; but, of these, I shall notice only the most important.

1. It has been contended, that we have no evidence when one combination only of two elements exist, that it must be a binary one; and that we might equally well suppose it to be a compound of two atoms of the one body, with one atom of the other. In answer to this objection, we may urge the probability that when two elementary bodies A and B unite, the most energetic combination will be that in which one atom of A is combined with one atom of B; for an additional atom of B will introduce a new force, diminishing the attraction of those elements for each other, namely, the mutual repulsion of the atoms of B; and this repulsion will be the greater, in proportion as we increase the number of the atoms of B.

2dly. It has been said, that, when more than one compound of two elements exist, we have no proof which of them is the binary compound, and which the ternary; for example, that we might suppose carbonic acid to be a compound of an atom of charcoal and an atom of oxygen, and carbonic oxide to be a compound of an atom of oxygen with two atoms of charcoal. To this objection, however, it is a satisfactory answer, that such a constitution of carbonic acid and carbonic oxide would be directly contradictory of a law of chemical combination, namely, that it is attendant, in most cases, with an increase of specific gravity. It would be absurd, therefore, to suppose carbonic acid, which is the heavier body, to be only once compounded, and carbonic oxide, which is the lighter, to be twice compounded. Moreover, it is universally observed, that of chemical compounds, the most simple are the most difficult to be decomposed; and this being the case with carbonic oxide, we may naturally suppose it to be more simple than carbonic acid.

3dly. It has been remarked, that instead of supposing water to consist of an atom of oxygen united with an atom of hydrogen, and that the atom of the former is $7\frac{1}{2}$ times heavier than that of the latter, we might, with equal probability, conclude that, in water, we have $7\frac{1}{2}$ times more atoms of oxygen than of hydrogen. But this, if admitted, would involve the absurdity, that in a mixture of hydrogen and oxygen gases, so contrived that the ultimate atoms of each should be in equal number, seven atoms of oxygen should desert all the proximate atoms of hydrogen, in order to unite with one at a distance, for which they must necessarily have a less affinity. In this case, a less force must overcome a greater; and, finally, only a small number of the atoms of hydrogen would be engaged by the atoms of oxygen, the rest remaining in a state of freedom.

* Thomson's Annals, iii. 174.

It would be claiming too much, however, for the theory of Mr. Dalton to assert that, in its present state, it is to be considered as fully established in all its details. In the further progress of chemical discovery, it is probable that it will receive considerable modifications, and that the relative weights of the atoms of bodies will, in many cases, be essentially changed. The instances, in which the theory agrees with the results of analysis, are already too numerous to allow them to be considered as accidental coincidences; and no phenomena have hitherto been shewn to be irreconcilable with the hypothesis. Its value and importance, if confirmed by the accession of new facts, will be scarcely less felt as a guide to further investigations into the constitution of bodies, than as a test of the accuracy of our present knowledge; and the universality of its application to chemical phenomena will be scarcely inferior to that of the law of gravitation in explaining the facts of natural philosophy.

A modification of the law of definite proportions, so far as respects æriform bodies, has been proposed by Gay Lussac, namely, that they combine in proportions determinable not by weight, but by *volume*, the ratios being 1 *measure* of A to 1 of B, or 1 to 2, or 1 to 3, &c. Water, for example, results from the union of two volumes of hydrogen with one of oxygen; muriate of ammonia from 1 volume of muriatic acid gas + 1 of ammonia; nitrous gas from 1 measure of oxygen + 1 of nitrogen; nitrous oxide from 1 oxygen + 2 nitrogen; nitrous acid from 2 oxygen + 1 nitrogen. In some instances, as in that of water, this law is not inconsistent with the atomic theory; but in other instances it cannot be reconciled with the relative weights assigned to the atoms of certain elementary bodies. In nitrous gas, for example, which Mr. Dalton conceives to be formed by the union of 1 atom of oxygen + 1 atom of nitrogen, equal volumes of those gases would give for the relative weights of oxygen and nitrogen, numbers very different from those derived by other methods. The two hypothesis of atoms and of volumes cannot, therefore, both be true; and from some well ascertained exceptions to the latter, it appears to me that the theory of volumes will scarcely be found tenable.

Before dismissing the consideration of the proportions in which bodies combine, it will be proper to notice a few general principles, which, though they are connected with the atomic theory, have been derived from experience.

1. When we have ascertained the proportion in which any two or more bodies A B C &c. of one class neutralize another body X of a different class, it will be found that the same relative proportions of A B C &c. will be required to neutralize any other body of the same class as X. Thus, since 100 parts of real 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 neutralize the same quantity (71) of lime. The great importance of this law will readily be perceived, not only as it enables us to anticipate, but also to correct, the results of analysis.

2dly. If the quantities of two bodies, A and B, that are neces-

sary to saturate a given weight of a third body, be represented by q and r , these quantities may be called *equivalents*. Thus, in the example above cited, 100 parts of sulphuric acid and 68 of muriatic acid, are equivalents of each other. A *Table of Equivalents*, which will be found extremely useful in various calculations, will be given in the Appendix. By adapting a table of this sort to a moveable scale, on the principle of Gunter's sliding rule, Dr. Wollaston has lately constructed an instrument, called the *Logometric Scale of Chemical Equivalents*, which is capable of solving, with great facility, a number of problems, interesting both to the scientific and practical chemist*.

SECTION. IV.

Of Elective Affinity.

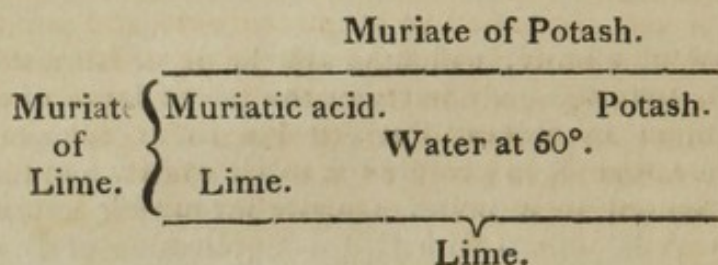
AN important law of affinity, which is the basis of almost all chemical theory, is, that one body has not the same force of affinity towards a number of others, but attracts them unequally. Thus A will combine with B in preference to C, even when these two bodies are presented to it under equally favourable circumstances. Or, when A is united with C, the application of B will detach A from C, and we shall have a new compound consisting of A and B. C being set at liberty. Such cases are examples of what is termed in chemistry *simple decomposition*, by which it is to be understood that a body acts upon a compound of two ingredients, and unites with one of its constituents, leaving the other at liberty. And as the forces of affinity of one body to a number of others vary, this body has been metaphorically represented as making an election; and the affinity has been called *single elective affinity*. Thus if to the muriate of lime, consisting of lime and muriatic acid, we add potash, the muriatic acid exerts a stronger elective affinity for the potash than for the lime; and the lime falls down in the state of a powder, or is *precipitated*. Of facts of this kind a great variety have been comprehended in the form of tables, the first idea of which seems to have occurred nearly a century ago, to Geoffrey, a French chemist. The substance whose affinities are to be expressed, is placed at the head of a column, and is separated from the rest by a horizontal line. Beneath this line are arranged the bodies, with which it is capable of combining, in the order of their respective forces of affinity; the substance which it attracts most strongly being placed nearest to it, and that, for which it has the least affinity, at the bottom of the column. The affinities of muriatic acid, for example, are exhibited by the following plan:—

* This scale, with its explanation, will be found at the end of the volume. See plate 11. C.

MURIATIC ACID.

Barytes,
Potash,
Soda,
Lime,
Ammonia,
Magnesia,
&c. &c.

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



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

No chemical facts can appear, on first view, more simple or intelligible, than those which are explained by the operation of single elective affinity. It will be found, however, on a more minute examination, that this force, abstractedly considered, is only one of several causes which are concerned in chemical decompositions, and that its action is modified, and sometimes even subverted, by counteracting forces.

SECTION V.

Of the Causes which modify the Action of Chemical Affinity.

THE order of decomposition is not, as might be inferred from the law of elective affinity, invariable; but, in certain cases, may even be reversed. Thus though A may attract B more strongly than either A or B is attracted by C, yet, under some circumstances, C may be employed to decompose partially the compound A B. Again, if we mix together A B and C, using the two first in the proportions required to neutralize each other, it will be found that A and B have not combined to the exclusion of C, but that we have a compound of B with A, and another of B with C, in proportions regulated by the quantities of A and C, which have been employed. Facts of this kind have been long known to chemists. It had been ascertained, for example, before the time of Bergman, that sulphate of potash, a salt composed of sulphuric acid and potash, is partly decomposed by nitric acid, although the nitric has a weaker affinity than the sulphuric acid for that alkali. Examples of the same kind have since been multiplied by Berthollet, who has asserted that in the following, as well as in other cases, a substance possessing a weaker attraction, displaces another having a stronger, for a third body* :

1. Potash separates sulphuric acid from barytes.
2. Lime separates sulphuric acid from potash.
3. Potash separates oxalic acid from lime.
4. Nitric acid separates lime from oxalic acid.
5. Potash separates phosphoric acid from lime.
6. Potash separates carbonic acid from lime.
7. Soda separates sulphuric acid from potash.

These facts, and a variety of similar ones, are to be explained, according to the views of Berthollet, on the following principles :—

1. When two substances are opposed to each other with respect to a third, as in the foregoing examples, they may be considered as antagonist forces; and they share the third body between them in proportion to the intensity of their action. But this intensity, according to Berthollet, depends not only on the *energy of the affinities*, but on the *quantities* of the two bodies opposed to each other. Hence a larger quantity of one of the substances may compensate a weaker affinity, and the reverse. To the absolute weight of a body, multiplied by the degree of its affinity, he has given the name of *mass*, a term in some degree objectionable from the different meaning which is affixed to it in mechanical philosophy. As an illustra-

* In each of the examples given in the Table, the body, first mentioned, decomposes a compound of the second and third, although its attraction for the second is inferior to that of the third.

tion, let us suppose (what is not accurate in point of fact) that the affinity of barytes for muriatic acid is twice as strong as that of potash, or that these affinities are respectively denoted by the numbers 4 and 2. In this case the same *mass* will result from 4 parts of barytes as from 8 of potash; because the same product (16) is obtained in each instance, by multiplying the number indicating the affinity into that denoting the quantity; for 4, (the affinity of barytes) multiplied by 4, (the quantity assumed in this example) is equal to 16; and 2 (the affinity of potash) multiplied by 8 (its quantity) is also equal to 16. In this case, therefore, to divide equally a portion of muriatic acid between barytes and potash, these bodies should be employed in the proportion of 2 of the former to 4 of the latter.

The influence of quantity explains also the difficulty which is observed in effecting, in any instance, the total decomposition of a compound of two principles by means of a third. The immediate effect of a third body C, when added to a compound A B, is to abstract from B a portion of the substance A; and consequently a portion of B is set at liberty, the attraction of which for A is opposed to that of the uncombined part of C. The farther this decomposition is carried, the greater will be the proportion of B, which is brought into an uncombined state; and the more powerfully will it oppose any further tendency of C to detach the substance A. At a certain point, the affinities of B and C for A will be exactly balanced, and the decomposition will proceed no farther. In a few cases it is acknowledged by Berthollet, a third body separates the whole of one of the principles of a compound; but this he supposes to happen in consequence of the agency of other extraneous forces, the nature of which remains to be pointed out.

2dly. *Cohesion* is a force, the influence of which over the chemical union of bodies has already been explained in a former section; and other illustrations of its interference will be given, when we consider the subject of the limitations to chemical combination.

3dly. *Insolubility* is another force, which essentially modifies the exertion of affinity. It is to be considered, indeed, merely as the result of cohesion, with respect to the liquid in which the effect takes place.

When a soluble substance and an insoluble one are presented, at the same time, to a third, for which they have nearly an equal affinity, the soluble body is brought into the sphere of action with great advantages over its antagonist. Its cohesion at the outset is but little, and by solution is reduced almost to nothing; while that of the insoluble body remains the same. The whole of the soluble substance also exerts its affinity at once; while a part only of the insoluble one can oppose its force. Hence the soluble substance may prevail, and may attach to itself the greatest proportion of the third body, even though it has a weaker affinity than the insoluble one to the subject of combination.

Insolubility, however, under certain circumstances, is a force which turns the balance in favour of the affinity of one body when

opposed to the affinity of another. For example, if to the soluble compound, sulphate of soda, we add barytes, the new compound, sulphate of barytes, is precipitated the instant it is formed; and being removed from the sphere of action, the soda can exert no effect upon it by its greater quantity or mass. For the same reason, when soda is added to sulphate of barytes, the sulphate is protected from decomposition both by its insolubility and by its cohesion.

These facts sufficiently prove that the order of precipitation, which was formerly assumed as the basis of tables of elective affinity, can no longer be considered as an accurate measure of that force; and that the body, which is precipitated, may, in some cases, be superior in affinity to the one which has caused precipitation. In these cases, a trifling superiority in affinity may be more than counterbalanced by the cohesive force, which causes insolubility.

4thly. *Great specific gravity* is a force, which must concur with insolubility or cohesion in originally impeding combination; and when chemical union has taken place, it must come in aid of affinity, by removing the new compound from the sphere of action. It is scarcely necessary to enlarge on the operation of a force, the nature of which must be so obvious.

5thly. *Elasticity*. Cohesion, it has already been stated, may prove an impediment to combination; and, on the other hand, it is possible that the particles of bodies may be separated so widely, as to be removed out of the sphere of their mutual attraction. Such appears to be the fact with regard to a class of bodies called airs or gases. The bases of several of these have powerful attractions for the bases of others, and for various liquids, and yet they do not combine on simple admixture, but strong mechanical pressure bring their particles sufficiently near, to be within the influence of their mutual attraction, and combination immediately ensues.

Again if two bodies, one of which has an elastic and the other a liquid form, be presented at the same time to a solid, for which they have both an affinity, the solid will unite with the liquid in preference to the gas. Or if we add to the compound of an elastic substance with an inelastic one, a third body also inelastic, the two latter combine to the exclusion of the elastic body. For example, if to the compound of potash and carbonic acid we add sulphuric acid, the latter acid, acting both by its affinity and its quantity, disengages a portion of carbonic acid. This, by its elasticity, is removed from the sphere of action, and presents no obstacle to the further operation of the sulphuric acid. Hence elastic bodies act only by their affinity; whereas liquids act both by their affinity and quantity conjoined. And though the affinity of the liquid, abstractedly considered, may be inferior to the affinity of the elastic body, yet, united with quantity, it prevails. In the above instances, the whole of the elastic acid may be expelled by the fixed acid; whereas, as it has already been observed, decomposition is incom-

plete, if the substance which is liberated remain within the sphere of action.

6thly. *Efflorescence* is a circumstance which occasionally influences the exertion of affinity; but this is only of very rare occurrence. The simplest example of it is that of lime, and muriate of soda. When a paste composed of these two substances with a great excess of lime, is exposed, in a moist state, to the air, the lime, acting by its quantity, disengages soda from the common salt, which appears in a dry form, on the outer surface of the paste, united with carbonic acid absorbed from the atmosphere. In this case the soda, which is separated, being removed from contiguity with the interior part of the mass, presents no obstacle to the farther action of the lime, and the decomposition is carried farther than it would have been, had no such removal happened.

6thly The influence of *temperature* over chemical affinity is extremely extensive and important; but at present a very general statement only of its effects is required. In some cases an increased temperature acts in promoting, and at others in impeding, chemical combination: and it materially affects also the order of decompositions.

An increased temperature promotes chemical union by diminishing or overcoming cohesion. Thus metals unite by fusion, and several salts are more soluble in hot than in cold water. Whenever heat is an obstacle to combination, it produces its effect by increasing elasticity. Hence water absorbs a less proportion of gas at a high than at a low temperature. A reduction of the temperature of elastic bodies, by lessening their elasticity, facilitates their union with other substances. In certain cases, an increased temperature has the combined effects of diminishing cohesion and increasing elasticity. When sulphur is exposed to oxygen gas, no combination ensues, until the sulphur is heated; and though the elasticity of the gas is thus increased, yet the diminution of cohesion is more than proportionate, and chemical union ensues between the two bodies.

8thly. The *electrical state* of bodies has a most important influence over their chemical union. This, however, is a subject, of which it would be difficult to offer a general view, and for its full development, I refer to a subsequent chapter on *Electro-chemistry*.

9thly. *Mechanical pressure* is another force, which has considerable influence over chemical affinity. With respect to solid bodies, its agency is not frequent; but we have unequivocal examples of its operation in cases, where detonation is produced by concussion. The effects of pressure are chiefly manifested, in producing the combination of æriform bodies either with solids, with liquids, or with each other; and in preserving combinations, which have been already formed, under circumstances tending to disunite them. Chalk, for example, is a compound of lime and carbonic acid; and these bodies, by the simple application of an intense heat, are separable from each other; but, under strong pressure, a heat may be applied sufficient to melt the chalk, without expelling the carbonic acid. It is this principle (of the influence of pressure in

opposing chemical decomposition), that is the foundation of Dr. Hutton's ingenious Theory of the Earth.

Such are the most important circumstances, that modify the exertion of chemical affinity. Of their influence, sufficient illustrations have been given to prove, that in every case of combination and decomposition, we are not to consider the force of affinity abstractedly; but are to take into account the agency of other powers, as cohesion, quantity, insolubility, elasticity, efflorescence, and temperature. By the action of these extraneous powers, Berthollet has endeavoured to explain certain facts which are not easily understood on any other principle. Of these the most important are, 1stly, the establishment of proportions in chemical compounds; and 2dly, the modification produced in the affinities of bodies by chemical union.

1. Independently of these extraneous forces, Berthollet imagines that there are no limits to combination, or that two bodies, which are now susceptible of union only in one or in few proportions, might, if these forces were annihilated, be united in every proportion. The causes which he has assigned, as chiefly regulating proportion, are cohesion and elasticity. To take one of the simplest cases, the proportion, in which a salt can be combined with water, depends on the balance between the chemical affinity of the bodies for each other, and the cohesive attraction of the salt. In this case, then, cohesion is the limiting power. As an example of the influence of this force when more energetic affinities are exerted, if we add to diluted sulphuric acid a solution of barytes, a compound is formed, consisting of sulphuric acid and barytes, which, in consequence of its great insolubility or cohesion, is instantly removed from contact with the redundant acid, and with established proportions.

The agency of elasticity in limiting proportion, may be exemplified by the combination of hydrogen and oxygen. If a mixture of the two gases be inflamed, the new compound, water, is immediately separated, from what is superfluous of both ingredients, by its superior density. In other instances the bases of æriform substances are combined in various proportions, and in such examples, there are several terms of greatest condensation, as in the case of oxygen and nitrogen.

2. Another important part of the theory of Berthollet is, that the affinities of a compound are not newly acquired; but are merely the modified affinities of its constituents, the action of which, in their separate state, was counteracted by the prevalence of opposing forces. By combination, these forces are so far overcome, that the affinities of the constituents are enabled to exert themselves.

The action of different affinities existing in one compound, Berthollet terms *resulting affinities*, while the individual affinities of the constituents he calls *elementary affinities*. Thus nitric acid acts on potash by an affinity, which results from those of oxygen and azote for potash. And as all affinity is mutual, the term *resulting affinity* is applied, also, to that force, with which a simple body acts on a compound; to the affinity for example, which any simple

body may exert on nitric acid. A simple body, indeed, may exert towards a compound both an elementary and resulting affinity. If the elementary affinity prevails, it will unite only with one of the principles of the compound, as when a simple body, by its affinity for oxygen, decomposes nitric acid, and liberates its nitrogen in a separate form. If the resulting affinity be predominant, the simple body will unite with the whole compound without effecting any disunion of its elements.

From these views it may be inferred, that we are not, in any case, to deny the existence of an affinity between two bodies, merely because they do not combine when presented to each other; for an affinity may exist, but may be suppressed by the prevalence of opposing forces. According to the doctrine of Berthollet, affinity is a force exerted by every body towards every other; even though not made apparent by any effect. On this principle, we are able to explain certain phenomena, which are wholly unintelligible on any other, and especially those which have been referred to *disposing affinity*. The action of sulphuret of potash, for example, on oxygen gas, has been ascribed to the disposing affinity of potash for sulphuric acid. This, however, is ascribing an affinity to a compound, before that compound has existence. It is much more probable, that besides the diminished cohesion of the sulphur, the affinity of potash for oxygen has some share in producing the combination. On this principle the united affinities of the potash and sulphur for oxygen (in other words the *resulting affinities* of the sulphuret of potash) are the efficient causes of chemical union. This explanation, at least, does not, like the theory of disposing affinities, involve an absurdity.*

The theory of Berthollet, however, which promised, on its first development, to form a new era in chemical philosophy, has lost much of its probability, by the subsequent progress of the science. It is directly, indeed, at variance with the doctrine of definite proportions, which every day gathers strength by the accumulation of new and well established facts. It is liable, moreover, to the following objections.

1st. It has been shown by professor Pfaff, of Kiell†, that, in various cases, where two acids are brought into contact with one base, the base unites with one acid, to the entire exclusion of the other. When, for example, to a given weight of lime, quantities of sulphuric and tartaric acids are put, either of which would exactly saturate the lime, the sulphuric acid unites with the lime, to the entire exclusion of the tartaric. The same evidence of a superior affinity of the sulphuric acid over that of the oxalic is obtained, by placing those acids in contact with as much oxide of lead, as would exactly saturate either of them. Again, comparing the action of two bases on one acid, the same law is found to hold good: for

* Dr. Henry has very justly stated the doctrine of *disposing* affinities to involve an absurdity, yet it is by this doctrine that an explanation is given in all writers, of the decomposition of water by sulphuric acid and iron; I believe it may be more satisfactorily elucidated without it.—C.

† 77 Ann. de Chim. p. 259.

when potash and magnesia are mixed with just as much sulphuric acid, as is required to saturate either of them, the potash seizes the whole of the acid, and no part of it unites with the magnesia. Nor can these effects be explained by any of those extraneous forces, which Berthollet supposes, in all cases, to regulate chemical combination; or by any principle, but a stronger affinity of sulphuric acid, than of tartaric or oxalic acid, for the different bases; and of potash, than of magnesia, for the same acid.

2dly. Some of the cases, before quoted from Berthollet, to show the reciprocal displacement of two bodies by each other from a third (it has been justly observed), are examples not of *single* elective affinity, in which three bodies only are concerned; but of *complex* affinity, in which the attractions of four bodies are brought into action. In the first case, for example, there is reason to believe, that sulphuric acid is displaced from barytes, not by pure potash, but by potash which has absorbed carbonic acid from the atmosphere.

3dly. In other cases, the consideration of the affinities of two bodies A and B, for a third C, is complicated with this circumstance, that the neutral compound of A and B has an affinity for a further portion of one of its ingredients. If then C be brought into contact with the compound A B, we have, acting at the same moment, the affinity of C for A, which partly decomposes the compound A B; and the affinity of the undecomposed part of A B, for that portion of B which is set at liberty. For instance, when nitric acid acts on sulphate of potash, some nitrate of potash is formed; and the sulphuric acid, which is set at liberty, uniting with the undecomposed sulphate of potash, composes a new salt, consisting of sulphate of potash with an excess of sulphuric acid.

4thly. It is a strong objection to the theory of Berthollet that, in some cases, decompositions happen, which, according to his views, ought not to take place; and that in others, decompositions do not ensue, which the theory would have led us to have anticipated.

5thly. The theory is objectionable, inasmuch as, in several instances properties are supposed to operate, before the bodies exist, to which those properties are attributed. It is inconceivable, for instance, that the cohesion, or insolubility of sulphate of barytes, can have any share in producing the decomposition of sulphate of potash by that earth; for the insolubility of sulphate of barytes can have no agency, till that compound is formed; which is the very effect to be explained.

Notwithstanding these objections to the theory of Berthollet, when carried so far as has been done by its author, in the explanation of chemical phenomena, it must still be admitted that the extraneous forces, pointed out by that acute philosopher, have great influence in modifying the effects of chemical affinity. But these forces are entitled only to be considered as secondary causes; and not as determining combinations or decompositions, nor as regulating the proportions in which bodies unite, independently of the superior force of chemical affinity.

SECTION VI.

Of the Estimation of the Forces of Affinity.

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

The observed order of decomposition, it has already been stated, does not enable us to assign the order of the forces of affinity; because, in all decompositions, other forces are concerned. We are, therefore, obliged to seek some other method of determining the problem. Of these several have been proposed.

When the surface of one body is brought into contact with another surface of the same kind, as when the smooth surfaces of a divided leaden bullet are pressed together, they adhere by the force of cohesion, their particles being all of *the same kind*. But when the surfaces of different bodies are thus brought into apparent contact, it is reasonable to suppose that their adhesion arises from chemical affinity, because their particles are of *different kinds*. Guyton proposed, therefore, the comparative force, with which different surfaces adhere, as a competent measure of chemical affinity. His experiments were made on plates of different metals, of precisely the same size and form, suspended by their centres from the arm of a sensible balance. The lower surfaces of the plates were successively brought into contact with mercury, which was changed for each experiment, and the weight was observed, which it was necessary to add to the opposite scale, in order to detach the several metals. Those which required the largest weight were inferred to have the greatest affinity; and it is remarkable, that the order of affinities, as determined in this way, correspond with the affinities as ascertained by other methods. The following were the results:—

Gold adhered to mercury with a force of	446 grains.
Silver	429
Tin	418
Lead	397
Bismuth	372
Zinc	204
Copper	142

Antimony	126 grains.
Iron	115
Cobalt	8

This method, it must be obvious, is of too limited application to be of much utility; for few bodies have the mechanical conditions, which can enable us to subject them to such a test. How, for example, could the affinities of acids for alkalies be examined on this principle? It may be doubted, also, whether in the cases to which it may be applied, it does not measure the facility of combination, rather than the actual force of affinity.

To determine the absolute forces, which one body exerts towards a number of others, Mr. Kirwan has proposed the quantity of each, which is required to produce neutralization. This he has ascertained by experiment in a great variety of instances, a few of which are contained in the following tables; the numbers being altered, to accommodate them to recent discoveries.

100 Parts of SULPHURIC ACID require for Neutralization
194 parts of barytes.
138 . . . of strontites.
118 . . . of potash.
78.2 . . of soda.
71 . . . of lime.
49.2 . . of magnesia.
43 . . . of ammonia.

100 Parts of POTASH require
115 of nitric acid.
93 of carbonic acid.
84.5 of sulphuric.
58 of muriatic.

In judging of the affinities of the same acid for different bases, Mr. Kirwan assumed that they are represented by the numbers indicating the quantities of each base required for neutralization. Thus, because 100 parts of sulphuric acid neutralize 194 of barytes, and 118 of potash, the affinity of the former is superior to that of the latter in the proportion of 194 to 118. So far the inference corresponds with the order of decomposition; for barytes takes sulphuric acid from potash. But if we examine the affinities of potash, as represented in the second table, we shall find that, on this principle, they are directly contradictory to fact. Thus the affinity of sulphuric acid should be inferior to that of the carbonic; whereas it is well known that the former displaces the latter from all its combinations. Mr. Kirwan was, therefore, driven to the necessity of establishing a precisely opposite rule in determining the affinities of different acids for the same base, and of assuming, that they are *inversely* proportionate to the affinity of the saturating acid. Thus the affinity of carbonic acid for potash would be 84.5, and that of sulphuric acid 93. This, however, involves a contradiction; since it is implied that a stronger affinity, in one instance, requires a greater quantity of the saturating principle, as in the relation of barytes and potash to sulphuric acid; and that, in the other, it requires a less

quantity, as in the instance of the sulphuric and carbonic acids with respect to potash.

Since neutralization is an effect of chemical affinity, which must in all cases bear a proportion to its cause, it has been assumed by Berthollet, that the substance which, in the *smallest quantity*, neutralizes another, is the one possessing the strongest affinity. On this principle the affinities of sulphuric acid for different bases, will be exactly the reverse of the order established by Mr. Kirwan; and to that order, which would have been assigned from observed decompositions. Thus ammonia will have a stronger affinity for sulphuric acid, than any of the substances which are placed above in the table; though it is separated, by each of these, from its union with that acid.

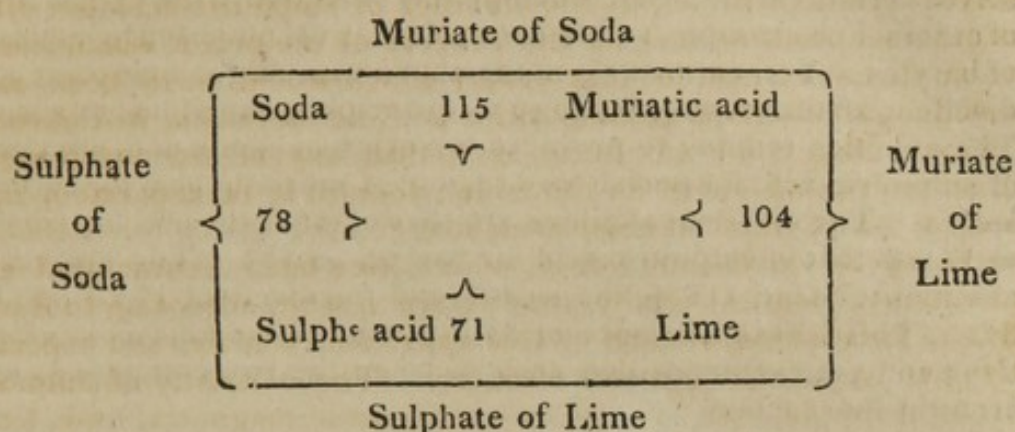
It is in the extraneous forces, which have been enumerated as influencing chemical affinity, that we are to seek, according to Berthollet, for the explanation of this apparent anomaly, and especially in those of cohesion and elasticity. The elasticity of ammonia, for example, turns the balance in favour of magnesia, lime, &c. There is an obvious difficulty, however, in the application of the theory. For as the elasticity of ammonia is suppressed by its combination with sulphuric acid, what, it may be asked, but a superior affinity can occasion the first commencement of decomposition? The problem, therefore of determining the absolute forces of affinity can scarcely be admitted to be solved. Even if it were, we should not be able to predict the order of decomposition, unless the modifying forces of cohesion, elasticity, &c., could be at the same time subjected to precise admeasurement. Until both these objects are accomplished, the results of chemistry can in no case be obtained by calculation, but the science must remain a collection of general principles, derived from experiment and induction.

SECTION VII.

Of Complex Affinity.

UNDER the more general name of *complex affinity*, Berthollet includes that which has hitherto been considered as produced by the action of four affinities, and which has commonly been denominated *double elective affinity*. It frequently happens that the compound of two principles cannot be destroyed either by a third or a fourth separately applied; but if the third and fourth be combined, and placed in contact with the former compound, a decomposition, or a change of principles will ensue. Thus when lime water is added to a solution of the sulphate of soda, no decomposition happens, because the sulphuric acid attracts soda more strongly than it attracts lime. If the muriatic acid be applied to the same compound, still its principles remain undisturbed, because the sulphuric acid attracts soda more strongly than the mu-

riatic. But if the lime and muriatic acid, previously combined, be mixed with the sulphate of soda, a double decomposition is effected. The lime, quitting the muriatic acid, unites with the sulphuric, and the soda, being separated from the sulphuric acid, combines with the muriatic. These decompositions are rendered more intelligible by the following diagram, contrived by Bergman.



On the outside of the vertical brackets are placed the original compounds; and above and below the diagram, the new compounds. The upper line, being straight, indicates that the muriate of soda remains in solution; and the middle of the lower line, being directed downwards, that the sulphate of lime is precipitated.

In all cases similar to the foregoing, Mr. Kirwan conceives that we may trace the operation of two distinct series of affinities. The affinities tending to preserve the original compounds (which in the above example are those between sulphuric acid and soda, and between muriatic acid and lime), he terms the *quiescent affinities*; because they resist any change of composition. On the other hand, the affinities which tend to disunite the original compounds and to produce new ones (such as those between muriatic acid and soda, and between sulphuric acid and lime), he terms *divellent affinities*. In order that an effect may be produced, the divellent affinities must necessarily be superior to the quiescent. Now assuming the numbers in Mr. Kirwan's tables to express accurately the forces of affinities, the double exchange of principles, which happens in the preceding instance, is readily explained. Thus the quiescent affinities are

Those of lime to muriatic acid = 104
of soda to sulphuric acid = 78

182

The divellent affinities, opposed to these, consist of

The affinity of soda to muriatic acid = 115
lime to sulphuric acid = 71

186

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

The theory of quiescent and divellent affinities, however, though highly attractive from its simplicity, and from the facility with which it solves certain phenomena, is completely defective in the explanation of others. For example, sulphate of potash is decomposed by muriate of barytes. Yet, estimating in the above manner the quiescent and divellent affinities, an exchange of principles ought not to ensue. The affinities tending to preserve the original compound, are those of sulphuric acid for potash = 118, and of muriatic acid for barytes = 285. The divellent affinities are that of muriatic acid for potash = 174 + that of sulphuric acid for barytes = 194. The quiescent affinities then are $118 + 285 = 403$, and the divellent $174 + 194 = 368$. This leaves a balance of 35 in favour of the quiescent affinities; and yet decomposition ensues, when the two compounds are brought into contact.

It must be acknowledged that the numbers, assumed by Mr. Kirwan, do not correspond with the actual forces of affinity. But even if they are taken according to the principle assumed by Berthollet, they will not be found universally applicable. The reason of this is, that the phenomena produced by complex affinity, like those occasioned by simple affinity, are materially influenced by the extraneous forces of cohesion, quantity, elasticity, temperature, &c. The effect of quantity is shown by the fact, that if two salts be mixed together in certain proportions, decomposition will ensue, but not if mixed in other proportions. Thus from the mingled solutions of two parts of muriate of lime and one of nitrate of potash, we obtain muriate of potash; but not from equal weights of the two salts. Insolubility, or precipitation, has also a considerable influence on the result. When this occurs, the influence of quantity is destroyed, as in the case of sulphate of potash and muriate of barytes. Elasticity, and an increased temperature (which operates by increasing elasticity), have also a powerful influence in promoting the action of complex affinities. Thus of four principles, two of which are volatile and two fixed, the two which are volatile will be disposed to unite, in preference to combining with either of those which are fixed. Hence the phenomena of complex decomposition concur with those of a more simple kind, in proving that affinity is not an uniform force, but is materially influenced by various modifying circumstances; and that we cannot confidently anticipate results, from comparing the numerical expressions of quiescent and divellent affinities.

One great obstacle to the construction of tables, capable of representing the affinity, is the difficulty of ascertaining, with precision, the quantities of bodies required for neutralization. Notwithstanding all the care employed by Mr. Kirwan, considerable errors appear to have crept into the results of his experiments. This will sufficiently appear, when they are examined by a test, originally proposed by Guyton. It must be obvious that if between two salts,

which are mixed together in solution, decomposition should ensue, and the mixture should afterwards be found neutral, the quantity of acid, which has quitted one of the bases, must have been exactly equivalent to the saturation of the other base, also deserted by its acid. If, for example, we mingle the muriate of magnesia and sulphate of soda, the mixture continues neutral; and hence it follows that the muriatic acid, which has quitted the magnesia, must have been exactly equal to the neutralization of the soda, deserted by the sulphuric acid. But from a calculation, founded on the proportion of the ingredients of these salts, as established by Mr. Kirwan, it appears that the soda, detached from the sulphuric acid, is not adequate to the saturation of the muriatic acid. The mixture, therefore, ought to be acid; and since this is contrary to fact, we may safely infer that there is an error in the estimation of the ingredients composing these salts. No tables, indeed, can be correct, unless they stand the test of this mode of verification. Such a table has been calculated by Fischer from the experiments of Richter; but even this table seems in several respects to be of questionable accuracy. I have thought it, however, entitled to a place among the tables in the Appendix; and I shall annex, also, a more correct one, the data of which are chiefly supplied by Dr. Wollaston's paper on Chemical Equivalents.*

SECTION VIII.

Experimental Illustrations of Chemical Affinity, Solution, &c.

For these experiments, a few wine glasses, or, in preference, deep ale glasses, will be required; and a Florence flask for performing the solutions.

I. *Some bodies have no affinity for each other.*—Oil and water, mercury and water, or powdered chalk and water, when shaken together in a vial, do not combine; the oil or water always rising to the surface, and the mercury or chalk sinking to the bottom.

II. *Examples of chemical affinity, and its most simple effect, viz. solution.*—Sugar or common salt disappears or dissolves in water; chalk in dilute muriatic acid.† Sugar and salt are, therefore, said to be *soluble* in water, and chalk in muriatic acid. The liquid in which the solid disappears, is termed a *solvent*. Chalk or sand, on the contrary, when mixed with water by agitation, always subside again. Hence they are said to be *insoluble*.

III. *Influence of mechanical division in promoting the action of chemical affinity, or in favouring solution.* Lumps of chalk or marble dissolve much more slowly in dilute muriatic acid, than equal weights of the same bodies in powder. Muriate of lime, or nitrate of ammonia, cast, after liquefaction by heat, into the shape of a solid

* Phil. Trans. 1814.

† I omit, purposely, the distinction between the solution and dissolution.

sphere, is very slowly dissolved; but with great rapidity when in the state of a powder or of crystals. When a lump of the Derbyshire fluuate of lime is immersed in concentrated sulphuric acid, scarcely any action of the two substances on each other takes place; but if the stone be finely pulverized, and then mingled with the acid, a violent action is manifested, by the copious escape of vapours of fluoric acid. In the common arts of life, the rasping and grinding of wood and other substances are familiar examples.

IV. *Hot liquids, generally speaking, are more powerful solvents than cold ones.*—To four ounce-measures of water, at the temperature of the atmosphere, add three ounces of sulphate of soda in powder. Only part of the salt will be dissolved, even after being agitated some time. Apply heat, and the whole of the salt will disappear. When the liquor cools, a portion of salt will separate again in a regular form or in crystals. This last appearance affords an instance of *crystallization*.

To this law, however, there are several exceptions; for many salts, among which is muriate of soda, or common salt, are equally, or nearly equally, soluble in cold as in hot water. (See the table of solubility of salts in water, in the Appendix.) Hence, a hot and saturated solution of muriate of soda does not, like the sulphate, deposit crystals on cooling. To obtain crystals of the muriate, and of other salts which observe a similar law as to solubility, it is necessary to evaporate a portion of the water; and the salt will then be deposited, even while the liquor remains hot. In general, the more slow the cooling, or evaporation, of saline solutions, the larger and more regular are the crystals.

V. *A very minute division of bodies is effected by solution.*—Dissolve two grains of sulphate of iron in a quart of water, and add a few drops of this solution to a wine-glass full of water, into which a few drops of tincture of galls have been fallen. The dilute infusion of galls will speedily assume a purplish hue. This shows that every drop of the quart of water, in which the sulphate of iron was dissolved, contains a notable portion of the salt.

VI. *Some bodies dissolve much more readily and copiously than others.*—Thus, an ounce measure of distilled water will dissolve half its weight of sulphate of ammonia, one third its weight of sulphate of soda, one sixteenth of sulphate of potash, and only one five-hundredth its weight of sulphate of lime.

VII. *Mechanical agitation facilitates solution.*—Into a wine-glass full of water, tinged blue with the infusion of litmus, let fall a small lump of solid tartaric acid. The acid, if left at rest, even during some hours, will only change to red that portion of the infusion which is in immediate contact with it. Stir the liquor, and the whole will immediately become red.

VIII. *Bodies do not act on each other, unless either one or both be in a state of solution.**—1. Mix some dry tartaric, or, in preference,

* This Law is made too general. Dr. Henry himself admits this, by what he says p. 12, under the consideration of Chemical affinity. If dry muriat of ammonia and acetat of lead be rubbed together in a mortar, they presently become

citric acid with dry carbonate of potash. No combination will ensue till water is added, which, acting the part of a solvent, promotes the union of the acid and alkali, as appears from a violent effervescence.

2. Spread thinly, on a piece of tinfoil, three or four inches square, some dry nitrate of copper*, and wrap it up. No effect will follow. Unfold the tinfoil, and having sprinkled the nitrate of copper with the smallest possible quantity of water, wrap the tinfoil up again as quickly as possible, pressing down the edges closely. Considerable heat, attended with fumes, will now be excited; and, if the experiment has been dexterously managed, even light will be evolved. This shows that nitrate of copper has no action on tin, unless in a state of solution.†

IX *Bodies, even when in a state of solution, do not act on each other at perceptible distances; in other words, contiguity is essential to the action of chemical affinity.*—Thus, when two fluids of different specific gravities, and which have a strong affinity for each other, are separated by a thin stratum of a third, which exerts no remarkable action on either, no combination ensues between the uppermost and lowest stratum. Into a glass jar, or deep ale glass, pour two ounce-measures of a solution of subcarbonate of potash, containing, in that quantity, two drachms of common salt of tartar. Under this introduce, very carefully, half an ounce-measure of water, holding in solution a drachm of common salt; and again, under both these, two ounce-measures of sulphuric acid, which has been diluted with an equal weight of water, and allowed to become cool. The introduction of a second and third liquid beneath the first, is best effected, by filling, with the liquid to be introduced, the dropping tube, fig. 15. pl. i., which may be done by the action of the mouth. The finger is then pressed on the upper orifice of the tube; and the lower orifice, being brought to the bottom of the vessel containing the liquid, the finger is withdrawn, and the liquid descends from the tube, without mingling with the upper stratum. When a solution of carbonate of potash is thus separated from diluted sulphuric acid, for which it has a powerful affinity, by the intervention of a thin stratum of brine, the two fluids will remain distinct and inefficient on each other; but, on stirring the mixture, a violent effervescence ensues, in consequence of the action of the sulphuric acid on the potash.

X. *Two bodies, having no affinity for each other, unite by the intervention of a third.*—Thus, the oil and water which, in Experi-

liquid, and a transfer of principles takes place; and if dry muriat of ammonia and lime be rubbed together, the decomposition is apparent, by the evolution of ammoniacal gas. Many other examples of the incorrectness of this law might be given, but the above are sufficient. C.

* To prepare nitrate of copper, dissolve the filings or turnings of that metal in a mixture of one part nitrous acid and three parts water; decant the liquor when it has ceased to emit fumes; and evaporate it to dryness, in a copper or earthen dish. The dry mass must be kept in a bottle.

† Mr. Murray has given us a better exposition of this interesting phenomenon. C.

ment I., could not, by agitation, be brought into union, unite immediately on adding a solution of caustic potash. The alkali, in this case, acts as an intermedium. The fact, indeed, admits of being explained by the supposition, that the oil and alkali form, in the first instance, a compound which is soluble in water.

XI. *Saturation and neutralization illustrated.*—Water, after having taken up as much common salt as it can dissolve, is said to be *saturated* with salt. Muriatic acid, when it has ceased to act any longer on lime, is said to be *neutralized*.

XII. *The properties characterizing bodies, when separate, are destroyed by chemical combination, and new properties appear in the compound.* Thus, muriatic acid and lime, which, in a separate state, have each a most corrosive taste, lose this entirely when mutually saturated; the compound is extremely soluble, though lime itself is very difficult of solution; the acid no longer reddens syrup of violets; nor does the lime change it, as before, to green. The resulting compound, also, muriate of lime, exhibits new properties. It has an intensely bitter taste; is susceptible of a crystallized form; and the crystals, when mixed with snow or ice, generate a degree of cold sufficient to freeze quicksilver.

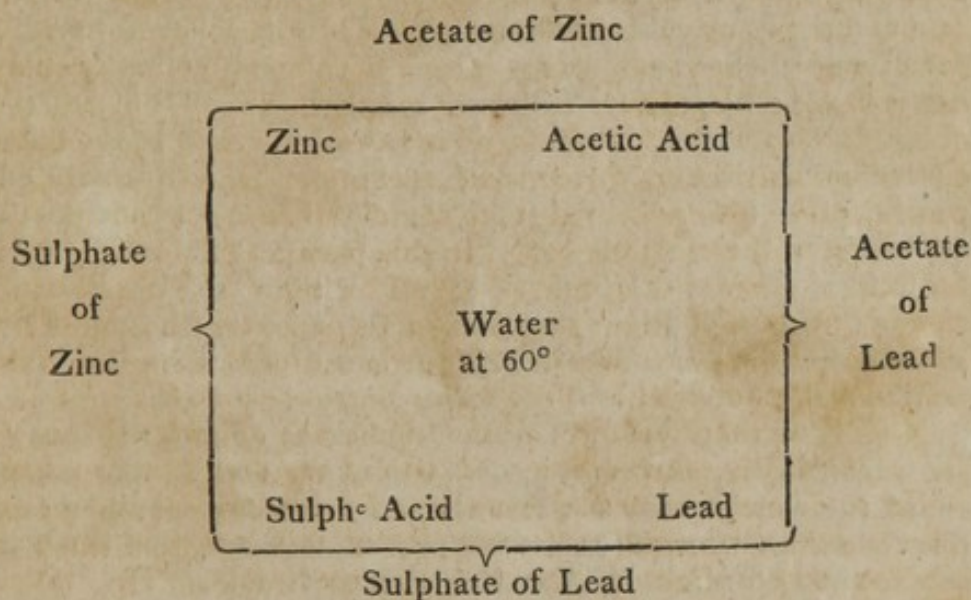
XIII. *Single elective affinity illustrated.*—1. Add to the combination of oil with alkali, formed in Experiment X., a little diluted sulphuric acid. The acid will seize the alkali, and set the oil at liberty, which will rise to the top. In this instance, the affinity of alkali for acid is greater than that of alkali for oil. 2. To a dilute solution of muriate of lime (prepared in Experiment II.), add a little of the solution of pure potash. The potash will seize the muriatic acid, and the lime will fall down, or be *precipitated*.

XIV. *In every instance, in comparing the affinities of two bodies for a third, a weaker affinity, in one of the two compared, will be found to be compensated by increasing its quantity.*—It is not easy to offer clear and unequivocal examples of this law, and such as the student may submit to the test of experiment. The following, however, may illustrate the proposition sufficiently: Mingle together, in a mortar, one part of muriate of soda (common salt) with half a part of red oxide of lead (litharge, or red lead), and add sufficient water to form a thin paste. The oxide of lead, on examining the mixture after twenty-four hours, will be found not to have detached the muriatic acid from the soda; for the strong taste of that alkali will not be apparent. Increase the weight of the oxide of lead to three or four times that of the salt; and, after the same interval, the mixture will exhibit, by its taste, marks of uncombined soda. This proves, that the larger quantity of the oxide must have detached a considerable portion of muriatic acid from the soda, though the oxide has a weaker affinity for that acid than the soda possesses.

Another illustration of the same general principle has been suggested by Berzelius. It is necessary to premise, that the colour of the compound of sulphuric acid with oxide of copper is blue, and that of muriatic acid with the same oxide, green. To a saturated solution of sulphate of copper in water, add by degrees con-

centrated muriatic acid. Every addition will render the colour of the liquid more distinctly green, showing an increased production of muriate of copper; the oxide of copper being divided between the sulphuric and muriatic acids, in proportion to the quantity of each acid that is present.

XV. *Double elective affinity exemplified.*—In a watery solution of sulphate of zinc, immerse a thin sheet of lead: the lead will remain unaltered, as also will the sulphate of zinc, because zinc attracts sulphuric acid more strongly than lead. But let a solution of acetate of lead be mixed with one of sulphate of zinc: the lead will then go over to the sulphuric acid, while the zinc passes to the acetic. The sulphate of lead, being insoluble, will fall down in the state of a white powder; but the acetate of zinc will remain in solution. The changes that occur in this experiment will be better understood from the following scheme:



The vertical brackets include the original compounds, *viz.* sulphate of zinc, and acetate of lead; and the horizontal line and bracket point out the new ones, *viz.* acetate of zinc and sulphate of lead. By the upper horizontal line, it is denoted, that the acetate of zinc remains in solution; and, by the point of the lower bracket being directed downwards, it is meant to express, that the sulphate of lead falls down, or is precipitated.

CHAPTER III.

OF HEAT OR CALORIC.

SECTION I.

General Observations on Heat.

WHEN we apply the hand to a body, which is hotter than itself, we are sensible of a peculiar feeling, which we agree to call the *sensation of heat*. At the same time we observe, in almost all bodies that are placed in the same situation with the hand, certain effects, the most remarkable of which is an enlargement of their dimensions. These circumstances, with very few exceptions, so constantly accompany each other, that we can have little or no hesitation in referring them to one and the same cause. Of the nature of this cause we have no satisfactory evidence; and we are unable to demonstrate either that it consists in any general quality of bodies, or that it resides in a distinct peculiar kind of matter. The opinion, however, which best explains the phenomena, is that which ascribes them to an extremely subtile fluid, of so refined a nature, as to be capable of insinuating itself between the particles of the most dense and solid bodies. To this fluid, as well as to the sensation which it excites, the term *heat* was formerly applied. But there was an obvious impropriety in confounding, under one appellation, two things so distinct as a sensation and its cause; and the term *caloric*, first proposed by Lavoisier, is now, therefore, generally adopted to denote the cause of heat. Occasionally, however, in order to avoid too frequent a repetition of the same word, the term *heat* is still employed in a more extensive sense, to express not only the sensation which it usually denotes, but also some of the modifications of caloric.

Caloric, so far as its chemical agencies are concerned, may be chiefly considered under two views—as an antagonist to the cohesive attraction of bodies—and as concurring with, and increasing elasticity. By removing the particles of any solid to a greater distance from each other, their cohesive attraction is diminished; and one of the principal impediments to their union with other bodies is overcome. On the other hand, caloric may be infused into bodies in such quantity, as not only to overcome cohesion, but to place their particles beyond the sphere of chemical affinity. Thus, in the class of substances called gases, the ponderable ingredient, whether solid or liquid, is dissolved in so much caloric, that in mechanical properties the gases agree with the air of our atmosphere, and especially in being permanently elastic. Different bodies of this class do not in general unite by simple mixture. But if, of two gases, we employ either one or both in a state of great condensation, or compress their particles nearer to each other by any means, the gravitating matter of both unites, and forms a new compound. Thus hydrogen and oxygen gases remain to-

gether in a state of mixture, for any length of time, without combining; but if we force their particles into a state of contiguity, by sudden and violent mechanical pressure, they unite and compose water. In many cases, also, when two bodies are combined together, one of which is fixed, and the other becomes elastic by union with caloric, we are able by its interposition alone, to effect their disunion. Thus carbonate of lime gives up its carbonic acid by the mere application of heat.

We may consider, then, all bodies in nature as subject to the action of two opposite forces, the mutual attraction of their particles on the one hand, and the repulsive power of caloric on the other;* and bodies exist in the solid, liquid, or elastic state, as one or the other of these forces prevails. Water, by losing caloric, has its cohesion so much increased, that it assumes the solid form of ice;† adding caloric, we diminish again cohesion, and render it fluid; and, finally, by a still farther addition of caloric, we change it into vapour, and give it so much elasticity, that it may be rendered capable of bursting the strongest vessels. In many liquids, the tendency to elasticity is even so great, that they pass to the gaseous form by the mere removal of the weight of the atmosphere.

Caloric, like all other bodies, may exist in two different states; in a state of freedom, and in a state, either of combination or of something nearly resembling it. In the former state, it is capable of exciting the sensation of heat, and of producing expansion in other bodies. To this modification the terms *free* or *uncombined caloric*, or *caloric of temperature*, have been applied. By the term tempera-

* Dr Henry in common with most chemists considers caloric as the sole source of repulsion in bodies. Now, although it may be difficult to substantiate the existence of such a force separate and independent of caloric; yet we ought, before we fully accede to the position, to be perfectly assured that caloric is a material substance, and that it is not as Sir H. Davy, Count Rumford, and other highly respected authorities maintain, the mere result of motion amongst the particles of matter; for however strong, those, who regard it as material, may consider their ground to be, the question cannot be regarded as fully settled. Presuming it however to be material, we must demand, by what means it is itself possessed of the property of repulsion in its own particles, and of communicating that influence to other bodies. If there exists any foreign power capable of imparting a repulsive agency to the matter of heat; that same power may be equally regarded as operating on other species of matter. Now, light, electricity and magnetism, if material, certainly possess a repulsive power amongst their respective particles, which cannot well be attributed to Caloric; and whatever that be which thus induces repulsion in them, may equally induce it in caloric and in all other bodies. The difference of effects perceived in these different bodies, may be ascribed to the variety of matter on which the power of repulsion acts; the cause in all, being probably identical.—C.

† However theoretically, this assertion may seem to be correct, experiment proves it to be erroneous; If the cohesion of water in becoming ice was really increased, we ought to find its specific gravity augmented. But this is so far from being the case that ice floats even in boiling water. And even for several degrees before water reaches the freezing point, it expands considerably, whilst it is losing caloric. The laws of heat have been drawn almost entirely from observations made on water, a fluid of all others, possessed of anomalies too numerous and striking, to render it a safe subject on which to form such important deductions. C.

ture we are to understand the state of a body relatively to its power of exciting the sensation of heat, and occasioning expansion; effects which, in all probability, bear a proportion to the quantity of free caloric in a given space, or in a given quantity of matter. Thus what we call a high temperature may be ascribed to the presence of a large quantity of free caloric; and a low temperature to that of a small quantity. We are unacquainted, however, with the extremes of temperature; and may compare it to a chain, of which a few middle links only are exposed to our observation.

The degree of expansion produced by caloric, it will afterwards appear, bears a sufficient proportion to its quantity, to afford us a means of ascertaining the latter with tolerable accuracy. In estimating temperature, indeed, our senses are extremely imperfect; for we compare our sensations of heat, not with any fixed or uniform standard, but with those sensations, of which we have had immediately previous experience. The same portion of water will feel warm to a hand removed from contact with snow, and cold to another hand, which has been heated before the fire. To convey, therefore, any precise notion of temperature, we are obliged to describe the degree of expansion produced in some one body, which has been previously agreed upon as a standard of comparison. The standard most commonly employed is a quantity of quicksilver, contained in a glass ball, which terminates in a long narrow tube. This instrument, called a *thermometer*, is of the most important use in acquiring and recording our knowledge of the properties and laws of caloric. The thermometer, however, it must be obvious, is no otherwise a measure of the quantity of caloric, than as it ascertains the amount of one of its principal effects. In this respect, it stands in much the same predicament as the hygrometer, when considered as a mean of determining the moisture of the atmosphere. This last instrument, it may be remembered, is composed of some substance, (such as a hair or a piece of whipcord,) which is lengthened by a moist atmosphere and contracted by a dry one; and in a degree proportionate to the moisture or dryness. But all the information, which the hygrometer gives us, is the degree of moisture between certain points that form the extremities of its scale; and it is quite incompetent to measure the absolute quantity of watery vapour in the air.

In explaining those properties and laws of caloric, which have become known to us by means of the thermometer, it appears a sufficiently natural division of the subject, to describe, 1stly, those effects which caloric produces, without losing its properties of exciting the sensation of heat and occasioning expansion;—and, 2dly, those agencies, in which its characteristic properties are destroyed, and in which it ceases to be cognizable by our senses or by the thermometer.

The EXPANSION OR DILATATION of bodies, it will appear, is almost an universal effect of an increase of temperature. Its amount, however, is not the same in all bodies, but differs very essentially. By the same increase of temperature, liquids expand more than solids, and aëriiform bodies more than either. Nor is the

same quantity of expansion effected in the *same* solid or liquid, by adding similar quantities of heat; for, generally speaking, bodies expand by equal increments of caloric, more in high than in low temperatures. The explanation of this fact is, that the force opposing expansion (*viz.* cohesion) is diminished by the interposition of caloric between the particles of bodies; and, therefore, when equal quantities of caloric are added in succession, the last portions meet with less resistance to their expansive force than the first. In gases, which are destitute of cohesion, equal increments of heat appear, on the contrary, to be attended with precisely equal augmentations of bulk.

An important property of free caloric, the knowledge of which has been acquired by means of the thermometer, is its *tendency to an equilibrium*. When a heated ball of iron is exposed to the open air, the caloric, which is accumulated in it, flows out; and its temperature is gradually reduced to that of the surrounding medium. This is owing to two distinct causes: the air, immediately surrounding the ball, acquires part of the caloric which escapes; and, having its bulk increased, is rendered specifically lighter and ascends. This is succeeded by a cooler and heavier portion of air from above, which, in its turn, is expanded and carries off a second quantity of caloric. Hence a considerable part of the caloric, which is lost by a heated body, is conveyed away by the ambient air. But the refrigeration cannot be wholly explained on this principle; for it has been long known that heated bodies cool, though with less celerity, under the exhausted receiver of an air pump, and even in a Torricellian vacuum.

When the phenomena accompanying the cooling of bodies are accurately examined, it is found that a part of the caloric, which escapes, moves through the atmosphere with immeasurable velocity. In an experiment of M. Pictet, no perceptible interval took place between the time at which caloric quitted a heated body, and its reception by a thermometer at the distance of sixty-nine feet. It appears also to move with equal ease in all directions, and not to be at all impeded by a strong current of air meeting it transversely.* Hence it follows that the propagation of caloric, in this state of rapid movement, does not depend on any agency of the medium through which it passes; a conclusion strengthened by the experiments of Sir H. Davy, who has shown that, in a receiver exhausted to $\frac{1}{128}$, the effect of radiation is three times greater than in an atmosphere of the ordinary density. Like light, heat appears to be transmitted in parallel rays; and it has, therefore, under this modification, been called **RADIANT CALORIC**.

The proportion of caloric, lost by a heated body, in these two different ways, may be approximated by observing what time it takes to cool, through the same number of degrees, in air and in vacuo. By experiments of this kind, Dr. Franklin thought he had ascertained that a body, which requires five minutes in vacuo, will

* If this be really the case, might not some objections be drawn from it as to the materiality of caloric? C.

cool in air, through the same number of degrees, in two minutes. Count Rumford's experiments with a Torricellian vacuum give the proportions of 5 to 3. It will, perhaps, not be very remote from the truth, if it be stated, in general terms, that one half of the caloric, lost by a heated body, escapes by radiation, and that the rest is carried off by the ambient atmosphere.

The radiation of caloric appears to bear a proportion to the elevation of temperature of a body above that of the surrounding medium. Hence in part it is, that a heated body, during refrigeration, loses unequal quantities of caloric in equal times. The series appears to be pretty nearly a geometrical one. Thus, supposing the temperature of a body to be 1000 degrees above the surrounding medium,

In the first minute it will lose	$\frac{9}{10}$ of its heat or	900°
In the second	$\frac{9}{10}$ of the remainder	= 90
In the third	$\frac{9}{10}$ of 10	= 9

This law of refrigeration, it is asserted by Dr. Delaroché, though nearly accurate at low temperatures, is far from being so at high ones.

The movement of caloric by radiation occurs only in free space, or through transparent media. But caloric is capable, also, of passing through dense and opaque bodies, though with prodigiously impaired velocity. Thus a long bar of iron, heated at one end, requires considerable time to become hot at the other. This property in bodies has been called their **CONDUCTING POWER**, and it exists, in different bodies, in very different degrees. It is not, however, found to bear a proportion to any other quality of bodies.

All the properties of caloric, which have been hitherto described, belong to it when in a free or uncombined form; for it continues to produce the sensation of heat and to expand the mercury of the thermometer. In the instances of its agency, also, that have been mentioned, no permanent change of form or of properties is effected in the bodies which have imbibed caloric. A bar of iron, after being expanded by heat, returns on cooling to the same state as before, and exhibits all its former qualities. In certain cases, however, caloric is absorbed by bodies, with the loss of its distinguishing properties. It can then be no longer discovered by our senses or by the thermometer; and it produces important and sometimes permanent changes in the bodies into which it enters.

Those effects of caloric, in the production of which it loses its distinguishing properties, may be classed under two general heads.

I. *All bodies, in passing from a denser to a rarer state, absorb caloric.**—Thus solids, during liquefaction, imbibe a quantity of caloric, which ceases to be apparent to our senses, or to the thermo-

* Ice, being expanded by the abstraction of caloric, must be considered as in a rarer state than water; and therefore presents an exception to this general head. The reverse of this, presents an equal exception to the 2d head noticed. C.

meter; or, as it has been termed, *becomes latent*. In a similar manner, solids and liquids, during their conversion into vapours or gases, render latent a quantity of caloric, which is essential to the elasticity of the new product. In common language, cold is, in such cases, said to be produced; but by the production of cold we are to understand, in philosophical language, nothing more than the passage of caloric from a free to a latent form.

II. *All bodies, by an increase of density, evolve or give out caloric, which passes from a latent to a free state.*—The simplest illustration of this law is in the effect of hammering a piece of metal, which may thus be intensely heated, while all that is effected is an augmentation of its density. Liquids by becoming solids, or gases by conversion into liquids, also, evolve caloric, or produce an increase of temperature. A pound of water, condensed from steam, will render 100 pounds of water at 50° warmer by 11° ; whereas a pound of boiling water will produce the same rise of temperature in no more than about $13\frac{1}{2}$ pounds. This is owing to the much greater quantity of caloric, existing in a pound of steam, than in a pound of boiling water, though steam and boiling water affect the thermometer in precisely the same degree.

It is a question which has excited considerable interest among philosophers, whether caloric, when thus absorbed and rendered latent, enters into chemical combination, or is merely united by the same kind of ties as that portion of caloric that produces the temperature of bodies. Does ice, for example, when changed into water, form a chemical union with caloric, similar to that which exists between potash and sulphuric acid? Such appears to have been the opinion of Dr. Black, who, by the powers of an original and well-directed genius, discovered the greater number of those facts that form the groundwork of the theory of latent heat. The resemblance, however, between chemical union and the disappearance of caloric, which, on first view, appears extremely striking, will be found, it must be confessed, less close on a nearer examination. For caloric may be made to quit those bodies, into which it has entered, with the loss of its peculiar properties, merely by reducing their temperature; whereas, chemical combinations in general cannot be destroyed, except by the interference of more energetic affinities. In opposition to the foregoing theory, it has been contended that the absorption of caloric by bodies is a consequence of what has been called a change of their *capacity*. Thus ice, it is supposed, in becoming water, has its capacity for caloric increased, and the absorption of caloric is a consequence of this increased capacity. The theory, however, is deficient, inasmuch as it fails to explain what is the cause of that change of form, which is assumed to account for the increase of capacity. Notwithstanding this obvious objection, I have retained the term capacity to express, in the abstract, that power by which bodies absorb and render latent different quantities of caloric; or the property of requiring more or less caloric for raising their temperature an equal number of degrees. The absorption of caloric, then, will always be owing to an increase, and its evolution to a decrease, of capacity.

The use of these terms may be exemplified by a slight change of the perspicuous language of Dr. Crawford. "The capacity for containing caloric,"* he observes, "and the absolute caloric contained, are distinguished as a force from the subject upon which it operates. When we speak of the *capacity*, we mean a power inherent in the heated body; when we speak of the *absolute caloric*, we mean an unknown principle, which is retained in the body by the possession of this power; and, when we speak of the *temperature*, we consider the unknown principle as producing certain effects upon the thermometer."

As the capacities of bodies determine their absolute quantities of caloric, it seems reasonable to conclude, that if we can ascertain how much caloric a body absorbs or gives out in changing its form, and in what proportion its capacity is at the same time altered, we may deduce the *absolute quantity of heat* which it contains. Now, it will be afterwards shown that the heat, evolved by water in freezing, is equal to 140° ; and the capacity of water has been stated to bear to that of ice the proportion of 10 to 9. Water, then, in becoming ice, must give out $\frac{1}{10}$ th of its whole caloric, and as this amounts to 140° , ten times 140 (or 1400°) is the whole quantity of caloric in water at the temperature of 32° ; and deducting 140 from 1400 , we have 1260° for the caloric contained in the ice itself. This method of determining the problem appears, however, to me, to be liable to several objections, which it would take up too much room to state in this place, and which I have elsewhere urged at considerable length.†

These general observations I have deemed it necessary to make, with a view of connecting together the propositions respecting caloric, and the experiments illustrating them, that form the subject of the following sections. The inquiry respecting heat is one which presents a boundless field for interesting speculation; and it would have been easy to have extended very considerably the discussion of its nature and properties. But in this work, I have no farther object than to lead the student, by easy steps, to a knowledge of what has been actually determined by experiment, or strictly and legitimately deduced from it.

* Dr. Crawford on Heat, p. 8.

† Manchester Memoirs, vol. v.; or Phil. Mag.

SECTION II.

Illustrations of the Effects of Free Caloric.

I. *Caloric expands all bodies.**—The expansion of *liquids* is shown by that of the mercury of a thermometer, or by immersing in hot water a glass mattras (pl. i. fig. 4), filled, up to a mark in the neck, with spirit of wine, tinged with any colouring substance. The spirit expands immediately when heated, and would overflow if not placed in a cooler situation. The degree of expansion produced in different liquids, by similar elevations of temperature, varies very considerably. Thus, water expands much more than mercury, and alcohol more than water. This difference of expansibility is even sufficiently striking to appear in a remarkable degree, when we immerse, in water heated to 150° , three equal glass vessels of the shape of thermometer tubes, containing the one mercury, the other water, and the third spirit of wine. The spirit will begin to escape from the aperture of the vessel before the mercury has ascended far in the stem.† The expansion of *aëri-form bodies* is shown, by holding, near the fire, a bladder filled with air, the neck of which is closely tied, so as to prevent the enclosed air from escaping. The bladder will soon be fully distended, and may even be burst by continuing and increasing the heat. All aëri-form bodies undergo the same expansion by the same additions of heat, or $\frac{1}{483}$ part of their bulk for each degree of Fahrenheit's thermometer, between the freezing and boiling points. The expansion of *solids* is evinced, by heating a rod of iron, of such a length as to be included, when cold, between two points, and the diameter of which is such, as barely to allow it to pass through an iron ring. When heated, it will have become sensibly longer; and it will be found incapable of passing through the ring. This property of metals has been applied to the construction of an instrument for measuring temperature, called a *pyrometer*, a neat and distinct representation of which is given in the first volume of "Chemical Conversations."

The degree of expansion is not the same for all solids, and even differs materially in substances of the same class. Thus, the metals expand in the following order, the most expansible being placed first; zinc, lead, tin, copper, bismuth, iron, steel, antimony, palladium, platina.‡

All the above bodies return again, on cooling, to their former dimensions.

II. *Construction of the thermometer founded on the principle of expansion.*—The thermometer is an instrument of so much im-

* Here we again find water opposing itself to this general law, at least below the temperature of 40° ,—a substance presenting such anomalies to the general doctrines of caloric, cannot surely be a proper one to found our speculations upon.—C.

† See a table of the expansion of liquids in the Appendix.

‡ See the table in the Appendix.

portance, that it may be expedient to explain the construction of the different kinds which are required in chemical researches.

The instrument employed by Sanctorio, to whom the invention of the thermometer is generally ascribed, was of a very simple kind, and measured variations of temperature by the variable expansion of a confined portion of air. To prepare this instrument, a glass tube (pl. i. fig. 9) is to be provided, eighteen inches long, open at one end, and blown into a ball at the other. On applying a warm hand to the ball, the included air expands, and a portion is expelled through the open end of the tube. In this state, the aperture is quickly immersed in a cup filled with any coloured liquid, which ascends into the tube, as the air in the ball contracts by cooling. The instrument is now prepared. An increase of temperature forces the liquor down the tube; and, on the contrary, the application of cold causes its ascent. These effects may be exhibited, by alternately applying the hand to the ball, and then blowing on it with a pair of bellows. By the application of a graduated scale, the amount of the expansion may be measured.

The ball of the above instrument, it must be obvious, cannot be conveniently applied to measure the temperature of liquids. For adapting it to this purpose, a slight variation may be made in its construction, as represented fig. 8, *a*. To prepare this instrument, a small spherical glass vessel is to be about one 6th or one 4th filled with any coloured liquid. The tube, open at both ends, is then to be cemented into the neck, with its lower aperture beneath the surface of the fluid. The expansion of the included air drives the liquid up the stem, to which we may affix a graduated scale, corresponding with that of a common mercurial thermometer. Other modifications have also been made by different philosophers. One of the most useful and simple forms is represented fig. 8, *b*. It consists merely of a tube of very small bore, from 9 to 12 inches long, at one end of which is blown a ball, from half an inch to an inch in diameter, which is afterwards blackened by paint, or by the smoke of a candle. A small column of coloured liquid, about an inch in length, is then introduced, by a manipulation similar to that already described. To fit the instrument for use, this column ought to be stationary about the middle of the tube, at the common temperature of the atmosphere. The slightest variation of temperature occasions the movement of the coloured liquid; and a scale of equal parts measures the amount of the effect.

An insuperable objection, however, to the air thermometer, as thus constructed, is, that it is affected, not only by changes of temperature, but by variations of atmospheric pressure. Its utility consists in the great amount of the expansion of air, which, by a given elevation of temperature, is increased in bulk above twenty times more than mercury. Hence it is adapted to detect minute changes of temperature, which the mercurial thermometer would scarcely discover.

An important modification of the air thermometer has been invented by Mr. Leslie, and employed by him, with great advantage,

in his interesting researches respecting heat. To this instrument he has given the name of, the Differential Thermometer. Its construction is as follows: "Two glass tubes of unequal length, each terminating in a hollow ball, and having their bores somewhat widened at the other ends (a small portion of sulphuric acid, tinged with carmine, being introduced into the ball of the longer tube), are joined together by the flame of a blow-pipe, and afterwards bent into the shape of the letter U (see fig. 7), the one flexure being made just below the joining, where the small cavity facilitates the adjustment of the instrument. This, by a little dexterity, is performed, by forcing, with the heat of the hand, a few minute globules of air from the one cavity into the other. The balls are blown as equal as the eye can judge, and from four 10ths to seven 10ths of an inch diameter. The tubes are such as are drawn for thermometers, only with wider bores; that of the short one, to which the scale is affixed, must have an exact calibre of a 50th, or a 60th, of an inch. The bore of the long tube need not be so regular, but should be visibly larger, as the coloured liquid will then move quicker under any impression. Each leg of the instrument is from three to six inches in height, and the balls are from two to four inches apart.

"A moment's attention to the construction of this instrument will satisfy us, that it is affected only by the *difference* of heat in the corresponding balls; and is calculated to measure such difference with peculiar nicety. As long as both balls are of the same temperature, whatever this may be, the air contained in both will have the same elasticity, and, consequently, the intercluded coloured liquor, being pressed equally in opposite directions, must remain stationary. But if, for instance, the ball which holds a portion of the liquor be warmer than the other, the superior elasticity of the confined air will drive the liquid forwards, and make it rise, in the opposite branch, above the zero, to an elevation proportional to the excess of elasticity, or of heat." The amount of the effect is ascertained by a graduated scale, the interval between freezing and boiling being distinguished into 100 equal degrees. This instrument, it must be obvious, cannot be applied to measure variations in the temperature of the surrounding atmosphere, for the reason already assigned. It is peculiarly adapted to ascertain the difference of the temperatures of two contiguous spots in the same atmosphere; for example, to determine the heat in the focus of a reflector.

Thermometers, filled with spirit of wine, (a liquid which has not been congealed by any degree of cold hitherto produced), are best adapted to the measurement of very low temperatures, at which mercury would freeze. The amount of the expansion of alcohol, also, which exceeds that of mercury above eight times, fits it for ascertaining very slight variations of temperature. But it cannot be applied to measure high degrees of heat; because the conversion of the spirit into vapour would burst the instrument.

The fluid, best adapted for filling thermometers, is mercury, which, though it expands less in amount than air, or alcohol, still

undergoes this change to a sufficient degree ; and, in consequence of its difficult conversion into vapour, may be applied to the admeasurement of more elevated temperatures. As a considerable saving of expense will accrue to the experimentalist, who is able to construct mercurial thermometers, I shall offer some rules for this purpose.* In general, however, I should deem it preferable merely to superintend their construction, and to be satisfied, by actual inspection, that the necessary accuracy is observed ; because much time must be unavoidably lost, in acquiring the manual skill which is essential to construct them neatly.

Thermometer tubes may be had at the glass-house, and of various philosophical instrument makers. In purchasing them, those should be rejected that are not hermetically sealed at both ends ; because the smallest condensation of moisture, which must take place when air is freely admitted within the tube, is injurious to the accuracy of the instrument. A small bottle of elastic gum should be provided, in the side of which a brass valve is fixed, or a piece of brass perforated by a small hole, to be occasionally stopped by the hand. A blow-pipe is also an essential part of the apparatus ; and, in addition to one of the ordinary kind, it will be found useful to have one which is supplied with air by a pair of double bellows, worked by the foot.

Before proceeding to the construction of the thermometer, it is necessary to ascertain, that the tube is of equal diameter in different parts. This is done by breaking off both of the sealed ends, immersing one of them an inch or two deep in clean and dry mercury, and then closing the other end with the finger. On withdrawing the tube from the mercury, a small column of that fluid remains in it, the length of which is to be examined, by laying the tube horizontally on a graduated ruler.† By inclining the tube, this column may be gradually moved through its whole length ; and if the tube be of uniform bore, it will measure the same in every part. Such a degree of perfection, however, is scarcely ever to be observed throughout tubes of considerable length ; but, in general, a portion of the tube will be found perfect, of sufficient length for a thermometer, and this part is to be broken off.

On one end of the tube let the neck of the elastic bottle be firmly tied ; and let the other end be heated by the flame of the blow-pipe, till the glass softens. The softened part must then be pressed, by a clean piece of metal, into the form of a rounded button ; and to this the flame of the lamp must be steadily applied, till it acquires a white heat, and seems about to enter into fusion. To prevent its falling on one side, the tube, during this time, must be constantly turned round by the hand. When the heated part ap-

* This may well admit of some doubt. What is saved in expense, will probably be lost in time ; and in general we may infer, that few persons will be able, however theoretically conversant in the manipulations necessary to the construction of thermometers and other philosophical instruments, to make them equally perfect with the experienced mechanic. C.

† If the tube be of an extremely small bore, the mercury will not enter, and must be drawn in by the action of the elastic bottle, and not by the mouth.

pears perfectly soft, remove it quickly from the lamp, and, holding the tube vertically, with the elastic bottle uppermost, press this last gently with the hand. The glass will be blown into a small ball, but not into one sufficiently thin for the purpose. To this the flame of the lamp must again be applied, turning it quickly round; and, on a second or third repetition of the process of blowing, the ball will be completely formed. The proportion of the size of the ball to the bore of the tube, can only be learned by some experience.

To fill the ball, which has been thus formed, with mercury, the air must first be expelled by holding it over the flame of an Argand's lamp, and then quickly immersing the open end of the tube in very clean and dry quicksilver. As the ball cools, the mercury will ascend, and will partly fill it. Let a paper funnel be tied firmly over the open end of the tube; into this pour a small portion of quicksilver, and apply the heat of the lamp to the ball. Any remaining portion of air will thus be expelled; and if the heat be raised so as to boil the mercury, the ball and stem will be filled with mercurial vapour, the condensation of which, on removing the ball from the lamp, will occasion a pretty complete vacuum. Into this vacuum, quicksilver will descend from the paper cone; and the instrument will be completely filled. But for the purpose of a thermometer, it is necessary that the mercury should rise only to a certain height of the stem; and a few drops may, therefore, be expelled by cautiously applying the heat of the lamp. To estimate whether the proper quantity of quicksilver has been left in the instrument, immerse the ball first in ice-cold water, and then in the mouth. The space between these two points will comprise 63 degrees, or pretty nearly one 3d of the whole space between the freezing and boiling points of water. If the empty part of the tube exceeds, in length, about three times the portion thus filled by the expanded quicksilver, we may proceed (when an instrument is wanted with a scale including only from 32° to 212°) to seal it hermetically: which is done as follows: The part to be sealed is first heated with the blow-pipe, and drawn out to a fine capillary tube; the bulb is then heated, till a few particles of quicksilver have fallen from the top of the tube: at this moment, the flame of another candle is directed, by the blow-pipe, on the capillary part of the tube, the candle is withdrawn from the ball, and the tube is sealed, at the instant when the mercury begins to descend. If this operation has been skilfully performed, so as to leave no air in the tube, the whole of the tube should be filled with quicksilver on holding the instrument with the ball uppermost.

To have very large degrees, the ball must bear a considerable proportion to the tube; but this extent of scale cannot be obtained without sacrificing, in some measure, the sensibility of the instrument. The whole of the process of constructing thermometers neatly and accurately, is connected with the possession of manual skill, which practice only can confer; and it is scarcely possible, without the most tedious minuteness, to describe all the necessary precautions and manipulations. These will readily suggest themselves to a person who carries the above instructions into effect.

In graduating thermometers, the first step consists in taking the two fixed points. The freezing point is ascertained, by immersing, in thawing snow or ice, the ball and part of the stem; so that the mercury, when stationary, shall barely appear above the surface. At this place let a mark be made with a file. In taking the boiling point, considerable caution is required; and, for reasons which will afterwards be stated, attention must be paid to the state of the barometer, the height of which, at the time, should be precisely 29.8. A tin vessel is to be provided, (for, according to Gay Lussac,* one of glass leads to erroneous results,) four or five inches longer than the thermometer, and furnished with a cover, in which are two holes. Through one of these, the thermometer stem must be passed, (the bulb being within the vessel), so that the part, at which the boiling point is expected, may be just in sight. The other hole may be left open; and the cover being fixed in its place, the vessel, containing a few inches of water at the bottom, is to be set on the fire. The thermometer will presently be wholly surrounded by steam; and when the mercury becomes stationary in the stem, its place must be marked. The scale of Fahrenheit is formed by transferring the intermediate space to paper by a pair of compasses, and dividing it into 180° , the lowest being called 32° , and the highest 212° . The scale of other countries, however, differs considerably; but these variations do not prevent the comparison of observations with different instruments, when the freezing and boiling points of water are agreed upon as fixed data. In the Appendix, rules will be given for converting the degrees of other scales to that of Fahrenheit.

III. *The dilatations and contractions of the fluid in the mercurial thermometer, are nearly proportional to the quantities of caloric, which are communicated to the same homogeneous bodies, or separated from them, so long as they retain the same form.*

Thus a quantity of caloric, required to raise a body 20° in temperature, by the mercurial thermometer, is nearly double that which is required to raise it 10° . Hence there appears to be a pretty accurate proportion between the increments or decrements of heat, and the increments and decrements of expansion in the mercury of a thermometer. On this principle, if equal quantities of hot and cold water be mixed together, and a thermometer be immersed in the hot water, and also in the cold, previously to the mixture, the instrument should point, after the mixture, to the arithmetical mean, or to half the difference of the separate heats, added to the less or subtracted from the greater. This will be proved to be actually the fact, from the following experiment. Mix a pound of water at 172° with a pound at 32° . Half the excess of the caloric of the hot water will pass to the colder portion; that is, the hot water will be cooled 70° , and the cold will receive 70° of temperature; therefore $172 - 70$, or $32 + 70 = 102$, will give the heat of the mixture. To attain the arithmetical mean exactly, several precautions must be observed.†

* 82 An. de Ch. 174.

† See Crawford on Animal Heat, p. 95, &c.

The experiments of De Luc, however, have shown, that the ratio of expansion does not, *strictly*, keep pace with the actual increments of temperature; and that the amount of the expansion increases with the temperature. Thus, if a given quantity of mercury, in being heated from 32 to 122°, the first half of the scale, be expanded 14 parts, in being raised from 122 to 212, the higher half, it will be expanded 15 parts.

From the inquiries of Mr. Dalton, it appears to follow, that the irregularity of the expansion of mercury is considerably greater than has been stated by De Luc. By the common mercurial thermometer, we cannot ascertain the true rate of expansion in quicksilver; for it must be obvious that the expansion of the glass ball, in which it is contained, must considerably affect the result. If its capacity remained unaltered, we should then be able to determine the actual rate of expansion; but by an increase of temperature its capacity is enlarged, and space is thus found within the ball, for the expansion of that mercury, which would otherwise be driven into the tube. By knowing the rate of expansion in glass itself, we can correct this error; but a small error in this datum will lead us considerably wrong as to the true expansion of quicksilver. The *real* expansion of mercury in glass is *greater* than the *apparent*, by the expansion of the glass itself.

Making due correction from this circumstance, Mr. Dalton has been led to conclude from his experiments, that notwithstanding the apparent diversities of expansion in different fluids, they all actually expand according to the same law; *viz. that the quantity of expansion is as the square of the temperature from their respective freezing points, or from their points of greatest density*. If, then, a thermometer be constructed, with degrees corresponding to this law, they will be found to differ very considerably from those of the common mercurial thermometer, in which the space between freezing and boiling is divided into 180 equal parts. In the Appendix will be found a table showing the correspondence between the old scale, and the new one constructed on Mr. Dalton's principle.

IV. *Uncombined caloric has a tendency to an equilibrium.*—Any number of different bodies, at various temperatures, if placed under similar circumstances of exposure, all acquire a common temperature. Thus, if in an atmosphere at 60°, we place iron filings heated to redness, boiling water, water at 32°, and various other bodies of different temperatures, they will soon affect the thermometer in the same degree. The same equalization of temperature is attained, though less quickly, when a heated body is placed in the vacuum of an air-pump. The rate of cooling in air is to that *in vacuo*, the temperatures being equal, nearly as five to two.

II. *Motion of Free Caloric.*—1. *Its Radiation.*—2. *Its passage through Solids and Fluids.*

Caloric escapes from bodies in two different modes.—Part of it finds its way through space, independently of other matter, and with im-

measurable velocity. In this state it has been called, radiant heat, or radiant caloric.

RADIANT CALORIC exhibits several interesting properties.

1. *Its reflection.* (a) Those surfaces, that reflect light most perfectly, are not equally adapted to the reflection of caloric. Thus, a glass mirror, which reflects light with great effect when held before a blazing fire, scarcely returns any heat, and the mirror itself becomes warm. On the contrary, a polished plate of tin, or a silver spoon, when similarly placed, reflects, to the hand, a very sensible degree of warmth; and the metal itself remains cool. Metals, therefore, are much better reflectors of caloric than glass; and they possess this property, exactly according to their degree of polish.

(b) Caloric is reflected according to the same law that regulates the reflection of light. This is proved by an interesting experiment of M. Pictet; the means of repeating which may be attained at a moderate expense. Provide two reflectors of planished tin (*a* and *b*, fig. 45), which may be 12 inches diameter, and segments of a sphere of nine inches radius. Parabolic mirrors are still better adapted to the purpose; but their construction is less easy. Each of these must be furnished, on its convex side, with the means of supporting it in a perpendicular position on a proper stand. Place the mirrors opposite to each other on a table, at the distance of from six to twelve feet. Or they may be placed in a horizontal position, as represented in the fourth plate to Sir H. Davy's Chemical Philosophy, an arrangement in some respects more convenient. In the focus of one, let the ball of an air thermometer, *c*, or (which is still better) one of the balls of a differential thermometer, be situated; and in that of the other, suspend a ball of iron, about four ounces in weight, and heated below ignition, or a small matras of hot water, *d*; having previously interposed a screen before the thermometer. Immediately on withdrawing the screen, the depression of the column of liquid, in the air thermometer, evinces an increase of temperature in the instrument. In this experiment, the caloric flows first from the heated ball to the nearest reflector; from this it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument. This is precisely the course that is followed by radiant light; for if the flame of a taper be substituted for the iron ball, the image of the candle will appear precisely on that spot (a sheet of paper being presented for its reception) where the rays of caloric were before concentrated.

(c) When a glass vessel, filled with ice or snow, is substituted for the heated ball, the course of the coloured liquid in the thermometer will be precisely in the opposite direction; for its ascent will show, that the air in the ball is cooled by this arrangement. This experiment, which appears, at first view, to indicate the reflection of cold, presents, in fact, only the reflection of heat in an opposite direction; the ball of the thermometer being, in this instance, the hotter body. "And since heat emanates from bodies in quantities greater as their temperature is higher, the intro-

duction of a cold body into the focus of one mirror, necessarily diminishes the temperature of a thermometer in the focus of the other, in the same manner as a black body placed in the focus of the one, would diminish the quantity of light in the focus of the other."*

(d) In Mr. Leslie's "Enquiry into the Nature, &c. of Heat," a variety of important experiments are detailed, which show the influence of covering the reflectors with various substances, or of mechanically changing the nature of their surfaces, on their power of returning caloric.

2. Caloric is *refracted*, also, according to the same law that regulates the refraction of light. This interesting discovery we owe to Dr. Herschel, whose experiments and apparatus, however, cannot be understood without the assistance of a plate. For this reason, I refer to his paper in the 90th vol. of the Philosophical Transactions, or in the 7th vol. of the Philosophical Magazine.

3. The nature of the *surface* of bodies has an important influence over their power of *radiating* caloric.

To exhibit this influence experimentally, let a canister of planished block tin, forming a cube of six or eight inches, be provided, having an orifice at the middle of its upper side, from half an inch to an inch diameter, and the same in height. This orifice is intended to receive a cap having a small hole, through which a thermometer is inserted, so that its bulb may reach the centre of the canister. Let one side of the canister be covered with black paint; destroy the polish of another side, by scratching it with sand-paper; tarnish a third with quicksilver; and leave the fourth bright. Then fill the vessel with boiling water. The radiation of caloric from the blackened side is so much more abundant than from the others, as to be even sensible to the hand. Place it before a reflector (fig. 45), in lieu of the heated iron ball already described. The thermometer, in the focus of the second reflector, will indicate the highest temperature, or most copious radiation of caloric, when the blackened side is presented to the reflector; less when the tarnished or scratched side is turned towards it; and least of all from the polished side.

4. These varieties in the radiating power of different surfaces, are attended, as might be expected, with corresponding variations in the *rate of cooling*. If water, in a tin vessel, all of whose sides are polished, cools through a given number of degrees in eighty-one minutes, it will descend through the same number in seventy-two minutes, if the surface be tarnished with quicksilver. Water, also, enclosed in a clean and polished tin ball, cools about twice more slowly than water in the same ball covered with oiled paper. Blackening the surface with paint, on the same principle, accelerates greatly the rate of cooling. These facts teach us, that vessels, in which fluids are to be long kept hot, should have their surfaces brightly polished; and they explain, among other

* Davy's Chem. Philos. p. 206.

things, the superiority of metallic tea-pots over those of earthenware.

5. Radiant caloric is *absorbed* with different facility by different surfaces. This is only stating, in other terms, that surfaces are endowed with various powers of reflecting caloric; since the power of absorbing caloric is precisely opposite to that of reflecting it. Hence the best reflectors of heat will absorb the least. It may be proper, however, to offer some illustrations of the principle under this form.

(a) Expose the bulb of a sensible thermometer to the direct rays of the sun. On a hot summer's day it will probably rise, in this climate, to 108° °. Cover it with Indian ink, and again expose it in a similar manner. During the evaporation of the moisture it will fall; but as soon as the coating becomes dry, it will ascend to 118° °, or upwards, of Fahrenheit, or 10° higher than when uncovered with the pigment. This cannot be explained, by supposing that the black coating is gifted with the power of retaining caloric, and preventing its escape; because, from experiments already related, it appears, that a similar coating accelerates the cooling of a body to which it is applied.

(b) Colour has considerable influence over the absorption of caloric. This is shown by the following very simple experiment of Dr. Franklin.†

On a winter's day, when the ground is covered with snow, take four pieces of woollen cloth, of equal dimensions but of different colours, *viz.* black, blue, brown, and white, and lay them on the surface of the snow, in the immediate neighbourhood of each other. In a few hours, the black cloth will have sunk considerably below the surface; the blue almost as much; the brown evidently less; and the white will remain precisely in its former situation. Thus, it appears, that the sun's rays are absorbed by the dark coloured cloth, and excite such a durable heat, as to melt the snow underneath; but they have not the power of penetrating the white. Hence the preference, generally given to dark coloured cloths during the winter season, and to light coloured ones in summer, appears to be founded on reason.

(c) This experiment has been varied by Sir H. Davy, in a manner which may be repeated at any season of the year. Take six similar pieces of sheet copper, each about an inch square, and colour the one white, another yellow, a third red, the fourth green, the fifth blue, and the sixth black. On the centre of one side of each piece, put a small portion of a mixture of oil and wax, or cerate, which melts at about 76° °. Then expose their coloured surfaces, under precisely equal circumstances, to the direct rays of the sun. The cerate on the black plate will begin to melt perceptibly before the red; the blue next; then the green and the red; and, lastly, the

* Watson's Essays, v. 193.

† This experiment ascribed to Franklin, was made long before his time by Hooke; and also by Boerhaave as may be seen in his excellent work on Chemistry, vol. 1, p. 262. Expt. 13. 2d Edit. by Shaw. C.

yellow. The white will scarcely be affected, when the black is in complete fusion.

Caloric passes, also, but much more slowly, through solid and liquid bodies, which are then termed, CONDUCTORS of caloric.

1. Solid bodies convey heat in all directions, upwards, downwards, and laterally; as may be shown, by heating the middle of an iron rod, and holding it in different directions.

2. Some bodies conduct caloric much more quickly than others. Coat two rods, of equal length and thickness, the one of glass, the other of iron, with wax, at one end of each only; and then apply heat to the uncoated ends. The wax will be melted vastly sooner from the end of the iron rod, than from the glass one; which shows, that iron conducts heat more quickly than glass.

Even the different metals possess very different powers of conducting caloric. An approximation to the degree in which they possess this property, may be attained by the following method, originally employed by Dr. Ingenhouz. Procure several solid cylinders, or rods, of the same size and shape, but of different metals. They may be six inches long, and one 4th of an inch in diameter. Coat them, within about an inch of one end, with bees-wax, by dipping them into this substance when melted, and allowing the covering to congeal. Let an iron heater be provided, in which small holes have been drilled, that exactly receive the clean ends of the cylinders. After heating it below ignition, insert the cylinders in their places. The conducting power may be estimated by the length of wax coating melted from each in a given time. According to the experiments of Dr. Ingenhouz, the metals may be arranged in the following order: Silver possesses the highest conducting power; next gold; then copper and tin, which are nearly equal; and, below these, platina, iron, steel, and lead, which are greatly inferior to the rest.

It is chiefly owing to the different conducting powers of bodies, that they affect us, when we touch them, with different sensations of cold. Thus, if we apply the hand in succession to a number of bodies, (as a piece of wood, another of marble, &c.), they appear cold in very different degrees. And as this sensation is occasioned by the passage of caloric out of the hand into the body which it touches, that body will feel the coldest, which carries away heat the most quickly; or which, in other words, is the best conductor. For the same reason, of two bodies which are heated to the same degree, and both considerably above the hand, the best conductor is the hottest to the touch. Thus the money in our pockets often feels hotter than the clothes which contain it.

3. Liquid and aëriiform bodies convey heat on a different principle from that observed in solids, *viz.* by an actual change in the situation of their particles. That portion of the fluid, which is nearest to the source of heat, is expanded, and becoming specifically lighter, ascends, and is replaced by a colder portion from above.

This, in its turn, becomes heated and dilated, and gives way to a second colder portion : and thus the process goes on, as long as the fluid is capable of imbibing heat.

(a) Take a glass tube, eight or 10 inches long, and about an inch in diameter. Pour into the bottom part, for about the depth of an inch, a little water tinged with litmus, and then fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. If the upper part of the tube be first heated, the coloured liquor will remain at the bottom. But if the tube be afterwards heated at the bottom, the infusion will ascend, and will tinge the whole mass of fluid.

(b) Into a cylindrical glass jar, four inches diameter, and 12 or 14 deep, let a circular piece of ice be fitted $3\frac{1}{2}$ inches thick, and of rather less diameter than the jar. Or water may be poured into the jar to the depth of $3\frac{1}{2}$ inches, and allowed to congeal by exposure to a freezing atmosphere, or by surrounding it with a mixture of snow and salt. The ice is to be secured in its place by two slips of wood, crossing each other like two diameters of a circle, set at right angles to each other. Pour, over the cake of ice, water of 32° temperature, to the depth of two inches ; and on its surface let there float a shallow circular wooden box, perforated with holes. From the cock of a tea-urn, filled with boiling water, and raised so that its spout may be above the top of the jar, suspend a number of moistened threads, the lower ends of which must rest on the surface of the box. By this arrangement, when the cock is turned, the hot water will trickle down the threads, and will have its fall considerably broken. It will then spread over the surface of the box, and pass through the perforated holes to the cold water beneath, over which it will float without mixing with it. Let the jar be thus completely filled with hot water. The ice will remain unmelted for several hours at the bottom of the vessel.

(c) Fill a similar jar with hot water; and, having provided a cake of ice, of equal size with the former one, let it be placed on the surface of the water. In about three minutes, the whole will be melted. Both these experiments are more striking, if the water, used for forming the cakes of ice, be previously coloured with litmus; for, in the latter experiment, the descending currents of cold water are thus made apparent.

(d) These experiments may be varied, by freezing, in the bottom of a tube one inch wide, a portion of water, about two inches in depth. Then fill the tube with water of the common temperature, and hold it inclined over an Argand's lamp, so that the upper portion only of the tube may be heated. When thus disposed, the water may be made to boil violently at the surface, and yet the ice will not be melted. But if the experiments be reversed, and (the ice floating on the surface) heat be applied to the bottom of the tub, the ice will be liquefied in a few seconds.

(e) Substituting water of the temperature of 41° for the boiling water used in experiment (c), Count Rumford found, that, in a given time, a much greater quantity of ice was melted by the cooler water. This appears, on first view, rather paradoxical. The fact,

however, is explained by a remarkable property of water, *viz.* that when cooled below 40° it ceases to contract, and experiences, on the contrary, an enlargement of bulk. Water, therefore, at 40° (at the bottom of which is a mass of ice at 32°), is cooled by contact with the ice, and is expanded at the same moment. It therefore ascends, and is replaced by a heavier and warmer portion from above.

It is a consequence of the same property that the surface of a deep lake is sometimes covered with ice, even when the water below is only cooled to 40° ; for the superficial water is specifically lighter than the warmer water beneath it, and retains its place, till it is changed into ice. This property of water is one of the most remarkable exceptions to the law, that bodies are expanded by an increase, and contracted by a diminution, of temperature.

From these facts, Count Rumford concluded, that water is a perfect non-conductor of caloric, and that it propagates caloric in one direction, *viz.* upwards, in consequence of the motions which it occasions among the particles of the fluid. The Count inferred also, that if these motions could be suspended, caloric would cease to pass through water; and, with the view of deciding this question, he made the following experiments, which admit of being easily repeated. A cylindrical tin vessel must previously be provided, two inches in diameter, and $2\frac{1}{2}$ inches deep, having a moveable cover, perforated with a small aperture, for transmitting the stem of a thermometer, which is to be inserted so that its bulb may occupy the centre of the vessel.

(*f*) Fill this vessel with water of the temperature of the atmosphere; let the cover be put in its place; and let the whole apparatus, except the scale of the thermometer, be immersed in water, which is to be kept boiling over a lamp. Observe how long a time is required to raise the water from its temperature at the outset to 180° , and remove it from its situation. Note, also, how long it takes to return to its former temperature.

(*g*) Repeat the experiment, having previously dissolved in the water 200 grains of common starch. The thermometer will now require about half as long again to arrive at the same temperature. A similar retardation, and to a greater amount, is produced by the mixture of eider-down, cotton-wool, and various other substances, which are not chemically soluble in water, and which can diminish its conducting power in no other way than by obstructing the motion of its particles.

This inference, however, respecting the complete non-conducting power of water, has been set aside by the subsequent inquiries of Dr. Thomson and Mr. Murray, especially by a most decisive experiment of the latter. To establish the conducting power of water, it was justly deemed indispensable, that caloric should be proved to be propagated through that fluid downwards. This, on actual trial, it appeared to be; but it was objected, that the sides of the containing vessel might be the conductor. To obviate this objection, Mr. Murray contrived to congeal water into the form of a jar capable of holding liquids. This was separately filled

with linseed oil and with mercury. At a proper distance below the surface, the bulb of a thermometer was placed; and on the surface of the liquid rested a flat iron vessel, containing boiling water. Under these circumstances, the thermometer invariably rose; and though it ascended only a very few degrees, yet it must be recollected, that the cooling power of the sides of the vessel would effectually prevent any considerable elevation of temperature. This experiment, in conjunction with others, decisively proves, that water is a conductor, though a slow or imperfect one, of caloric.

SECTION III.

Caloric the Cause of Fluidity.

I. *The temperature of melting snow, or of thawing ice, is uniformly the same at all times, and in all places.*—This may be ascertained by the thermometer, which will always, when immersed in liquefying ice or snow, point to 32° of Fahrenheit, whatsoever may be the height of the barometer, or the elevation, above the sea, of the place where the experiment is made*.

II. *The sensible heat, or temperature of ice, is not changed by liquefaction.*—A thermometer in pounded ice stands at 32° , and at the very same point in the water which results from the liquefaction of ice.

III. *Yet ice, during liquefaction, must absorb much caloric.*—Expose a pound of water at 32° , and a pound of ice at 32° , in a room, the temperature of which is several degrees above the freezing point, and uniformly the same during the experiment. The water will arrive at the temperature of the room, *several hours before the ice is melted*†; and the melted ice will have, as before its liquefaction, the temperature of 32° . Yet the ice must, during the whole of this time, have been imbibing caloric, because (according to Experiment IV. § 2.) a colder body can never be in contact with a warmer one, without receiving caloric from it. The caloric, therefore, which has entered the ice, but is not to be found in it by the thermometer, is said to have *become latent*. As it is the cause of the liquefaction of the ice, it is sometimes called *caloric of fluidity*‡.

IV. *The quantity of caloric that enters into a pound of ice, and becomes latent, during liquefaction, may be learned by experiment.*—To a pound of water, at 172° , add a pound of ice at 32° . The temperature will not be the arithmetical mean (102°), but much below it, viz. 32° . All the excess of caloric in the hot water has therefore

* Shuckburgh, Philosophical Transactions, lxix.

† How does this comport with the fact stated in the preceding section II. ? C.

‡ Caloric of fluidity seems to be a better term than latent heat, and its use would perhaps obviate some difficulties in comprehending the subject of heat. There are many other cases in which caloric may be considered as latent, without producing fluidity. C.

disappeared. From 172° take 32° ; the remainder, 140° , shows the quantity of caloric that enters into a pound of ice during liquefaction; that is, as much caloric is absorbed by a pound of ice during its conversion into water, as would raise a pound of water from 32° to 172° .

It is from the property of its uniformly absorbing the same quantity of caloric for conversion into water, that ice has been ingeniously applied, by Lavoisier and Laplace, to the admeasurement of the heat, evolved in certain operations. Let us suppose the body (from which the caloric, evolved either by simple cooling or combustion, is to be measured) to be inclosed in a hollow sphere of ice, with an opening at the bottom. When thus placed, the heat, which is given out, will be all employed in melting the ice; and will produce this effect in direct proportion to its quantity. Hence the quantity of ice, which is converted into water, will be an accurate measure of the caloric, that is separated from the body submitted to experiment. In this way Lavoisier ascertained, that equal weights of different combustible bodies melt, by burning, very different weights of ice. The apparatus which he employed for this purpose, he has called the *calorimeter*. Its construction can scarcely be understood without the plate, which accompanies the description in his "Elements of Chemistry."

V. *Other examples of the absorption of caloric, during the liquefaction of bodies*, are furnished by the mixture of snow and nitric acid, or of snow and common salt, both of which, in common language, produce intense cold.

1. Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption, and intimate fixation, of the free caloric of the mixture, by the liquefying snow.

2. Mix quickly together equal weights of fresh-fallen snow at 38° , and of common salt cooled, by exposure to a freezing atmosphere, down to 32° . The two solid bodies, on admixture, will rapidly liquefy; and the thermometer will sink 32° , or to 0; or, according to Sir C. Blagden, to 4° lower.* To understand this experiment, it must be recollected, that the snow and salt, though at the freezing temperature of water, have each a considerable portion of uncombined caloric. Now, salt has a strong affinity for water; but the union cannot take place while the water continues solid. In order, therefore, to act on the salt, the snow absorbs all the free caloric required for its liquefaction; and during this change, the free caloric, both of the snow and of the salt, amounting to 32° , becomes latent, and is concealed in the solution. This solution remains in a liquid state at 0, or 4° below 0 of Fahrenheit; but if a greater degree of cold be applied to it, the salt separates in a concrete form.

3. Most neutral salts, also, during solution in water absorb much

* Philosophical Transactions, lxxvii. 281.

caloric ; and the cold, thus generated, is so intense as to freeze water, and even to congeal mercury. The former experiment, however, (*viz.* the congelation of water,) may easily be repeated on a summer's day. Add to 32 drachms of water, 11 drachms of muriate of ammonia, 10 of nitrate of potash, and 16 of sulphate of soda, all finely powdered. The salts may be dissolved separately, in the order set down. A thermometer, put into the solution, will show, that the cold produced is at or below freezing ; and a little water, in a thin glass tube, being immersed in the solution, will be frozen in a few minutes. Various other freezing mixtures are described in Mr. Walker's papers in the Philosophical Transactions for 1787, 88, 89, 95, and 1801. Of these the table, given in the Appendix, for which I am indebted to the obliging communication of the author, contains an arranged abstract.

4 Crystallized muriate of lime, when mixed with snow, produces a most intense degree of cold. This property was discovered some years ago by M. Lovitz, of St. Petersburg, and has been since applied, in this country, to the congelation of mercury on a very extensive scale. The proportions which answer best are, about equal weights of the salt finely powdered, and of fresh-fallen and light snow. On mixing these together, and immersing a thermometer in the mixture, the mercury sinks with great rapidity. For measuring exactly the cold produced, a spirit-thermometer, graduated to 50° below 0 of Fahrenheit, or still lower, should be employed. A few pounds of the salt are sufficient to congeal a large mass of mercury. By means of 13 pounds of the muriate, and an equal weight of snow, Messrs. Pepys and Allen froze 56 pounds of quicksilver into a solid mass. The mixture of the whole quantity of salt and snow, however, was not made at once, but part was expended in cooling the materials themselves.

On a small scale it may be sufficient to employ two or three pounds of the salt. Let a few ounces of mercury, in a very thin glass retort, be immersed, first in a mixture of one pound of each ; and, when this has ceased to act, let another similar mixture be prepared. The second will never fail to congeal the quicksilver.

In plate iv. fig. 42, a very simple and cheap apparatus is represented, which I have generally employed to freeze mercury. The dimensions will be given in the description of the plates*.

The salt thus expended may be again evaporated, and crystallized for future experiments.

The reader, who wishes for farther particulars respecting these experiments, is referred to the Philosophical Magazine, vol. iii. p. 76.

VI. *On the contrary, liquids, in becoming solid, evolve or give out caloric, or, in common language, produce heat.*

1. Water, if kept perfectly free from agitation, may be cooled down several degrees below 32° ; but, on shaking it, it immediately congeals, and the temperature rises to 32° .

2. Expose to the atmosphere, when at a temperature below freez-

* See Appendix.

ing (for example, at 25° of Fahrenheit), two equal quantities of water, in one only of which about a fourth of its weight of common salt has been dissolved. The saline solution will be gradually cooled, without freezing, to 25° . The pure water will gradually descend to 32° , and will there remain stationary a considerable time before it congeals. Yet while thus stationary, it cannot be doubted, that the pure water is yielding caloric to the atmosphere, equally with the saline solution; for it is impossible that a warmer body can be surrounded by a cooler one, without imparting caloric to the latter. The reason of this equitable temperature is well explained by Dr. Crawford. (*On Heat*, p. 80.) Water, he observes, during freezing, is acted upon by two opposite powers: it is deprived of caloric by exposure to a medium, whose temperature is below 32° ; and it is supplied with caloric, by the evolution of that principle from itself, viz. of that portion which constituted its fluidity. As these powers are exactly equal, the temperature of the water must remain unchanged, till the caloric of fluidity is all evolved.

3. The evolution of caloric, during the congelation of water, is well illustrated by the following experiment of Dr. Crawford:—Into a round tin vessel put a pound of powdered ice; surround this by a mixture of snow and salt in a larger vessel; and stir the ice in the inner one, till its temperature is reduced to $+4^{\circ}$ of Fahrenheit. To the ice thus cooled, add a pound of water at 32° . One 5th of this will be frozen; and the temperature of the ice will rise from 4° to 32° . In this instance, the caloric, evolved by the congelation of one 5th of a pound of water, raises the temperature of a pound of ice 28° .

4. If we dissolve sulphate of soda in water, in the proportion of one part to five, and surround the solution by a freezing mixture, it cools gradually down to 31° . The salt, at this point, begins to be deposited, and stops the cooling entirely. This evolution of caloric, during the separation of a salt, is exactly the reverse of what happens during its solution.*

5. To a saturated solution of sulphate of potash in water, or of any salt that is insoluble in alcohol, add an equal measure of alcohol. The alcohol, attracting the water more strongly than the salt retains it, precipitates the salt, and considerable heat is produced.†

* Blagden, Philosophical Transactions, lxxviii. 290.

† Dr. Henry has well remarked in a preceding page, that "the inquiry respecting heat is one which presents a boundless field for interesting speculation." That part of the inquiry which relates to Latent Heat, or Caloric of Fluidity, is not inferior in this respect to any other. Although we cannot doubt the fact of caloric being thus rendered latent, or evolved, according to the change of state in bodies; yet great difficulty occurs as to its explanation, conformably to the ideas of the illustrious discoverer of latent heat. I shall here barely propose for consideration, the observation made in the "*Conversations on Chemistry*," (p. 89, Am. edit.) by one of the presumed pupils of Mrs. B.—and I may add, the further this observation is considered, the more difficult does it evince the common received opinions on the subject of heat to be.—"*According to this theory of latent heat, it appears to me (says Miss Emily) that the weather should be warm when it freezes, and cold in a thaw: for latent heat is liberated from every*

SECTION IV.

Caloric the Cause of Vapour.

I. *Every liquid, when of the same degree of chemical purity, and under equal circumstances of atmospheric pressure, has one peculiar point of temperature, at which it invariably boils.*—Thus, pure water always boils at 212° , alcohol at 176° , and ether at 98° , Fahrenheit; and, when once brought to the boiling point, no liquid can be made hotter, however long the application of heat be continued. The boiling point of water may be readily ascertained, by immersing a thermometer in water boiling, in a metallic vessel, over the fire. As there is some danger in applying heat directly to a vessel containing either ether or alcohol, the ebullition of these fluids may be shown, by immersing the vessel containing them in water, the temperature of which may be gradually raised. The appearance of boiling is owing to the formation of vapour at the bottom of the vessel, and its escape through the heated fluid above it. That the steam, which escapes, is actually formed at the bottom, and not at the top of the water, may be seen by boiling some water in a Florence flask, or other transparent vessel, over an Argand's lamp. The bubbles of vapour will all ascend from the bottom of the vessel.

II. *Steam has exactly the same temperature as boiling water.*—Let a tin vessel be provided, having two holes in its cover, one of which is just large enough to admit the stem of a thermometer. Fill it partly with water, and let the bulb of the thermometer be an inch or two above the surface of the water, leaving the other aperture open for the escape of vapour. When the water boils, the thermometer, surrounded by steam, will rise to 212° , which is precisely the temperature of the water beneath: yet water, placed on a fire, continues to receive heat, very abundantly, even when boiling hot; and as this heat is not appreciable by the thermometer, it must exist in the steam, in a latent state.

Perfectly formed steam is entirely invisible. We may satisfy ourselves of this by boiling strongly a small quantity of water in a

substance that freezes, and such a large supply must warm the atmosphere; whilst, during a thaw, that very quantity of free heat must be taken from the atmosphere, and return to a latent state in the bodies which it thaws.—Whoever reads the apparent explanation, given to this undoubtedly correct and apposite objection, must be struck with its inadequacy to the end intended; for admitting, "that in a frost the atmosphere is so much colder than the earth, that all the caloric which it takes from the freezing bodies is insufficient to raise its temperature above the freezing point;" we cannot but be sensible, that the atmosphere in common with all the surrounding bodies, is growing co-equally colder; whereas the atmosphere should certainly grow warmer (if the doctrine is correct in all points) by the evolution of the latent heat in those bodies; and the reverse of this ought equally to occur, in the opposite state of things. It is surprising to me that the difficulty thus stated in the work alluded to, has never been noticed and properly appreciated by the numerous systematic writers on the doctrines of caloric. C.

flask; for complete transparency will exist in the upper part of the vessel. It is only when it begins to be condensed, that steam becomes visible. We have a proof also of the same fact in the thick fogs which are produced by a sudden transition from warm to cold weather; the vapour, which was imperceptible at the higher temperature, being condensed and rendered visible by the lower.

III. *The boiling point of the same fluid varies, under different degrees of atmospheric pressure.*—Thus water, which has been removed from the fire, and ceased to boil, has its ebullition renewed when it is placed under a receiver, the air of which is quickly exhausted by an air pump. Alcohol and ether, confined under an exhausted receiver, boil violently at the temperature of the atmosphere. In general, liquors boil *in vacuo*, with about 140° less of heat, than are required under a mean pressure of the atmosphere.* Even the ordinary variations in the weight of the air, as measured by the barometer, are sufficient to make a difference in the boiling point of water of about 5° between the two extremes.† On ascending considerable heights, as to the tops of mountains, the boiling point of water gradually falls on the scale of the thermometer. Thus on the summit of Mount Blanc, water was found by Saussure to boil at 187° Fahrenheit.

The influence of a diminished pressure in facilitating ebullition may, also, be illustrated by the following very simple experiment:—Place, over a lamp, a Florence flask, about three fourths filled with water; let it boil briskly during a few minutes; and, immediately on removing it from the lamp, cork it tightly, and suddenly invert it. The water will now cease to boil; but, on cooling the convex part of the flask by a stream of cold water, the boiling will be renewed. Applying boiling water from the spout of a tea-kettle to the same part of the flask, the water will again cease to boil. This renewal of the ebullition, by the application of the cold, (an apparent paradox,) is owing to the formation of an imperfect vacuum over the hot water, by the condensation of steam; and the suspension of the boiling, on re-applying the heat, to the renewed pressure on the surface of the hot water, occasioned by the formation of fresh steam.

From these facts, it may be inferred, that the particles of caloric are mutually repulsive, and that they communicate this repulsive tendency to other bodies in which caloric is contained. This repulsive power tends to change solids into fluids, and liquids into æriform bodies, and is chiefly counteracted by the pressure of the atmosphere.‡

* Black's Lectures, i. 151.

† Sir G. Shuckburgh, in Philosophical Transactions, lxxix. 375.

‡ Whoever adverts to the circumstances attending the combustion of gunpowder, cannot but be struck with the imperfection of that theory, which so dogmatically assumes as a fact, that the respective states of all bodies depend altogether on the repulsive power of caloric; and that the solid, fluid, and æriform states, are dependant on various doses of caloric, unconnected with other causes. If gunpowder owes the solid state of its ingredients to a diminution of caloric, and if their gaseous state after combustion, is the result of caloric conjoined to

Were this counteracting cause removed, many bodies, which at present have a liquid form, would cease to be such, and would be changed into a gaseous state. Precisely the same effect, therefore, results from the prevalence of either of these forces. Add to certain liquids a quantity of caloric, in other words, place them in a high temperature, and they are immediately converted into gases: or, their temperature remaining the same, diminish the weight of the atmosphere; and the caloric, which they naturally contain, exerts its repulsive tendency with equal effect, and they are in like manner converted into gases. These facts are best shown by the following experiments on ether:

1. Ether, at the temperature of 104° , exists in the state of a gas. This may be shown by filling a jar with water of this temperature, and inverting it in a vessel of the same. Then introduce a little ether, by means of a small glass tube closed at one end. The ether will rise to the top of the jar, and, in its ascent, will be changed into gas, filling the whole jar with a transparent, invisible, elastic fluid. On permitting the water to cool, the ethereal gas is condensed, and the inverted jar again becomes filled with water.

2. Ether is changed into gas by diminishing the weight of the atmosphere. Into a glass tube, about six inches long, and half an inch in diameter, put a tea-spoonful of ether, and fill up the tube with water; then, pressing the thumb on the open end of the tube, place it, inverted, in a jar of water. Let the whole be set under the receiver of an air pump, and the air exhausted. The ether will be changed into gas, which will expel the water entirely from the tube. On re-admitting the air into the receiver, the gas is again condensed into a liquid form.

IV. *On the contrary, by considerably increasing the pressure, water may be heated to above 400° Fahrenheit, without being changed into vapour.*—This experiment requires, for its performance, a strong iron vessel, called a Papin's digester, a plate of which may be seen in Gren's Chemistry. That the boiling point of water, and the temperature of steam, are raised by an increased pressure, may be shown, however, by means of the small boiler, represented plate v. fig. 46, which will be found extremely useful in experiments on this subject. Its precise size, and directions for its construction, will be given in the Description of the Plates.

On the cock *c* may be screwed, occasionally, a valve, loaded in the proportion of 14 pounds to the square inch. The boiler being rather more than half filled with water, and the perforated cap *d* being screwed into its place, the ball of the thermometer will be an inch or more above the surface of the water, and will indicate its temperature, as well as that of the steam, both being, necessarily, in all cases, precisely the same. Allowing the steam to

it in greater amount, the negative property of cold should be produced, by the absorption of caloric from surrounding sources; but the extrication, or excitation of caloric, so conspicuous to us, forbids our belief that this curious subject has been as yet properly explained; or that it can be explained by commonly received opinions. C.

escape through the cock *c*, before affixing the valve, the temperature of the steam, under a mean atmospheric pressure, will be 212° . When an additional atmosphere is added by the weighted valve, it will rise to above 240° ; by a valve twice as heavy as the first, or loaded in the proportion of 28 pounds to the square inch, the temperature of the steam will be raised to nearly 270° . This is as far as it is safe to carry the experiment; but by substituting a strong iron vessel, the numbers have been obtained, which will be found in the form of a table, in the Appendix.

V. *The absorption of caloric, during evaporation, shown by experiment.*—Moisten a thermometer with alcohol, or with ether, and expose it to the air, repeating these operations alternately. The mercury of the thermometer will sink at each exposure, because the volatile liquor, during evaporation, robs it of its heat. In this way, (especially with the aid of an apparatus described by Mr. Cavallo, in the Philosophical Transactions, 1781, p. 509,) water may be frozen in a thin and small glass ball, by means of ether. The same effect may be obtained, also, by immersing a tube, containing water at the bottom, in a glass of ether, which is to be placed under the receiver of an air pump; or the ether may be allowed to float on the surface of the water. During the exhaustion of the vessel, the ether will evaporate rapidly; and, robbing the water of heat, will completely freeze it; thus exhibiting the singular spectacle of two fluids in contact with each other, one of which is in the act of boiling, and the other of freezing, at the same moment.

By a little modification of the experiment, mercury itself, which requires for congelation a temperature of almost 40° below 0 of Fahrenheit, may be frozen, as was first shown by Dr. Marcet.* A conical receiver, open at the top, is placed on the plate of an air pump, and a mercurial thermometer is suspended within the receiver, through the aperture, by means of a brass plate, perforated in its centre, and fitting the receiver air tight, when laid upon its open neck. The thermometer passes through this plate, to which it is fitted by a leather adjustment, or simply by a cork secured with sealing wax; and it is so graduated, that, when its bulb is sunk a few inches within the receiver, the stem rises externally through the plate, above which the scale begins. The bulb is then wrapped up in a little cotton wool, or, what is better, in a small bag of fine fleecy hosiery; and, after being dipped into ether, the apparatus is quickly laid over the receiver, which is exhausted as rapidly as possible. In two or three minutes the temperature sinks to about 45° below 0, at which moment the quicksilver in the stem suddenly descends with great rapidity. If it be desired to exhibit the mercury in a solid state, common tubes may be used, which have originally been about an inch diameter, but have been flattened by pressure, when softened by the blow-pipe. The experiment succeeds, when the temperature of the room is as high as 40° Fahrenheit.

* 34 Nich. Journal, p. 119.

VI. *The fixation of caloric in water, by its conversion into steam, may be shown by the following experiments:—*1. Let a pound of water at 212° , and eight pounds of iron filings at 300° , be suddenly mixed together. A large quantity of vapour will be instantly generated; and the temperature of the mixture will be only 212° ; but that of the vapour produced is also not more than 212° ; and the steam must therefore contain, in a latent or combined form, all the caloric which raised the temperature of eight pounds of iron filings from 212° to 300° .

2. The quantity of caloric, which thus becomes latent during the formation of steam, may be approximated, by repeating the following experiment of Dr. Black: He placed two cylindrical flat bottomed vessels of tin, five inches in diameter, and containing a small quantity of water at 50° , on a red hot iron plate, of the kind used in kitchens. In four minutes the water began to boil, and in twenty minutes the whole was boiled away. In four minutes, therefore, the water received 162° of temperature, or $40\frac{1}{2}^{\circ}$ in each minute. If we suppose,* therefore, that the heat continues to enter the water at the same rate, during the whole ebullition, we must conclude that $41\frac{1}{2}^{\circ} \times 20 = 810^{\circ}$ have entered the water, and are contained in the vapour.

It has been found by experiment that 75 pounds of Newcastle coal, or 100 pounds of coal of medium quality, applied in the best manner, are required for the vaporization of 12 cubic feet, or about $89\frac{3}{4}$ wine gallons, of water. A pound of coal, on the average, may be considered as equivalent to convert a gallon of water into vapour. Wood charcoal, by combustion, is capable of melting 94 times its weight of ice, and of evaporating 13 times its weight of water, previously at 32° Fahrenheit. Peat of the best quality, when properly applied, evaporates 10 times its weight of water, but, as commonly used, only 4 or 5 times. Even with the assistance of heated air, only six times its weight can be evaporated, though Curaudau pretends to have evaporated 25 times its weight.† From evidence given before the House of Commons on the Gas Light Bill, $17\frac{1}{4}$ pounds of good London cork appear to be capable of raising from 66 to 70 pounds of water into vapour, or about 4 times their weight.‡

VII. *Water, by conversion into steam, has its bulk prodigiously enlarged, viz. according to Mr. Watt's experiments, about 1800 times, or, according to Gay Lussac, only 1698 times.*§—A cubic inch of wa-

* It is too much the custom for chemical writers to assert as a fact, what they admit at best as only supposition! This is the case in the above instance. Since both Dr. H. and Dr. Black himself *suppose* the circumstance stated to be as they mention, it is requisite for us, according to the strict laws of philosophical research, to be *assured*, that the fact does truly accord with their supposition. By this remark, I do not oppose the opinion of Caloric becoming latent, but the amount as founded on *supposition*, probable as that may be. C.

† 79 An. Ch. 86.

‡ See also Count Rumford's Researches on the Heat developed in Combustion. Phil. Mag. vol. xli. xlii. and xliii.

§ Here is one proof of many that might be adduced, how very incorrect must

ter (or 252 grains) occupies, therefore, when converted into steam, the space of rather more than a cubic foot. Hence its specific gravity, under the ordinary pressure of the air, is to that of common air, nearly as 450 to 1000; or, taking Gay Lussac's data, as 10 to 16, or 625 to 1000.

VIII. *On the contrary, vapours, during their conversion into a liquid form, evolve, or give out, much caloric.*—The heat given out, by the condensation of steam, is rendered apparent by the following experiment: Mix 100 gallons of water at 50° , with 1 gallon of water at 212° . The temperature of the water will be raised about $1\frac{1}{2}^{\circ}$. Condense by a common still-tub, 1 gallon of water, from the state of steam, by 100 gallons of water, at the temperature of 50° . The water will be raised 11° . Hence, 1 gallon of water, condensed from steam, raises the temperature of 100 gallons of cold water $9\frac{1}{2}^{\circ}$ more than 1 gallon of boiling water; and, by an easy calculation, it appears that the caloric imparted to the 100 gallons of cold water by 8 pounds of steam, if it could be condensed in 1 gallon of water, would raise it to 950° .* The quantity of ice, which is melted by steam of ordinary density, is invariably $7\frac{1}{2}$ times the weight of the steam.

For exhibiting the latent heat of steam, by means of a small apparatus, which may be placed on a table, and with the assistance only of a lamp, the boiler already described (fig. 46) will be found extremely well adapted. The right angled pipe *c* must be screwed, however, into its place, and must be made to terminate at the bottom of a jar, containing a known quantity of water of a given temperature. This conducting pipe and the jar should be wrapped round with a few folds of flannel. The apparatus being thus disposed, let the water in the boiler be heated by an Argand's lamp, with double concentric wicks, till steam issues in considerable quantity through the cock *c*, which is then to be closed. The steam will now pass through the right angled pipe into the water contained in the jar, which will condense the steam, and will have its temperature very considerably raised. Ascertain the augmentation of temperature and weight; and the result will show, how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, equal in weight and temperature to that contained in the jar at the outset of the experiment, add a quantity of water at 212° , equal in weight to the condensed steam; it will be found, on comparison of the two 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. This will be better understood by the following example, taken from actual experiment.

be the experiments of one or the other inquirer, when such diversity of result occurs in their proceedings. Which of these philosophers is right?—It is of consequence to correct opinions on the subject, that the data we proceed on be strictly so. C.

* Black's Lectures, i. 169.

Into eight ounces of water, at 50° Fahrenheit, contained in the glass jar, *f*, fig. 46, steam was passed from the boiler, till the temperature of the water in the jar rose to 173° . On weighing the water, it was found to have gained $8\frac{1}{2}$ drachms; that is, precisely $8\frac{1}{2}$ drachms of steam had been condensed, and had imparted its heat to the water.—To facilitate the explanation of this experiment, it is necessary to premise the following remarks.

To measure the whole quantities of caloric contained in different bodies, is a problem in chemistry which has not yet been solved. But the quantities of caloric, added to, or subtracted from, different bodies (setting out from a given temperature) may, in many cases, be measured and compared with considerable accuracy. Thus, if, as has been already stated, two pounds of water at 120° be mixed with two pounds at 60° , half the excess of caloric in the hot water will pass to the colder portion; that is, the hot water will be cooled 30° , and the cold will receive 30° of temperature; and if the experiment be conducted with proper precautions, 90° , the arithmetical mean of the temperature of the separate parts, will be the temperature of the mixture. If three pounds of water at 100° be mixed with one pound at 60° , we shall have the same quantity of heat as before, *viz.* four pounds at 90° . Hence, if the quantity of water be multiplied by the temperature, the product will be a comparative measure of the quantity of caloric which the water contains, exceeding the zero of the thermometer employed.

Thus, in the last example,

$$\begin{aligned} 3 \times 100 &= 300 = \text{the caloric above zero in the first portion.} \\ 1 \times 60 &= 60 = \text{the caloric above zero in the second do.} \end{aligned}$$

The sum, $360 =$ the caloric above zero in the mixture.

Dividing 360 by 4, the whole quantity of water, we obtain 90° , the temperature of the mixture.

This method of computation may be conveniently applied to a variety of cases. Thus, in the foregoing experiment, $8\frac{1}{2}$ drachms of steam at 212° , added to 64 drachms of water at 50° , produced $72\frac{1}{2}$ drachms of water at 173° . Now,

$$\begin{aligned} 72\frac{1}{2} \times 173 &= 12542\frac{1}{2} = \text{whole heat of the mixture.} \\ 64 \times 50 &= 3200 = \left\{ \begin{array}{l} \text{heat of 64 drachms, one of the compo-} \\ \text{nent parts.} \end{array} \right. \\ \hline 9342\frac{1}{2} &= \left\{ \begin{array}{l} \text{heat of } 8\frac{1}{2} \text{ drachms, the other compo-} \\ \text{nent part.} \end{array} \right. \end{aligned}$$

Therefore $9342\frac{1}{2}$ divided by $8\frac{1}{2} = 1099$, should have been the temperature of the latter portion (*viz.* $8\frac{1}{2}$ drachms), had none of its heat been latent: and $1099 - 212 = 887$ gives the latent heat of the steam. This result does not differ more than might be expected, owing to the unavoidable inaccuracies of the experiment, from Mr. Watt's determination, which states the latent heat of steam at

900°, or from that to 950°.* Lavoisier, with the aid of the calorimeter, makes it 1000°, or a little more.†

IX. *The same weight of steam contains, whatever may be its density, the same quantity of caloric; its latent heat being increased in exact proportion as its sensible heat is diminished; and the reverse.*—This principle, though scarcely admitting of illustration by any easy experiment, is one of considerable importance; and an ignorance of it has been the occasion of many fruitless attempts to improve the economy of fuel in the steam engine. The fact, so far as respects steam of lower density than that of 30 inches of mercury, was long ago determined experimentally by Mr. Watt.‡ As the boiling point of liquids is known to be considerably reduced under a diminished pressure, it seemed reasonable to suspect that, under these circumstances, steam might be obtained from them with a less expenditure of heat. Water, Mr. Watt found, might easily be distilled in vacuo when in the temperature of only 70° Fahrenheit. But, by condensing steam formed at this temperature, and observing the quantity of heat which it communicated to a given weight of water, he determined that its latent heat, instead of being only 950°, was between 1200° and 1300°.

The same principle may be explained also by the following illustration, which was suggested to me by Mr. Ewart. Let us suppose that in a cylinder, furnished with a piston, we have a certain quantity of steam, and that it is suddenly compressed, by a stroke of the piston, into half its bulk. None of the steam will in this case be condensed; but it will acquire double elasticity, and its temperature will be considerably increased. Now if we either suppose the cylinder incapable of transmitting heat, or take the moment instantly following the compression before any heat has had time to escape, it must be evident that the sensible and latent heat of the steam, taken together before compression, are precisely equal to the sensible and latent heat taken together of the denser steam. But in the dense steam, the sensible heat is increased, and the latent heat proportionably diminished. The explanation of this fact will be furnished by a principle, to be hereafter explained, that the capacities of elastic fluids for caloric are uniformly diminished by increasing their density.

X. *The evaporation of water is carried on much more rapidly under a diminished pressure, especially if the vapour, which is formed, be condensed as soon as it is produced, so as to keep up the vacuum.*

On this principle depends Mr. Leslie's new and ingenious mode of freezing water, in an atmosphere of medium temperature, by producing a rapid evaporation from the surface of the water itself. The water to be congealed is contained in a shallow vessel, which is supported above another vessel, containing strong sulphuric acid, or dry muriate of lime. The whole is covered by the receiver of an air pump, which is rapidly exhausted; and as soon as

* Black's Lectures, i. 174.

† Ibid, 175.

‡ Black, i. 190.

this is effected, crystals of ice begin to shoot in the water, and a considerable quantity of air makes its escape, after which the whole of the water becomes solid. The rarefaction required is to about 100 times; but to support congelation, after it has taken place, 20 or even 10 times are sufficient. The sulphuric acid becomes very warm; and it is remarkable, that if the vacuum be kept up, the ice itself evaporates. In five or six days, ice of an inch in thickness will entirely disappear. The acid continues to act, till it has absorbed an equal volume of water.

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

In this interesting process, if it were not for the sulphuric acid, an atmosphere of aqueous vapour would fill the receiver; and, pressing on the surface of the water, would prevent the further production of vapour. But the steam, which rises, being condensed the moment it is formed, the evaporation goes on very rapidly, and has no limits but the quantity of the water, and the diminished concentration of the acid.

It is on the same principle, that the instrument invented by Dr. Wollaston, and termed by him the *Cryophorus*, or *Frost-bearer*, is founded.* It may be formed by taking a glass tube, having an internal diameter of about $\frac{1}{8}$ th of an inch diameter, the tube bent to a right angle at the distance of half an inch from each ball. One of these balls should be about half filled with water, and the other should be as perfect a vacuum as can readily be obtained, the mode of effecting which is well known to those accustomed to blow glass. One of the balls is made to terminate in a capillary tube; and when the water in the other ball has been boiled over a lamp a considerable time, till all the air is expelled, the capillary extremity, through which the steam is still issuing with violence, is held in the flame of the lamp, till the force of the vapour is so far reduced, that the heat of the flame has power to seal it hermetically.

When an instrument of this kind is well prepared, if the empty ball be immersed in a mixture of snow and salt, the water in the other ball, though at the distance of two or three feet, will be frozen solid in the course of very few minutes. The vapour in the empty ball is condensed by the common operation of cold; and the vacuum produced by this condensation, gives opportunity for a fresh quantity to arise from the opposite ball, with a proportional reduction of its temperature.

The large quantity of caloric, latent in steam, renders its appli-

* See Plate 10.

cation extremely useful for practical purposes. Thus, water may be heated, at a considerable distance from the source of heat, by lengthening the conducting pipe *e*, fig. 46. This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of importance to have near the patient's bed-room; for the boiler, in which the water is heated, may thus be placed on the ground-floor, or in the cellar of a house; and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus. Fig. 46, *g*, represents the apparatus for boiling water by the condensation of steam, without adding to its quantity; a circumstance occasionally of considerable importance. The steam is received between the vessel, which contains the water to be heated, and an exterior case; it imparts its caloric to the water, through the substance of the vessel; is thus condensed, and returns to the boiler by the perpendicular pipe. An alteration of the form of the vessel adapts it to evaporation (fig. 46, *h*). This method of evaporation is admirably suited to the concentration of liquids, that are decomposed, or injured, by a higher temperature than that of boiling water, such as medicinal extracts; to the drying of precipitates, &c. In the employment of either of these vessels, it is expedient to surround it with some slow conductor of heat. On a small scale, a few folds of woollen cloth are sufficient; and, when the vessel is constructed of a large size for practical use, this purpose is served by the brick-work in which it is placed.

SECTION V.

Specific Caloric.

EQUAL weights of the *same* body, at the same temperature, contain the same quantities of caloric. But equal weights of *different* bodies, at the same temperature, contain unequal quantities of caloric. The quantity of caloric, which one body contains, compared with that contained in another, is called its *specific caloric*; and the power or property, which enables bodies to retain different quantities of caloric, has been called *capacity for caloric*. The method of determining the specific caloric, or comparative quantities of caloric in different bodies, is as follows:

It has already been observed, that equal weights of the *same* body, at different temperatures, give, on admixture, the arithmetical mean. Thus, the temperature of a pint of hot water and a pint of cold, is, after mixture, very nearly half way between that of the two extremes. But this is not the case, when equal quantities of *different* bodies, at different temperatures, are employed.

(a) If a pint of quicksilver at 100° Fahrenheit, be mixed with a pint of water at 40° , the resulting temperature will not be 70° (the arithmetical mean), but only 60° . Here the quicksilver loses 40°

of heat, which nevertheless raise the temperature of the water only 20° ; in other words, a larger quantity of caloric is required to raise the temperature of a pint of water, than that of a pint of mercury, through the same number of degrees. Hence it is inferred, that water has a greater capacity for caloric than is inherent in quicksilver.

(b) The experiment may be reversed, by heating the water to a greater degree than the quicksilver. If the water be at 100° , and the mercury at 40° , the resulting temperature will be nearly 80° ; because the pint of hot water contains more caloric, than is necessary to raise the quicksilver to the arithmetical mean.

(c) Lastly, if we take two measures of quicksilver to one of water, it is of no consequence which is the hotter; for the resulting temperature is always the mean between the two extremes; for example, 70° , if the extremes be 100° and 40° . Here, it is manifest, that the same quantity of caloric, which makes one measure of water warmer by 30° , is sufficient for making two measures of quicksilver warmer by the same number. Quicksilver has, therefore, a less capacity than water for caloric, in the proportion, when equal measures are taken, of one to two.

If, instead of equal *bulks* of quicksilver and water, we had taken equal *weights*, the disparity between the specific caloric of the mercury and water would have been still greater. Thus a pound of water at 100° , mixed with a pound of mercury at 40° , gives a temperature of $97\frac{1}{2}^{\circ}$, or $27\frac{1}{2}^{\circ}$ above the arithmetical mean. In this experiment, the water, being cooled from 100° to $97\frac{1}{2}^{\circ}$ has lost a quantity of caloric, reducing its temperature only $2\frac{1}{2}^{\circ}$; but this caloric, communicated to the pound of mercury, has produced, in its temperature, a rise of no less than $57\frac{1}{2}^{\circ}$. Therefore, a quantity of caloric, necessary to raise the temperature of a pound of water $2\frac{1}{2}^{\circ}$, is sufficient to raise that of a pound of mercury $57\frac{1}{2}^{\circ}$; or, by the rule of proportion, the caloric, which raises the temperature of a pound of water 1° , will raise that of a pound of quicksilver about 23° . Hence it is inferred, that the quantity of caloric contained in water, is to that contained in the same *weight* of quicksilver as 23° to 1° . Or, stating the caloric of water at 1° , that of quicksilver will be $\frac{1}{23}$ part of 1° , or 0,0435.*

When this comparison is extended to a great variety of bodies, they will be found to differ very considerably in their capacities for caloric. The results of numerous experiments of this kind are comprised in a table of specific caloric†.

The capacities of bodies for caloric influence, considerably, the rate at which they are heated and cooled. In general, those bodies are most slowly heated, and cool most slowly, which have the greatest capacities for heat‡. Thus, if water and quicksilver be set, in similar quantities, and at equal distances before the fire, the quicksilver will be much more rapidly heated than the water; and, on re-

* The above numbers, which differ from those commonly stated, are given on the authority of Mr. Dalton.

† See the Appendix.

‡ See Martine on Heat, page 74.

moval from the fire, it will cool with proportionally greater quickness than the water. By ascertaining the comparative rates of cooling, we may even determine, with tolerable exactness, the specific caloric of bodies; and particularly of one class (the gases), which are not easily compared in any other way.* The specific heat of the different æriform fluids will be stated, on the authority of Delaroche and Berard, in the chapter on gases.

CHAPTER IV.

OF LIGHT.

THE laws of light, so far as they relate to the phenomena of its movement, and to the sense of vision, constitute the science of optics; and are the objects, therefore, not of Chemistry, but of Natural Philosophy. Light, however, is capable of producing important chemical effects, and of entering into various chemical combinations. Its action is, for the most part, exerted in de-oxidizing bodies; and facts of this kind cannot be perfectly understood, until two important classes of bodies have been described, viz. those of oxides and of acids. In this place, therefore, I shall state only a few of its least complicated effects; and shall trace its agency on different bodies, as they become the objects of experiment in the sequel.

I. Light, in the state in which it reaches the organ of vision, it is well known, is not a simple body,† but is capable of being divided, by the prism, into seven primary rays or colours, viz. red, orange, yellow, green, blue, indigo, and violet. These are refrangible in the above order, the red being least refrangible, and the violet most so. The image formed by the different rays, thus separated, constitutes the SOLAR SPECTRUM. If it be divided into 360 parts, the red 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.

II. Heat and light are not present, in corresponding degrees, in different parts of the solar spectrum. With respect to the *illuminating* power of each colour, Dr. Herschell found that the red rays are far from having it in an eminent degree. The orange possesses more of it than the red; and the yellow rays illuminate objects still more perfectly. The maximum of illumination lies in the brightest yellow or palest green. The green itself is nearly equally bright with the yellow; but from the full deep green, the illuminating power decreases very sensibly. That of the blue is nearly on a par with that of the red; the indigo has much less than the blue, and the violet is very deficient.‡

* See Leslie on Heat, chap. xxi.

† Fourcroy (Gen. Syst. of Chem. knowledge, 1. p. 156) classes light amongst the simple or undecomposable bodies; and at p. 164 he asserts that "no fact has yet proved this pretended decomposition of light!" C.

‡ Philosophical Transactions, 1800, page 267.

III. The *heating* power of the rays follows a different order. If the bulb of a very sensible air thermometer be moved in succession, through the differently coloured rays, it will be found to indicate the greatest heat in the red rays; next in the green; and so on, in a diminishing progression, to the violet. The precise effects of the different rays, determined by Dr. Herschell's experiments, are as follows:

The thermometer rose			
In the blue,	in 3 minutes	from	55° to 56°
— green,	in 3	—	54 to 58
— yellow,	in 3	—	56 to 62
— full red,	in 2½	—	56 to 72
— confines of red,	in 2½	—	58 to 73½

IV. When the thermometer is removed entirely out of the confines of the red rays, but with its ball still in the line of the spectrum, it rises even higher than in the red rays; and continues to rise, till removed half an inch beyond the extremity of the red rays. In this situation, quite out of the visible light, the thermometer rose in 2½ minutes from 61 to 79. The ball of the thermometer, employed for this purpose, should be extremely small, and should be blackened with Indian ink. An air thermometer is better adapted than a mercurial one, to exhibit the minute change of temperature that ensues. These INVISIBLE HEAT-MAKING RAYS may be reflected by the mirror, and refracted by the lens, exactly in the same manner as the rays of light.

A new fact has been lately ascertained by Dr. Delaroche, which seems to point out a close connection between heat and light, and a gradual passage of the one into the other. The rays of invisible heat pass through glass with difficulty, at a temperature below that of boiling water; but they traverse it with a facility always increasing with the temperature, as it approaches the point when bodies become luminous. From these experiments, it would appear that the modification, whatever it be, which must be impressed on the invisible rays, to render them capable of penetrating through glass, makes them approach more and more to the state in which they must be, when they enter the eye, and occasion the sensation of vision.

The experiments of Dr. Herschell, already confirmed by Sir H. Englefield and other philosophers, were found correct in the main, when repeated by Mr. Berard,* the same progressive heating power being observed in the rays from the violet to the red. But he found the greatest heating power at the extremity of the spectrum, and not beyond it. He fixed it at the point, where the bulb of the thermometer was still entirely covered by the red ray; and the thermometer sunk progressively, in proportion as the distance of its bulb from the red ray increased. Entirely out of the visible

* Thomson's Annals, ii. 162.

spectrum, where Herschell fixed the maximum of heat, its elevation above the ambient air was only one fifth of what it had been in the red ray itself. The reflection of invisible radiant heat, Mr. Berard found, follows precisely the same law as that of light.

V. Beyond the confines of the spectrum on the other side, *viz.* a little beyond the violet ray, the thermometer is not affected; but in this place it is remarkable, that there are also invisible rays of a different kind, which exert all the chemical effects of the rays of light, and with even greater energy. One of the chemical properties of light, it will hereafter be stated, is, that it speedily changes, from white to black, the fresh-precipitated muriate of silver.* This effect is produced most rapidly by the direct light of the sun; and the rays, as separated by the prism, have this property in various degrees. The blue rays, for example, effect a change of the muriate of silver in 15 seconds, which the red require 20 minutes to accomplish; and, generally speaking, the power diminishes as we recede from the violet extremity. But entirely out of the spectrum, and beyond the violet rays, the effect is still produced. Hence it appears, that the solar beams consist of three distinct kinds of rays: of those that excite heat, and promote oxidation; of illuminating rays; and of DE-OXIDIZING OR HYDROGENATING RAYS.† A striking illustration of the different powers of these various rays is furnished, by their effect on phosphorus. In the rays beyond the red extremity, phosphorus is heated, smokes, and emits white fumes; but these are presently suppressed, on exposing it to the de-oxidizing rays, which lie beyond the violet extremity.

"I found," says Sir H. Davy,‡ "that a mixture of chlorine and hydrogen acted more rapidly upon each other, combining without explosion, when exposed to the red rays, than when placed in the violet rays; but that solution of chlorine in water became solution of muriatic acid most rapidly, when placed in the most refrangible rays of the spectrum. Puce-coloured oxide of lead, when moistened, gradually gained a tint of red in the least refrangible rays, and at last became black, but was not affected in the most refrangible rays; and the same change was produced by exposing it to a current of hydrogen gas. The oxide of mercury, procured by solution of potash and calomel, exposed to the spectrum, was not changed in the most refrangible rays, but became red in the least refrangible ones, which must have depended on its absorbing oxygen. The violet rays produced, upon moistened red oxide of mercury, the same effects as hydrogen gas."

The recent experiments of Berard§ confirm those of Ritter and Wollaston. To shew the disproportion between the energies of the different rays, he concentrated, by means of a lens, all that part of the spectrum, which extends from the green to the extreme violet; and, by another lens, all that portion, which extends

* See chap. xviii. sect. 4.

† It requires yet to be proved, that either light or caloric emanate from the sun. C.

‡ El. of Chem. Phil. p. 211.

§ Thomson's Annals, ii. 165.

from the green to the extremity of the red. In the focus of this last, though intensely bright to the eyes, muriate of silver remained above two hours unaltered; but in that of the former, though much less bright, it was blackened in less than six minutes.

VI. There is an exception, however, as stated by Dr. Wollaston, to the de-oxidizing power of the rays above-mentioned. The substance, termed gum guaiacum, has the property, when exposed to the light, of changing from a yellowish colour to green; and this effect he has ascertained to be connected with the absorption of oxygen. Now, in the most refrangible rays, which would fall beyond the violet extremity, he found that this substance became green, and was again changed to yellow by the least refrangible. This is precisely the reverse of what happens to muriate of silver, which is blackened, or de-oxidized, by the most refrangible; and has its colour restored, or is again oxygenized, in the least refrangible rays.

VII. Certain bodies have the property of absorbing the rays of light in their totality; of retaining them for some time; and of again evolving them unchanged, and unaccompanied by sensible heat. Thus, in an experiment of Du Fay, a diamond exposed to the sun, and immediately covered with black wax, shone in the dark, on removing the wax, at the expiration of several months. Bodies, gifted with this property, are called SOLAR PHOSPHORI. Such are Canton's, Baldwin's, Homberg's, and the Bolognian phosphori, which will be described hereafter. To the same class belong several natural bodies, which retain light, and give it out unchanged. Thus snow is a natural solar phosphorus. So also is, occasionally, the sea when agitated; putrid fish have a similar property; and the glow-worm belongs to the same class. These phenomena are independent of every thing like combustion; for artificial phosphori, after exposure to the sun's rays, shine in the dark, when placed in the vacuum of an air-pump, or under water, &c., where no air is present to effect combustion.*

VIII. From solar phosphori, the extrication of light is facilitated by the application of an elevated temperature; and, after having

* This opinion of the absorption of light, requires further proof before it can be safely admitted. A fact stated by Sir H. Davy strongly opposes it. He says, "If specific highly rare imponderable fluids be assumed to account for the phenomena (of Light), as many must be adopted, as there are different series of effects produced by different rays. There must be a matter of violet light, a matter of blue light, and so on: and likewise, a de-oxydating ethereal matter, a calorific solar matter, and a calorific terrestrial matter, which is very contradictory to the usual simplicity of causes observable in the economy of things; and the idea is likewise rendered improbable by experiments on solar phosphori. When a mixture of calcined oyster shells and sulphur, that have been heated together, is exposed to the solar rays, it forms a good solar phosphorus, it becomes luminous, and continues so for some minutes in the dark: and to *whichever* of the prismatic rays it be exposed, *its light is always the same, pale yellow.*"—"But if light be supposed specific in its kind, and absorbed and emitted; then, when the phosphorus is exposed to blue rays, blue rays alone ought to be emitted, which is not the case." *El. of Ch. Phil.* p. 219. Eng. edit. C.

ceased to shine at the ordinary temperature, they again emit light when exposed to an increase of heat. Several bodies, which do not otherwise give out light, evolve it, or become phosphorescent, when heated. Thus, powdered fluat of lime becomes luminous, when thrown on an iron plate raised to a temperature rather above that of boiling water. The yolk of an egg, when dried, becomes luminous, on being heated; and so also does tallow during liquefaction. To exhibit the last mentioned fact, it is merely necessary to place a lump of tallow on a coal, heated below ignition, making the experiment in a dark room.

IX. Attrition, also, evolves light. Thus, two pieces of common bonnet cane, rubbed strongly against each other in the dark, emit a faint light. Two pieces of borax have the same property much more remarkably.

X. Light is disengaged in various cases of chemical combination. Whenever combustion is a part of the phenomena, this is well known to happen; but light is evolved, also, in other instances, where nothing like combustion goes forward. Thus, fresh prepared pure magnesia, added suddenly to highly concentrated sulphuric acid, exhibits a red heat.*

XI. For measuring the relative intensities of light from various sources, an instrument has been contrived, called the PHOTOMETER. That of Count Rumford, described in the 84th volume of the Philosophical Transactions, being founded on optical principles, does not fall strictly within the province of this work. It is constructed on the principle, that the power of a burning body, to illuminate any defined space, is directly as the intensity of the light, and inversely as the square of the distance. If two unequal lights shine on the same surface at equal obliquities, and an opaque body be interposed between each of them and the illuminated surface, the two shadows must differ in intensity or blackness; for the shadow formed by intercepting the greater light will be illuminated by the lesser light only; and, reversely, the other shadow will be illuminated by the greater light; that is, the stronger light will be attended with the deeper shadow. But it is easy, by removing the stronger light to a greater distance, to render the shadow which it produces, not deeper than that of the smaller, or of precisely the same intensity. This equalization being effected, the quantity of light emitted by each lamp, or candle, will be as the square of the distance of the burning body from the white surface.

The photometer of Mr. Leslie is founded on a different principle, *viz.* that light, in proportion to its absorption, produces heat. The degree of heat produced, and consequently of light absorbed, is measured by the expansion of a confined portion of air. A minute description of the ingenious instrument contrived by Mr. Leslie with this view, may be seen in his work on Heat, or in the 3d vol. of Nicholson's 4to Journal. In its construction, it bears a considerable resemblance to the differential thermometer, already de-

* From whence do the heat and light arise in this case—for both bodies are incombustible, and therefore oxygen gas is not present in the process? C

scribed, page 114, and represented plate i. fig. 7. As both the balls of the latter instrument, however, are transparent, no change ensues in the situation of the coloured liquid when it is exposed to the variations of light. But, in the photometer, one of the balls is rendered opaque, either by tinging the glass, or by covering it with a pigment; and hence this ball, absorbing the incident light which passes freely through the transparent one, the air included in it becomes warmer than that of the other ball, and, by its great elasticity, forces the liquid up the opposite leg of the instrument. A graduated scale measures the amount of the effect; and a glass covering defends the photometer from being influenced by the temperature of the atmosphere.

The important discoveries of Malus, respecting the polarisation of light, scarcely fall within the province of this work, and I refer, therefore, for a popular statement of them to the 33d vol. of Nicholson's Journal, p. 344.

CHAPTER V.

OF GASES.

SECTION I.

Of the Apparatus for Gases.

FOR performing the necessary experiments on gases, many articles of apparatus are essential, that have not hitherto been described. It may assist the student in obtaining the necessary instruments, if a few of the most essential be here enumerated. In this place, however, I shall mention such only, as are necessary in making a few general experiments on this interesting class of bodies.

The apparatus, required for experiments on gases, consists partly of vessels fitted for containing the materials that afford them, and partly of vessels adapted for the reception of gases, and for submitting them to experiment.

1. For procuring such gases as are producible without a very strong heat, glass bottles, furnished with ground stoppers and bent tubes, are sufficient (plate ii. fig. 18.) Of these several will be required, of different sizes and shapes, adapted to different purposes. If these cannot be procured, a Florence flask, with a cork perforated by a bent glass tube, or even by a tin pipe, will serve for obtaining some of the gases.

Those gases that require, for their liberation, a red heat, may be procured, by exposing to heat the substance capable of affording them, in earthen retorts or tubes; or in a gun-barrel, the touch-hole of which has been accurately closed by an iron pin. To

the mouth of the barrel must be affixed a glass tube, bent so as to convey the gases where it may be requisite.

A very convenient apparatus, for obtaining such gases as cannot be disengaged without a red heat, is sold at the shops for philosophical apparatus in London. It consists of a cast-iron retort, to which a jointed metallic conducting tube is fitted by grinding; and by means of which the gas may be conveyed in any direction, and to any moderate distance. It is represented as placed, when in actual use, between the bars of a common fire-grate (plate ix. fig. 35, *a*, *b*.)

2. For receiving the gases, glass jars, of various sizes, (figs. 21, 22, 23,) are required, some of which should be furnished with necks at the top, fitted with ground stoppers. Others should be provided with brass caps, and screws, for the reception of air-cocks (fig. 22). Of these last, (the air-cocks,) several will be found necessary; and, to some of them, bladders, or elastic bottles, should be firmly tied, for the purpose of transferring gases. These jars will also be found extremely useful in experiments on the properties and effects of the gases. Some of them should be graduated into cubical inches.

To contain these jars, when in use, a vessel will be necessary, capable of holding a few gallons of water. This may either be of wood, if of considerable size; or, if small, of tin, japanned or painted. Plate iv. fig. 41, *ff* exhibits a section of this apparatus, which has been termed the pneumato-chemical trough, or pneumatic cistern. Its size may vary with that of the jars employed; and, about two or three inches from the top, it should have a shelf, on which the jars may be placed, when filled with air, without the risk of being upset. In this shelf should be a few small holes, to which inverted funnels may be soldered.

A glass tube, about 18 inches long, and three quarters of an inch diameter (fig. 24,) closed at one end, and divided into cubic inches, and tenths of inches, will be required for ascertaining the purity of air by nitrous gas. It should be accompanied also with a small measure, containing about two cubic inches, and similarly graduated. For employing the solution of nitrous gas in liquid sulphate of iron, (a happy invention of Sir H. Davy, which leaves very little to be desired in eudiometry,) glass tubes, about five inches long, and half an inch wide, divided decimally, are also necessary. Besides these, the experimentalist should be furnished with air funnels, (fig. 19,) for transferring gases from wide to narrow vessels.

An apparatus, almost indispensable in experiments on this class of bodies, is a GAZOMETER, which enables the chemist to collect and to preserve large quantities of gas, with the aid of only a few pounds of water. In the form of this apparatus there is considerable variety; but, at present, I have no other view than that of explaining its general construction and use. It consists of an outer fixed vessel *d*, (plate iv. fig. 35,) and an inner moveable one *c*, both of japanned iron. The latter slides easily up and down within the other, and is suspended by cords passing over pulleys, to which are

attached the counterpoises, *ee*. To avoid the incumbrance of a great weight of water, the outer vessel *d* is made double, or is composed of two cylinders, the inner one of which is closed at the top and at the bottom. The space of only about half an inch is left between the two cylinders, as shown by the dotted lines. In this space the vessel *c* may move freely up and down. The interval is filled with water as high as the top of the inner cylinder. The cup, or rim, at the top of the outer vessel, is to prevent the water from overflowing, when the vessel *c* is forcibly pressed down, in which situation it is placed whenever gas is about to be collected. The gas enters from the vessel in which it is produced, by the communicating pipe *b*, and passes along the perpendicular pipe marked by dotted lines in the centre, into the cavity of the vessel *c*, which continues rising till it is full.

To transfer the gas, or to apply it to any purpose, the cock *b* is to be shut, and an empty bladder, or bottle of elastic gum, furnished with a stop cock, to be screwed on *a*. When the vessel *c* is pressed down with the hand, the gas passes down the central pipe, which it had before ascended, and its escape at *b* being prevented, it finds its way up a pipe which is fixed to the outer surface of the vessel, and which is terminated by the cock *a*. By means of an ivory mouth-piece screwed upon this cock, the gas, included in the instrument, may be respired; the nostrils being closed by the fingers. When it is required to transfer the gas into glass jars standing inverted in water, a crooked tube may be employed, one end of which is screwed upon the cock *b*; while the other aperture is brought under the inverted funnel, fixed into the shelf of the pneumatic trough. (See fig. 41, *c*.)

Several alterations have been made in the form of this apparatus; but they are principally such as add merely to its neatness and beauty, and not to its utility; and they render it less easy of explanation. The counterpoises *ee* are now, generally, concealed in the framing, and the vessel *c* is frequently made of glass.

When large quantities of gas are required, (as at a public lecture,) the gas-holder, (plate iv. fig. 36,) will be found extremely useful. It is made of tinned iron plate, japanned both within and without. Two short pipes, *a* and *c*, terminated by cocks, proceed from its sides, and another, *b*, passes through the middle of the top or cover, to which it is soldered, and reaches within half an inch of the bottom. It will be found convenient also to have an air-cock, with a very wide bore, fixed to the funnel at *b*. When gas is to be transferred into this vessel from the gazometer, the vessel is first completely filled with water through the funnel, the cock *a* being left open, and *c* shut. By means of a horizontal pipe, the aperture *a* is connected with *a* of the gazometer. The cock *b* being shut, *a* and *c* are opened, and the vessel *c* of the gazometer, (fig. 35,) gently pressed downwards with the hand. The gas then descends from the gazometer till the air-holder is full, which may be known by the water ceasing to escape through the cock *c*. All the cocks are then to be shut, and the vessels disunited. To apply this gas to any purpose, an empty bladder may be screwed on

a; and water being poured through the funnel *b*, a corresponding quantity of gas is forced into the bladder. By lengthening the pipe *b*, the pressure of a column of water may be added; and the gas being forced through *a* with considerable velocity, may be applied to the purpose of a blow-pipe, &c. &c. The apparatus admits of a variety of modifications. The most useful one appears to me to be that contrived by Mr. Pepys, consisting chiefly in the addition of a shallow cistern, (*c*, plate ix. fig. 85,) to the top of the air-holder, and of a glass register tube *f*, which shows the height of the water, and consequently the quantity of gas, in the vessel. A more minute account of it will be given in the description of the ninth plate.*

The gazometer, already described, is fitted only for the reception of gases that are confinable by water; because quicksilver would act on the tinning and solder of the vessel, and would not only be spoiled itself, but would destroy the apparatus. Yet an instrument of this kind, in which mercury can be employed, is peculiarly desirable, on account of the great weight of that fluid; and two varieties of the mercurial gazometer have, therefore, been invented. The one, of glass, is the contrivance of Mr. Clayfield, and may be seen represented in the plate prefixed to Sir H. Davy's Researches. In the other, invented by Mr. Pepys, the cistern for the mercury is of cast-iron. A drawing and description of it may be found in the 5th vol. of the Philosophical Magazine; but as neither of these instruments are essential to the chemical student, and as they are required only in experiments of research, I deem it sufficient to refer to the minute descriptions of their respective inventors.

For those gases that are absorbed by water, a mercurial trough is necessary. For the mere exhibition of a few experiments on these condensable gases, a small wooden trough, 11 inches long, two wide, and two deep, cut out of a solid block of mahogany, is sufficient; but for experiments of research, one of considerable size is required. (See plate iii. fig. 31, *f. f*.)

The apparatus, required for submitting gases to the action of electricity, is shown in plate ix. fig. 84; where *a* represents the knob of the prime conductor of an electrical machine; *b* a Leyden jar, the ball of which is in contact with it, as when in the act of charging; and *c* the tube standing inverted in mercury, and partly filled with gas. The mercury is contained in a strong wooden box *d*, to which is screwed the upright iron pillar *e*, with a sliding collar for securing the tube *c*, in a perpendicular position. When the jar *b* is charged to a certain intensity, it discharges itself between the knob *a* and the small ball *i*, which, with the wire, connected with it, may be occasionally fitted on the top of the tube *c*. The strength of the shocks is regulated by the distance between *a* and *i*.

By the same apparatus, inflammable mixtures of gases may be exploded by electricity. In this case, however, the jar *b* is unne-

* Descriptions and figures of improved gas-holders may be seen also in the 13th, 24th, 27th, and 44th vols. of the Philosophical Magazine.

cessary, a spark received by *i* from *a* being sufficient to kindle the mixture.

The method of *weighing gases* is very simple and easily practised. For this purpose, however, it is necessary to be provided with a good air pump; and with a globe or flask, furnished with a brass cap and air-cock, as shown fig. 22, *b*. A graduated receiver is also required, to which an air-cock is adapted, as shown at fig. 22, *a*.

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 transfer 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 Appendix. Great care is to be taken, also, not to warm any of the vessels by contact with the hands, from which they should be defended by a glove. On opening the communication between 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 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

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

One hundred inches of carbonic acid, therefore, will weigh 47 grains.

Previously to undertaking experiments on other gases, it may be well for an unpractised experimentalist to accustom himself to the dexterous management of gases, by transferring common air from one vessel to another of different sizes.

1. When a glass jar, closed at one end, is filled with water, and held with its mouth downwards, in however small a quantity of water, the fluid is retained in its place by the pressure of the atmosphere on the surface of the exterior water. Fill in this manner, and invert, on the shelf of the pneumatic trough, one of the jars, which is furnished with a stopper (fig. 23). The water will remain in the jar so long as the stopper is closed; but immediately on removing it, the water will descend to the same level within as without; for it is now pressed, equally upwards and downwards, by the atmosphere, and falls, therefore, in consequence of its own gravity.

2. Place the jar, filled with water and inverted, over one of the funnels of the shelf of the pneumatic trough. Then take another jar, filled (as it will be of course) with atmospherical air. Place the latter with its mouth on the surface of the water; and on pressing it in the same position below the surface, the included air will remain in its situation. Bring the mouth of the jar beneath the funnel in the shelf, and incline it gradually. The air will now rise in bubbles, through the funnel, into the upper jar, and will expel the water from it into the trough.

3. Let one of the jars, provided with a stop-cock at the top, be placed full of air on the shelf of the trough. Screw upon it an empty bladder; open the communication between the jar and the bladder, and press the former into the water. The air will then pass into the bladder, till it is filled; and when the bladder is removed from the jar, and a pipe screwed upon it, the air may be again transferred into a jar inverted in water.

4. For the purpose of transferring gases from a wide vessel, standing over water, into a small tube filled with and inverted in mercury, I have long used the following contrivance of Mr. Cavendish. A tube, eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at this end, so as to resemble the italic letter *l*. The point is then immersed in quicksilver, which is drawn into the tube till it is filled, by the action of the mouth. Placing the finger over the aperture at the straight end, the tube is next conveyed through the water, with the bent end uppermost, into an inverted jar of gas. When the finger is removed, the quicksilver falls from the tube into the trough, or into a cup placed to receive it, and the tube is filled with the gas. The whole

of the quicksilver, however, must not be allowed to escape; but a column must be left, three or four inches long, and must be kept in its place by the finger. Remove the tube from the water; let an assistant dry it with blotting paper; and introduce the point of the bent end into the aperture of the tube standing over quicksilver. On withdrawing the finger from that aperture which is now uppermost, the pressure of the column of quicksilver, added to the weight of the atmosphere, will force the gas from the bent tube into the one standing in the mercurial trough.

On every occasion, when it is necessary to observe the precise quantity of gas, at the commencement and close of an experiment, it is essential that the barometer and thermometer should exactly correspond at both periods. An increased temperature, or a fall of the barometer, augments the apparent quantity of gas; and a reduced temperature or a higher barometer diminishes its bulk. Another circumstance, an attention to which is indispensable in all accurate experiments, is that the surface of the fluid, by which the gas is confined, should be precisely at the same level within and without the jar. If the fluid be higher within the jar, the contained gas will be under a less pressure than that of the atmosphere, the weight of which is counterpoised by that of the column of fluid within. In mercury, this source of error is of very considerable amount; as any person may be satisfied by pressing down, into quicksilver, a tube partly filled with that fluid, and partly with air, for the volume of the air will gradually decrease, the deeper the tube is immersed.

In experiments on gases, it is not always possible, however, to begin and conclude an experiment at precisely the same temperature, or with the same height of the barometer; or even to bring the mercury within and without the receiver to the same level. In these cases, therefore, calculation becomes necessary; and, with the view of comparing results more readily and accurately, it is usual to reduce quantities of gas to the bulk they would occupy under one given pressure, and at a given temperature. In this country, it is now customary to assume as a standard 30 inches of the barometer, and 60° of Fahrenheit's thermometer; and to bring to these standards observations made under other degrees of atmospheric pressure and temperature. The rules for these corrections, which are sufficiently simple, I shall give in the Appendix.

Of experiments illustrative of the nature of gases in general, it may be proper to mention one or two that show the mode in which caloric exists in this class of bodies. In vapours, strictly so called, as the steam of water, caloric seems to be retained with but little force; for it quits the water when the vapour is merely exposed to a lower temperature. But, in gases, caloric is united by very forcible affinity, and no diminution of temperature, that has ever yet been effected, can separate it from some of them.* Thus the air of

* Has this opinion, so universally received, ever been shewn to be substantially correct? I believe not. That gases, in common with all matter, contain a due

our atmosphere, in the most intense artificial or natural cold, still remains in the aëriform state. Hence is derived one character of gases, *viz.* that they remain aëriform under almost all variations of pressure and temperature; and in this class are also included those aërial bodies, which, being condensed by water, require confinement over mercury. The following experiment will show, that the caloric, contained in gases, is chemically combined.

Into a small retort (plate ii. fig. 26, *b*) put an ounce or two of well dried common salt, and about half its weight of sulphuric acid. By this process, a great quantity of gas is produced, which might be received and collected over mercury. But, to serve the purpose of this experiment, let it pass through a glass balloon, *c*, having three openings, into one of which the neck of the retort passes, while, from the other, a tube *e* proceeds, which ends in a vessel of water, *f*, of the temperature of the atmosphere. Before closing the apparatus, let a thermometer, *d*, be included in the balloon, to show the temperature of the gas. It will be found that the mercury, in this thermometer, will rise only a few degrees, whereas the water, in the vessel which receives the bent tube, will soon become boiling hot. In this instance, caloric flows from the lamp to the muriatic acid, and converts it into gas; but the heat, thus expended, is not appreciable by the thermometer, and must, therefore, be chemically combined. The caloric, however, is again evolved, when the gas is condensed by water. In this experiment, we trace caloric into a latent state, and again into the state of free or uncombined caloric.

A considerable part of the caloric, which exists in gases in a latent state, may be rendered sensible by rapid mechanical compression. Thus, if air be suddenly compressed in the ball of an air-gun, the quantity of caloric liberated by the first stroke of the piston, is sufficient to set fire to a piece of the tinder called *amadou*.* A flash of light is said, also to be perceptible at the moment of con-

proportion of caloric, which according to circumstances is liberated or absorbed, is undoubtedly true; but that caloric is the sole cause of their elastic aëriform state, I cannot credit. The amount of caloric given off in the condensation of some of those bodies, as ammonia, muriatic acid, &c. is far too small to be accounted for on this principle; and when muriatic acid gas and ammonical gas meet together, and form a solid muriat of ammonia, where is the caloric perceived, which in conformity with the common opinion, ought to be extricated. Is not the small quantity apparent, more rationally deducible from the water which these gases always hold in solution, and which by passing from the vaporous to the fluid state, must necessarily part with its caloric of vaporization? All our deductions relative to the gases, are improperly derived from experiments on water, whose numerous anomalies I have already adverted to. There is in fact, no good reason assigned, why we should not believe that oxygen, nitrogen, and the other gases, are elastic aërial fluids, *per se*, equally as much so, as that light, magnetism, electricity, and caloric are independent of any known cause for their peculiar state of cohesion. C.

* Philosophical Magazine, xiv. 363, and xl. 424.

densation. This fact has been applied to the construction of a portable instrument for lighting a candle. It consists of a common syringe, concealed in a walking stick. At the lower extremity, the syringe is furnished with a cap, which receives the substance intended to be fired, and which is attached to the instrument by a male and female screw. The rapid depression of the piston condenses the air, and evolves sufficient heat to set the tinder on fire.*

For demonstrating the influence of variations of atmospheric pressure on the formation of gases, better experiments cannot be devised than those of Lavoisier.† But as some students, who have the use of an air-pump, may not possess the apparatus described by Lavoisier (the glass bell and sliding wire), it may be proper to point out an easier mode of showing the same fact. This proof is furnished by the experiment already described, in which ether is made to assume alternately an æriform and liquid state, by removing and restoring the pressure of the atmosphere.

Gases, when once formed, undergo a considerable change of bulk by variations of external pressure. The general law which has been established on this subject is, that *the volume of gases is inversely as the compressing force*. If, for example, we have a quantity of gas occupying 60 cubic inches under the common pressure of the atmosphere, they will fill the space of only 30 cubic inches, or one half under a double pressure; of 20 inches, or one 3d, under a triple pressure; of 15 inches, or one 4th, under four times the pressure; and so on.

The law of the dilatibility of gases by heat has already been stated to be an enlargement of about $\frac{1}{480}$ th part of their bulk for each degree of Fahrenheit's scale, between the freezing and boiling points of water.

Before dismissing the consideration of the gases in general, there are a few properties, which it may be proper to notice, with the view of comparing the degree, in which they belong to different individuals of the class.

1. The exact *specific gravity* of the different gases is a most important element, in calculating the proportion of the ingredients of compounds, into which they enter. Nothing, indeed, can show the importance of this object more strikingly, than the fact, that on the precise specific gravities of hydrogen and oxygen gases, depend the whole series of numbers, which are used to express the weights of the atoms of bodies on the Daltonian theory. The following Table exhibits the specific gravities of the most important of this class of bodies.

* Philosophical Magazine, xxxi. 130.

† See his Elements, chap. 1.

TABLE OF THE SPECIFIC GRAVITY OF GASES.

Barometer 30. Thermometer 60°.

	NAMES OF GASES.	Specific Gravity	Wt. of 100 cub. inches.	Authority.
			Grains.	
Simple Gases.	Atmospherical air	1.0000	30.50	Shuckburgh.
	Oxygen gas	1.1088	33.82	Allen and Pepys.
	Ditto	1.10359	. . . .	Biot and Arago.
	Hydrogen gas	0.7321	2.23	Ditto.
	Nitrogen gas	0.9691	29.55	Ditto.
Compound combustible Gases.	Chlorine gas	2.5082	76.50	Davy.
	Ammoniacal gas	0.5960	18.18	Allen and Pepys.
	Carbd. Hydr. from stagnant water	0.666	20.66	Dalton.
	Olefiant gas	0.974	29.72	Thomson.
	Phosphuretted hydrogen	0.852	25.98	Dalton and Henry.
	Ditto	0.435	13.26	Davy.
	Hydro-Phosphoric gas	0.870	26.53	Ditto.
	Sulphuretted hydrogen	1.177	35.89	Ditto.
	Ditto	1.231	38.17	Thenard.
	Arsenuretted hydrogen	0.529	16.13	Tromsdorff.
	Vapour of alcohol	2.100	65.	Dalton.
	Ditto of ether	2.250	70.	Ditto.
Oxides.	Carbonic oxide	0.967	30.19	Cruikshank.
	Nitrous oxide	1.614	49.22	Davy.
	Nitrous gas	1.049	32.	Ditto.
	Ditto	1.0388	31.684	Berard.
Acid Gases.	Carbonic acid	1.518	46.31	Saussure.
	Ditto	1.5495	47.26	Allen and Pepys.
	Muriatic acid	1.278	38.97	Davy and Biot.
	Nitric acid	2.425	76.	Davy.
	Sulphurous acid	2.193	66.89	Ditto.
	Ditto	2.303	70.24	Gay Lussac.
	Phosgene gas*	3.669	111.91	John Davy.
	Silicated fluoric	2.990	91.19	Ditto.
	Fluoboracic	2.370	72.31	Ditto.

2. The determination of the *specific heat* of gases is a difficult and important problem, which has successively employed the labour and ingenuity of Crawford, Lavoisier and De la Place, Leslie, Gay Lussac, Dalton, and Delaroche and Berard. The results of the two last-mentioned philosophers, having been attained with the advantages of an improved state of the science, and of instruments of the greatest delicacy and refinement, are most entitled to confidence. The details of their experiments are given in the 85th volume of the *Annales de Chimie*, preceded by an historical review of the labours of their predecessors. The following Table contains the general results.

* This most barbarous term, has been properly objected to by Thenard in his *Chemistry*. "Mr. J. Davy, says he, has proposed the name of *phosgene*—as much as to say, produced by light. We do not adopt it, because it gives no idea of the nature of the substance." Mr. T. has given it the appellation of carbo-muriatic acid gas. C.

TABLE OF THE SPECIFIC HEAT OF SOME GASES.

NAMES OF GASES.	Under equal volumes.	Under equal weights.	Specific gravi- ties.
Atmospheric air	1.0000	1.0000	1.0000
Hydrogen gas	0.9033	12.340	0.0732
Oxygen gas	0.9765	0.8848	1.1036
Nitrogen gas	1.0000	1.0318	0.9691
Nitrous oxide	1.3503	0.8878	1.5209
Olefiant gas	1.5530	1.5763	0.9885
Carbonic oxide	1.0340	1.0805	0.9569
Carbonic acid	1.2583	0.8280	1.5196

3. The colour of the electric spark, when transmitted through different gases, has been observed by De Grothuis* to be as follows :

In atmospheric air of double density, the spark was more brilliant, but not coloured.

In hydrogen gas purple.
 — phosphuretted hydrogen red.
 — ammonia red.
 — dry carbonic acid gas violet.
 — oxygen gas ditto.
 — aqueous vapour orange.
 — vapour of ether }
 — ditto of alcohol } celadon green.

The general inference from his experiments is, that the intensity of electric light is always in a direct proportion to the density of the gas, and in the inverse proportion to the conducting power of the gas for electricity.

4. The comparative soniferous properties of the gases have been determined by Messrs. Kerby and Merrick ; but as these belong rather to mechanical than to chemical science, I shall content myself with referring to the account of them in the 27th and 33d volumes of Nicholson's Journal.

SECTION II.

Oxygen Gas.

WE have no knowledge of the properties of oxygen in a state of complete separation. In the most simple form, under which we can procure it, it is combined with caloric, and probably with light and electricity, constituting oxygen gas.

I. *Oxygen gas may be procured from various substances.*

1. From the black oxide of manganese, heated to redness in a

* 82 An. Ch. 34.

gun-barrel, or in an iron or earthen retort; or, from the same oxide, heated by a lamp in a retort or gas bottle, with half its weight of strong sulphuric acid.

2. From the red oxide of lead (the common red lead used by painters), heated either with or without sulphuric acid.

3. From various other oxides, as will be hereafter mentioned.

4. From nitrate of potash (common saltpetre) made red hot in a gun barrel, or in an earthen retort.

5. From oxygenized muriate of potash, heated in a small glass retort over an Argand's lamp. The oxygen gas thus produced, is much purer than that obtained in any other mode, especially the last portions, which should be kept separate.*

All these substances, after having yielded oxygen gas, are found considerably diminished in weight; and calculating each cubic inch of gas to be equal to one third of a grain, the loss of weight will be found pretty exactly equivalent to that of gas generated.

II. This gas has the following properties:

1. *It is not absorbed by water;*† or, at least, is so sparingly absorbed, that, when agitated in contact with water, no perceptible diminution takes place.

2. *It is rather heavier than common air.*—Sir H. Davy originally stated 100 cubic inches, at 55° Fahrenheit, and 30 inches of the barometer, to weigh 35.06 grains; and at the temperature of 60°, the same quantity would weigh 34.70, or, according to the same author, in his Elements of Chemical Philosophy, 34 grains. Messrs. Allen and Pepys have determined 100 cubic inches to weigh 33.82 grains, the barometer being 30, and thermometer 60°. By Biot and Arago its specific gravity is stated to be 1.10359.

2. *All combustible bodies burn in oxygen gas with greatly increased splendour.*

(a) A lighted wax taper, fixed to an iron wire, and plunged into a vessel of this gas, burns with great brilliancy, pl. iv. fig. 38. If the taper be blown out, and let down into a vessel of the gas while the snuff remains red hot, it instantly rekindles, with a slight explosion.

(b) A red hot bit of charcoal, fastened to a copper wire, and immersed in the gas, throws out beautiful sparks.

(c) The light of phosphorus, burnt in this gas, is the brightest that can be in any mode produced. Let the phosphorus be placed in a small hemispherical tin cup, which may be raised by means of the wire stand, pl. ii. fig. 25, two or three inches above the surface

* Oxygen gas is found in a pure state in the air vessel of a fresh laid egg. It becomes deteriorated as the chick advances to maturity. This fact I pointed out in 1794, in my inaugural dissertation. The operation of the solar light on vegetables, omitted in this place, is stated by Dr. H. as an abundant source of oxygen, in a subsequent part of his work. C.

† In this as in several other instances, where a gas is said not to be absorbed by water, the assertion is not to be taken strictly, but merely as implying that only a minute and difficultly appreciable portion is absorbed. The precise proportion of each gas absorbed by water is stated in Chap. vi. Sec. 3, in the form of a table.

of water contained in a broad shallow dish. Fill a bell-shaped receiver, having an open neck at the top, to which a compressed bladder is firmly tied, with oxygen gas; and, as it stands inverted in water, press a circular piece of pasteboard, rather exceeding the jar in diameter, over its mouth. When an assistant has set fire to the phosphorus, cover it instantly with the jar of oxygen gas, retaining the pasteboard in its place, till the jar is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas will escape; and the inflammation of the phosphorus will be extremely brilliant. The expanded gas rises into the flaccid bladder, and is thus prevented from escaping into the room, and proving disagreeable by its suffocating smell.

(d) Substitute, for the phosphorus in experiment c, a small ball formed of turnings of zinc, and in which about a grain of phosphorus is inclosed. Set fire to the phosphorus, and cover it expeditiously with the jar of oxygen. The zinc will be inflamed, and will burn with a beautiful white light. A similar experiment may be made with metallic arsenic, which may be moistened with spirit of turpentine. The filings of various metals may also be inflamed, by placing them in a small cavity, formed in a piece of charcoal, igniting the charcoal, and blowing, on the part containing the metal, a stream of oxygen gas.

(e) Procure some thin harpsichord wire, and twist it round a slender rod of iron or glass, so as to coil it up in a spiral form. Then withdraw the rod, and tie a little thread or flax round one end of the wire, for about one 20th of an inch; which end is to be dipped into melted sulphur. The other end of the wire is to be fixed into a cork; so that the spiral may hang vertically (fig. 39). Fill, also, with oxygen gas, a bottle capable of holding about a quart, and set it with its mouth upwards. Then light the sulphur, and introduce the wire into the bottle of gas, suspending it by the cork. The iron will burn with a most brilliant light, throwing out a number of sparks, which fall to the bottom of the bottle, and generally break it. This accident, however, may frequently be prevented by pouring sand into the bottle, so as to lie about half an inch deep on the bottom (see plate iv. fig. 39.) According to Mr Accum,* a thick piece of iron or steel, such as a file, if made sharp pointed, may be burnt in oxygen gas. A small bit of wood is to be stuck upon its extremity, and set on fire, previously to immersion in the gas.

(f) A little of Homberg's pyrophorus, a substance to be hereafter described, when poured into a bottle full of this gas, immediately flashes like inflamed gunpowder.

III. *During every combustion in oxygen gas, the gas suffers a considerable diminution.*—To exhibit this, experimentally, in a manner perfectly free from all sources of error, would require such an apparatus as but few adepts in chemistry are likely to possess. The apparatus required for this purpose is described in the 6th chapter of Lavoisier's Elements. The fact may, however, be shown, less accurately, in the following manner: Fill, with oxygen gas, a jar of

* Nicholson's Journal, 8vo. i. 320.

moderate size, which has a neck and ground-glass stopper at the top. Then, with the assistance of a stand, formed of bent iron wire, (plate ii. fig. 25,) place a shallow tin vessel, containing a bit of phosphorus or sulphur, three or four inches above the level of the water of a pneumatic trough. Invert the jar of oxygen gas, cautiously and expeditiously, over this cup, so as to confine it, with its contents, in the gas, and, pressing down the jar to the bottom of the trough, open the stopper. A quantity of gas will immediately rush out, and the water will rise to the same level within the jar as without. When this has taken place, set fire to the sulphur or phosphorus by a heated iron wire, and instantly put in the stopper. The first effect of the combustion will be a depression of the water within the jar; but when the combustion has closed, and the vessel has cooled, a considerable absorption will be found to have ensued.

Those persons who are possessed of a mercurial apparatus may repeat this experiment in a less exceptionable manner. On the surface of the quicksilver let a small hemispherical cup float, made of untinned sheet-iron; and, in order to keep it from the sides of the jar, it may rest on a wire-stand, shaped like the figure 43, plate iv. Let a jar, the height and diameter of which must be regulated by the size of the mercurial trough, be filled with oxygen gas over water, and be removed, by means of a piece of pasteboard, as before described, to the mercurial bath, inverting it dexterously over the tin cup. If the phosphorus had been previously set on fire, a large quantity of the gas, expanded by the heat, would have escaped, and would have prevented the accurate measurement of the absorption. After drying the surface of the mercury within the jar by blotting paper, a portion of the included gas must, therefore, be removed. This is done by an inverted syphon, one leg of which is to be introduced (in the same manner as is shown at fig. 41, *g*) within the jar before placing it over the mercury; and the gas will be forced through the open extremity of the other, when the jar is pressed down into the quicksilver. When the proper quantity has been expelled, remove the syphon. The cup, containing the phosphorus, will thus rest on the surface of the quicksilver within the jar, and above the level of the mercury without. The phosphorus is to be inflamed by passing a crooked iron wire, made red hot, through the quicksilver. On the first impression of the heat arising from its combustion, the included gas will be considerably expanded; but when the phosphorus has ceased to burn, a considerable absorption will be found to have taken place, the amount of which may be measured by ascertaining the height of the quicksilver within the jar, before and after the experiment. The quantity of phosphorus employed should be very small, and should not bear a greater proportion than that of 10 grains to each pint of gas; otherwise the combustion will go on so far as to endanger the breaking of the jar, by the approach of the inflamed phosphorus.

In this process, a white dense vapour is produced, which condenses on the inner surface of the jar in solid flakes. This sub-

stance has strongly acid properties ; and, being formed by the union of oxygen with phosphorus, is termed the phosphoric acid.

The diminution of the volume of oxygen gas, by the combustion of other bodies, may be ascertained in a similar manner. When the substance employed is not easily set on fire, it is proper to enclose, along, and in contact with it, a small bit of phosphorus, the combustion of which excites sufficient heat to inflame iron-turnings, charcoal, &c. In the instance of charcoal, however, though that substance undergoes combustion, no absorption ensues ; because, as will appear in the sequel, the product is a gas, occupying exactly the same bulk as the oxygen gas submitted to experiment.

IV. *All bodies, by combustion in oxygen gas, acquire an addition to their weight ; and the increase is in proportion to the quantity of gas absorbed, viz. about one third of a grain for every cubic inch of gas.*—To prove this by experiment, requires also a complicated apparatus.

But sufficient evidence of this fact may be obtained by the following very simple experiment. Fill the bowl of a tobacco pipe with iron wire coiled spirally, and of known weight : let the end of the pipe be slipped into a brass tube, which is screwed to a bladder filled with oxygen gas : heat the bowl of the pipe, and its contents, to redness in the fire, and then force through it a stream of oxygen gas from the bladder. The iron wire will burn ; will be rapidly oxydized ; and will be found, when weighed, to be considerably heavier than before. When completely oxydized in this mode, 100 parts of iron wire gain an addition of about 30.

V. *Every substance, capable of union with oxygen, affords, by combustion, either an oxide, an acid, or an alkali.**—When a body, by being burnt in oxygen gas, affords a compound, which has none of those qualities that characterize acids or alkalis, we denominate this product an *oxide*. If we collect, for example, the iron wire, which was burned in the last experiment, we shall find that it has lost all its metallic qualities, and has become a brittle, dark-coloured substance totally destitute of lustre and of taste, and termed an *oxide of iron*. But if, instead of iron wire, we had burned a quantity of sulphur in oxygen gas, the result would have been that the water, which confined the gas, would have become acid or sour. Potassium, on the contrary, (one of the new metals discovered by Sir H. Davy,) would have yielded an alkali under the same circumstances. Hence the extensive class of combustible bodies may be subdivided into three orders ; 1st, those which afford oxides by combustion ; 2dly, those which yield acids ; and 3dly, those which give alkalis. In many instances, however, a body is capable of passing

* The statement thus made of its affording alkaline properties to some bodies, sufficiently evinces on what unfounded grounds the name of this substance was appropriated to it. That there is no such thing as an acidifying principle, in the proper acceptation of the term, is now admitted even by the French themselves ; for they have shown that acids of a different nature are constituted from the same base, when conjoined with oxygen on the one hand, or with hydrogen on the other ; as the iodic and hydriodic acids. C.

through the intermediate state of an oxide, before it is converted either into an acid or an alkali.

VI. *Oxygen gas supports, eminently, animal life.*—It will be found that a mouse, bird, or other small animal, will live four or five times longer in a vessel of oxygen gas, than in one of atmospherical air of the same dimensions.

VII. *This effect seems connected with the absorption of oxygen by the blood.*—Pass up a little dark-coloured blood into a jar partly filled with oxygen gas, and standing over mercury. The gas will be in part absorbed, and the colour of the blood will be changed to a bright and florid red. This change to red may be shown, by putting a little blood into a common vial filled with oxygen gas, and shaking it in contact with the gas.

SECTION III.

Nitrogen or Azotic Gas.

AFTER separating, from any quantity of atmospherical air, all the oxygen which it contains, there remains a gas which was called by Lavoisier *azotic gas*, a name applied to it in consequence of its unfitness for supporting animal life; and derived from the Greek privative *a* and *ζωη* *vita*. This, however, as being merely a negative property, has since been deemed an improper foundation for its nomenclature; and the term **NITROGEN** gas has been substituted; because one of the most important properties of its base is, that by union with oxygen it composes nitric acid. By this appellation, therefore, I shall hereafter distinguish it.

1. Nitrogen gas may be procured, though not absolutely pure, yet sufficiently so for the purpose of exhibiting its general properties, in any of the following manners: 1. Mix equal weights of iron filings and sulphur into a paste with water, and place the mixture, in a proper vessel, over water, supported on a stand: then invert over it, a jar full of common air, and allow this to stand exposed to the mixture for a day or two. The air contained in the jar will gradually diminish, as will appear from the ascent of the water within the jar, till at last only about four 5ths of its original bulk will remain. The vessel containing the iron and sulphur must next be removed, by withdrawing it through the water; and the remaining air may be made the subject of experiment.

2. A quicker process, for procuring nitrogen gas, consists in filling a bottle, about one 4th, with the solution of nitrous gas in liquid sulphate of iron, or with liquid sulphuret of lime, and agitating it with the air which fills the rest of the bottle. During the agitation, the thumb must be firmly placed over the mouth of the bottle; and, when removed, the mouth of the bottle must be immersed in a cup full of the same solution, which will supply the place of the absorbed air.

3. Atmospheric air, also, in which phosphorus has burned out, affords, when time has been allowed for the condensation of the phosphoric acid, tolerably pure nitrogen gas.

4. Azotic gas may be procured from the lean part of flesh meat (beef for example), which may be put into a glass bottle, along with very dilute nitric acid. By a heat of about 100° , the gas is disengaged, and may be collected over water. Its source has been satisfactorily traced to the animal substance, no part of it proceeding from the nitric acid.*

II. Nitrogen gas has the following properties :

1. It is not absorbed by water.

2. *It is a little lighter than atmospheric air*, 100 cubic inches being found by Sir H. Davy to weigh 30.04 grains under a pressure of 30 inches, and at the temperature of 55° Fahrenheit. At 60° Fahrenheit 100 inches weigh, therefore, 29.73 grains. According to Biot and Arago, its specific gravity is 0.96913.

3. It immediately extinguishes a lighted candle, and all other burning substances.

Even phosphorus, in a state of active inflammation, is instantly extinguished when immersed in nitrogen gas. This is best shown by placing the burning phosphorus in a tin cup, raised by a stand above the surface of the water, and quickly inverting over it a jar filled with nitrogen gas.

4. It is fatal to animals that are confined in it.

5. When mixed with pure oxygen gas, in the proportion of four parts to one of the latter, it composes a mixture resembling atmospheric air in all its properties. Of this any one may be satisfied, by mixing four parts of azotic gas with one of oxygen gas, and im-

* Certainly not satisfactorily, at least not to every person. Is it reasonable to imagine, that a body so energetic as nitric acid, and one so easily decomposed on numerous occasions, as even to render it one of the most powerful agents we possess for chemical research ; a body too, admitted to be essential to the above process ; is it reasonable, I ask, to imagine it a negative substance in this case ? If it is not here decomposed, it is a folly to talk of chemical affinities ; the process might as well be effected without its presence ! The only reason assigned for this assertion is, that the acid can decompose as much alkali after as before the process. But is this true ? or is it not like too many other points in chemistry, taken for granted without due investigation ? Has the experiment been *duly repeated*, with this particular object of inquiry kept in view ? I do not recollect to have seen it announced ; each author copies from his predecessor, without sufficiently demanding at every step, whether fact will warrant his assertion. Admitting however, for an instant, that the acid is equal in amount after, as before the process ; a reference to the principles brought together will shew, that it is probably a case of compound affinity, in which the nitrogen of the acid is liberated, and escapes into the receiver, whilst the oxygen of the acid combines with the hydrogen of the decomposed water ; the oxygen of this last, uniting simultaneously with the nitrogen of the flesh, acted on by the acid. By this means, a *fresh portion* of acid is produced, from materials previously in a different state of combination. The utility of the original acid to the process is maintained, without the necessity of referring to the doctrine of disposing affinity, so properly called absurd by Dr. H. on a former occasion ; but which must otherwise be here adopted ; and the acid thus newly produced, is that which goes to the decomposition of the alkali. C.

mersing, in the mixture, a lighted taper. The taper will burn as in atmospherical air.

Composition of Nitrogen.

That nitrogen is not an element, but itself a compound, has been long suspected, and various attempts have been made to discover its ingredients. Some of the facts, which have been supposed to throw light on its nature, I shall reserve for the chapter on ammonia, because they will be better understood in connection with that subject.

Berzelius, from the combination of experiment with much theoretical reasoning, has deduced, that nitrogen is compounded of oxygen and an unknown base, in the following proportions :*

Base . . .	44.32	79.64	100.00
Oxygen .	55.68	100.	125.51
	<hr/>	<hr/>	<hr/>
	100	179.64	225.51

This base, it must be observed, however, is purely hypothetical; and, as it has never yet been exhibited in a separate state, we cannot at present know any thing of its properties. Berzelius has proposed for it the name of *nitricum*.

A series of experiments to prove the composition of nitrogen by synthesis, has been published in the 4th volume of Dr. Thomson's Annals, by Mr. Miers, of London. He attempted to deprive water of part of its oxygen by transmitting it, along with sulphuretted hydrogen, through an ignited copper tube ; by which process he obtained a mixture of oxygen and nitrogen gases, in proportions the same as those constituting atmospheric air. If no source of fallacy existed in the experiment, it would follow that nitrogen is composed of oxygen and hydrogen, with less oxygen than exists in water. But the experiments, though ingeniously devised, require the most careful repetition, before so important a conclusion can be established ; and there is reason to suspect, from the nature of the products, that atmospheric air must, by some means, have found its way into the apparatus. It is remarkable, however, that the proportions of the elements of ammonia, deduced by Mr. Miers from his experiments, precisely agree with the hypothetical proportions assigned by Berzelius, viz. 55.6 oxygen and 44.4 hydrogen per cent. in weight.

The experiments of Sir H. Davy,† directed to the decomposition of nitrogen, on the presumption of its being an oxide, have not been attended with any better success. Potassium was ignited, by intense Voltaic electricity, in nitrogen gas ; and the result was, that hydrogen appeared, and some nitrogen was found deficient. This, on first view, would lead us to the suspicion, that nitrogen was decomposed. But, in subsequent experiments, in proportion as the

* 2 Thomson's Annals, 284.

† Phil. Trans. 1810.

potassium was more free from a coating of potash, which would introduce water, so, in proportion, was less hydrogen evolved, and less nitrogen found deficient. The general tenor of these enquiries, therefore, lends no strength to the opinion, that nitrogen is a compound body.

SECTION IV.

Atmospheric Air.

THE air of our atmosphere, it appears, from the facts stated in the preceding section, is a mixture, or possibly a combination, of two different gases, *viz.* oxygen gas and azotic gas. The former of these seems to be the only ingredient on which the effect of the air, as a chemical agent, depend. Hence combustible bodies burn in atmospheric air, only in consequence of the oxygen gas which it contains; and, when this is exhausted, air is no longer capable of supporting combustion.* Its analysis is most satisfactorily demonstrated by the action of heated mercury, as explained by Lavoisier, in the third chapter of his *Elements of Chemistry*. By exposure, during 12 days, to mercury heated in a retort, a given quantity of atmospheric air was found to be diminished in bulk, and to have lost its property of supporting combustion. The mercury, also, had suffered a considerable change; a part of it was no longer a shining fluid metal; but was changed into red scaly particles; and its weight was also increased. These red particles were collected, and distilled in a retort; by which operation a quantity of oxygen gas was evolved, precisely equal in bulk to what the air had lost in the first part of the experiment. These results afford the most satisfactory evidence, that the air of our atmosphere is composed of two distinct fluids. The one is capable of yielding its base to mercury; and, when separate, is eminently adapted to the support of combustion and of animal life; the other is not absorbable by mercury, and is destitute of both those important qualities.

The details of this method of analyzing atmospheric air I omit, on account of the extreme tediousness of the process. Sufficient evidence of its composition may be obtained, however, much more expeditiously, by the following experiments.

1. Burn a little sulphur or phosphorus, in the manner described, sect. ii. substituting, for oxygen gas, common atmospherical air. The combustion will, in this instance, be less vivid; will cease sooner; and the absorption, when the vessels have cooled, will be much less considerable than in the former case.

The phosphorus, however, will have absorbed the whole of the oxygen gas contained in the air submitted to experiment; and hence it may be employed for measuring the quantity of oxygen

* Certain combustible bodies even cease to burn in atmospheric air, long before its oxygenous portion is consumed, for reasons that will hereafter be given.

gas in a given bulk of atmospherical air. This may be accomplished, either by its slow or rapid combustion. Berthollet proposes* to expose a cylinder of phosphorus, fastened to a glass rod, in a narrow glass vessel, graduated into equal parts, and standing full of air over water. (See fig. 24). The phosphorus immediately begins to act on the included air; and in six or eight hours its effect is completed. The residuary azotic gas has its bulk enlarged about one 40th, by absorbing a little phosphorus; and, for this, allowance must be made in measuring the diminution.

In the eudiometer of Seguin, the rapid combustion of phosphorus is employed with the same view. A glass tube, open at one end only, about an inch in diameter, and eight or ten high, is filled with, and inverted in, mercury. A small bit of phosphorus, dried with blotting paper, is then introduced, and, by its inferior specific gravity, rises to the top of the tube, where it is melted, by bringing a red-hot poker near to the outer surface of the glass. When the phosphorus is liquefied, a measured portion of the air to be examined is admitted, by a little at once, into the tube. The phosphorus inflames at each addition, and the mercury rises. When all the air under examination has been added, the red-hot poker is again applied to ensure the completion of the process, and the residuary gas is transferred into a graduated measure, where its bulk is carefully ascertained. In this instance, about one 40th the volume of the residuary gas is to be deducted from the apparent quantity of azotic gas, because, in this case also, a small portion of phosphorus is dissolved by the latter, and occasions a trifling expansion. With this deduction, atmospheric air loses pretty accurately 21 parts out of each 100; and contains, therefore, 21 *per cent.* of oxygen, and 79 of azote by measure.† And it is remarkable, that no appreciable difference exists between the proportions of oxygen and azote in the atmospheres of distant places; from which it appears, that the purity and salubrity of air depend on some other circumstances than the proportion of these its chief elements.‡

II. The inferior fitness of atmospherical air, to that of oxygen gas, for supporting combustion, may be shown also by a comparative experiment with two candles. Provide a circular piece of lead, three inches diameter, and half an inch thick, from the centre of which proceeds a perpendicular iron wire, six or eight inches high; to the end of this wire fasten a piece of wax taper. Set the candle, supported by its stand, on the shelf of a pneumatic cis-

* Annales de Chimie, xxxiv. 78.

† Various other methods of analyzing atmospherical air will be described in the course of the work. References to them may be found in the Index, article Eudiometer.

‡ A small proportion of carbonic acid gas is so invariably found to be present in atmospheric air, even when taken from the summit of Mont Blanc, or from still higher regions, by various aeronauts, that we can scarcely persuade ourselves that it is not essential to its composition. It is however so very trifling in quantity, that we may admit the possibility of a portion, continually emitted from the lungs in respiration, to have found its way into the bottles which were employed in the above researches, along with the atmospheric mass.—C.

tern; and place, also, the conducting pipe from the bladder (*c*, fig. 41), in the position shown by the figure; the cock *d*, however, being shut. Then, having the syphon *g* in the inverted position shown in the plate, sink the whole apparatus into the water. Part of the air in the jar *a* will escape through the syphon, and will be replaced by water. When we have left, in the jar, the proper quantity of air, the syphon must be removed, and the jar returned to its place. The level of the water will now be considerably higher within than without the receiver; and its height must be noted. On passing a succession of electrical sparks from the conducting wire to the bent pipe, and opening the cock *d* from the bladder filled with hydrogen gas, we shall have a small flame, which is to be extinguished as soon as, by its means, we have lighted the candle. The candle may be suffered to burn till it is extinguished; and the duration of its burning, and the diminution it occasions in the air, are to be noted. When the combustion is repeated in the same manner, but with the substitution of oxygen gas, it will be found to last considerably longer, and the diminution of volume in the gas will be much greater.

The same fact may be demonstrated, but less accurately, by a simple apparatus. Provide two jars, each two inches diameter, and 12 inches long, and each having a neck at the top with a compressed bladder tied upon it. Fill one of the jars, leaving the bladder empty, with oxygen gas; and, at the same instant, with the aid of an assistant, invert both jars over the burning candles, keeping the oxygen gas in its place till the jar is inverted by a piece of pasteboard. In the common air, the candle will soon be extinguished; but that confined in oxygen gas will burn with much greater splendour, and will continue burning long after the other is extinguished. On the first impression of the flame, a quantity of expanded gas will rise into each bladder, which is to be pressed out at the close of the experiment, in order that the absorption may be compared in both cases. The diminution in the jar of oxygen gas will be found greatly to exceed that of the common air.

III. Take two tubes, each a few inches long, closed at one end, and divided into 100 aliquot parts. Fill the one with atmospherical air, the other with oxygen gas, and invert them in two separate cups filled with a solution of sulphuret of potash. The sulphuret will ascend gradually within the tube of common air, till, after a few days, only about four 5ths of its original volume will remain; but, in that containing oxygen, it will ascend much higher, and, if the gas be pure, will even absorb the whole.

The explanation of this fact is, that liquid sulphuret of potash has the property of absorbing oxygen, but not nitrogen. It therefore acts on atmospheric air only as long as any oxygen gas remains, and may be employed as a means of ascertaining the quantity of this gas in the atmosphere at different times, and in distant places. An improved instrument*, thus graduated, has lately been employ-

* See Nicholson's *Philosophical Journal*, 4to. vol. i. page 268; or Tilloch's *Philosophical Magazine*, vol. iii. page 171.

ed by Guyton as an *Eudiometer*.* But an apparatus, of much greater simplicity, and facility of application, is that of Professor Hope of Edinburgh, announced in Nicholson's Journal, 8vo. iv. 210. It consists of a small bottle, of the capacity of 20 or 24 drachms (fig. 20, pl. ii.), destined to contain the eudiometric liquid, and having a small stopper at *b*. Into the neck of the bottle a tube is accurately fitted, by grinding, which holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first filled with the liquid employed, which is best prepared by boiling a mixture of quicklime and sulphur with water, filtering the solution, and agitating it for some time in a bottle half filled with common air. The tube, filled with the gas under examination (or with atmospherical air, when the quality of this compound is to be ascertained), is next to be put into its place; and, on inverting the instrument, the gas ascends into the bottle, where it is brought extensively into contact with the liquid, by brisk agitation. An absorption ensues; and, to supply its place, the stopper *b* is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation renewed; and these operations are performed alternately, till no farther diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be apparent. Its amount may be measured by the graduated scale engraved on the tube.

To the eudiometer of Dr. Hope there are, however, a few objections. If the tube *a* and the stopper *b* are not both very accurately ground, air is apt to make its way into the instrument, to supply the partial vacuum, occasioned by the absorption of oxygen gas. This absorption, also, occasions a diminished pressure within the bottle; and, consequently, towards the close of each agitation, the absorption goes on very slowly. Besides, the eudiometric liquid is constantly becoming more dilute by the admission of water through *b*. To obviate all these difficulties, I have substituted for the glass bottle, one of elastic gum, as shown by fig. 21, *b*. The tube *a* is accurately ground into a short piece of very strong tube of wider bore, as shown at *c*, the outer surface of which is made rough by grinding, and shaped as represented, that it may more effectually retain the neck of the elastic bottle when fixed by a string. This instrument is used, in every respect, in the same way as Dr. Hope's. The only difficulty is, in returning the whole of the residuary gas into the tube; but the art of doing this will be acquired by practice.

An ingenious modification of the eudiometer, which enables us to measure an absorption of only $\frac{1}{1000}$ th part of the gas employed, is described by Mr. Pepys, in the Philosophical Transactions for 1807, or Philosophical Magazine, vol. xxix.

IV. *Atmospheric air supports animal life, only in consequence of the oxygen gas which it contains.*—Air, after having been received into

* Other eudiometers will be described hereafter.

the lungs, and again respired, is found to have lost considerably of its oxygenous part, viz. 10 to 12 *per cent.* It proves fatal to animals, however, long before this purer portion is wholly exhausted; and hence it appears, that a considerable portion of oxygen gas is even necessary to fit the air for supporting respiration. As the analysis of expired air requires an acquaintance with another gas, not hitherto described, viz. carbonic acid, its examination will be postponed to a future occasion.

V. *Atmospheric air is diminished in volume by animal respiration.*—This may be shown by repeating a very simple experiment, originally contrived by Mayow. He confined a mouse in a small glass jar, and tied the jar over, quickly and firmly, with moistened bladder. The heat of the animal first expanded the air, and rendered the bladder convex outwards; but when the animal after death had become cold, the bladder exhibited a hollow surface, proving that the air within was diminished in its bulk.

The exact amount of the diminution may be shown, by confining a mouse, over water, in a graduated jar, furnished with a stop-cock, and containing common air. As the heat of the animal, however, would occasion the expulsion of part of the air, it is expedient, on first depressing the jar into water, to open the cock, through which a part of the air will escape: the cock is then to be shut, and the height of the water within to be accurately noted. At first, the level will be depressed, in consequence of the expansion of the air by the warmth of the animal; but, after its death, a considerable diminution will be observed.

VI. The weight of 100 cubic inches of atmospheric air, at 60° Fahrenheit and 30 inches barometer, is said by Mr. Kirwan to be 30.92 grains. Sir H. Davy states it, when under the same pressure, but at 55° Fahrenheit, to be 31.10 grains, from which may be deduced that, with the temperature and pressure assumed by Mr. Kirwan, 100 inches would weigh 30.78 grains. Under the same circumstances, Sir George Shuckburgh's experiments fix its weight at 30.5 grains; and this is probably the most correct determination.

SECTION V.

Hydrogen Gas.

THE most simple form, in which HYDROGEN has hitherto been obtained, is in that of a gas, or of union with caloric, and perhaps with electricity and light. From this combination we are not able to separate it, except by availing ourselves of the affinity of some other substance, in which case the hydrogen separates from the caloric, and forms, with the body which has been added, a new combination. Of its nature, we know but little; but as it has not yet been resolved into any more simple state, it is still arranged among elementary bodies. From the recent experiments of Sir H. Davy,

(which will be described under the article ammonia,) it appears not improbable that hydrogen is a metallic body.

The most important compound of hydrogen, and the only one which will be noticed at present, is that which it affords by union with the base of oxygen gas. It is on its affinity for this base that all the properties depend, which are illustrated by the following experiments. Much of the force of this attraction, it will appear probable from the sequel, depends on its being in a state of opposite electricity to oxygen; for, in common with all inflammable substances, it is naturally in a state of *positive* electricity.

I. *To procure hydrogen gas*, let sulphuric acid, previously diluted with five or six times its weight of water, be poured on iron filings; or on small iron nails; or (what is still better) pour sulphuric acid, diluted with eight parts of water, on zinc,* granulated by pouring it melted into cold water, and contained in a gas bottle or small retort. An effervescence will ensue, and the escaping gas may be collected in the usual manner.

II. This gas has the following properties:

1. *It remains permanent over water*, or is not absorbed in any notable proportion.

2. *It is inflammable*. This may be shown by the following experiments:

(a) Fill a small jar with the gas, and, holding it with the mouth downwards, bring the gas into contact with the flame of a candle. The air will take fire, and will burn silently with a lambent flame.

(b) Fill with this gas a bladder which is furnished with a stop-cock, and with a small pipe, of diameter less than that of a common tobacco pipe. Press the air out through the pipe, and, on presenting a lighted candle, the stream will take fire. If this apparatus cannot be procured, a very simple contrivance will answer the purpose: break off part of an eight-ounce vial, within an inch or two from the bottom, by setting fire to a string tied round it, and moistened with spirit of turpentine. The vial will then resemble a jar with an open neck at the top. Next bore a small hole through a cork that fits the neck of the vial, and insert in it part of a common tobacco pipe, which may be fixed into the neck of the bottle, by a cement of resin and bees-wax. Then fill the bottle with water, and hold it, with the thumb pressed down on the aperture of the pipe, while hydrogen gas is passed into it. When the bottle is full of gas, remove the thumb, press the bottle down into the water, and, on the approach of a candle, the stream of air from the pipe will take fire.

Persons, who are provided with the jars represented pl. ii. fig. 22, *a*, may screw to the cock a brass pipe with a small aperture. On pressing the jar, filled with hydrogen gas, into the water, and opening the cock, the gas will be forced out in a stream, which may be set on fire. On this principle are founded the artificial fire-

* Zinc may be purchased at the brass-founders or copper-smiths, under the name of speltre.

works without smell or smoke. They consist of pipes, having variously sized apertures, some of which have a rotatory motion: but their precise construction it is impossible to describe, without very tedious details.

(c) In a strong bottle, capable of holding about four ounces of water, mix equal parts of common air and hydrogen gas. On applying a lighted candle, the mixture will burn, not silently, as in experiment (a), but with a sudden and loud explosion. If a larger bottle be used, it should be wrapped round with a handkerchief, to prevent the glass from doing any injury, in case the bottle should be burst.*

(d) The same experiment may be repeated with oxygen gas, instead of atmospherical air; changing the proportions, and mixing only one part of oxygen gas with two of hydrogen. The report will be considerably louder. The bottle should be a very strong one, and should be wrapped round with cloth, to prevent an accident.

(e) The same experiment may be made over water, by means of the electric spark. Procure a strong tube, about three quarters of an inch diameter, and 12 inches long, closed at one end (plate ii. fig. 28). About a quarter or half an inch from the sealed end, let two small holes be drilled, opposite to each other, and into each of these let a brass conductor be cemented, so that the two points may be distant from each other, within the tube, about one 8th of an inch. An apparatus, serving the same purpose, and much more easily constructed, may be formed by hermetically sealing a piece of brass wire, or still better platina wire, into the end of a glass tube (fig. 29.) With this conductor, an interrupted circuit may be formed, by introducing into the tube a longer wire, one end of which terminates one 10th of an inch from the upper one, while the other extends beyond the aperture of the tube. (See fig. 84.) Into this tube, standing over water, pass about half a cubic inch of a mixture of hydrogen and oxygen gases; in the proportion of two measures of the former to one of the latter. Hold the tube firmly, and pass an electric spark through the mixed gases. For relieving the shock, which is sometimes considerable on firing, an ingenious contrivance of Sir H. Davy may be employed. It is described in the Philosophical Magazine, xxxi. 3. An immediate explosion will take place; after which the gases, if pure, and in the proper proportion, will be found to have disappeared entirely.

It has been ascertained by the recent experiments of Grotthuss, that a mixture of two measures of hydrogen gas with one of oxygen, cannot be inflamed by the electric spark, when expanded to 16 times its volume by diminished pressure; nor, when dilated by heat to only six times its volume. In the latter case, even a lighted taper does not kindle the mixture; but water is formed silently by a continued succession of electric sparks.†

It is rarely, however, that the gases can be used in such a state

* These experiments may also be made advantageously, by means of an apparatus sold under the name of the inflammable air-pistol.

† 82 An. de Chimie, 37.

of purity as to leave absolutely no residuum. To determine, indeed, the purity either of the oxygen or hydrogen gas employed, it is sometimes necessary so to adjust their proportions, that the whole mixture may not be condensed by firing. If, for example, we wish to know the purity of a quantity of oxygen gas, we are to use about three times its bulk of hydrogen. Let us suppose that 100 measures of oxygen are detonated with 300 of hydrogen gas, and that the total 400 is reduced by firing to 130; the diminution of volume will be 270. This number, divided by three, gives 90 for the quantity of oxygen; that is, the oxygen employed must have contained 10 *per cent.* of nitrogen, or of some foreign gas not condensable by hydrogen.

If atmospherical air be employed, a diminution, though not equal in amount, will be produced by the union of the hydrogen with the oxygen gas contained in the air; and if a sufficient quantity of hydrogen gas be employed, the whole of the atmospherical oxygen will thus be removed. On this principle is founded the EUDIOMETER OF VOLTA, which may be constructed, by graduating either of the tubes already described, into equal parts. If, in one of these tubes, we mix 300 parts of common air, and 200 of pure hydrogen gas, there will remain, after the explosion excited by passing an electric spark between the two wires, about 305 measures. There will, therefore, have been a diminution of 195 measures, of which pretty exactly one 3d may be estimated to be pure oxygen. In this instance, therefore, 65 of oxygen have been lost by 300 of air, or 21 and a fraction *per cent.*

The general rule for ascertaining the purity of air by hydrogen gas, may be stated as follows: Add to three measures of the air under examination, two measures of pure hydrogen gas; inflame the mixture by electricity; observe the diminution when the vessel has cooled; and, dividing its amount by three, we obtain pretty nearly the quantity of oxygen gas which has been condensed.

In the reverse process, *i. e.* in determining the purity of hydrogen gas, we mix it with more oxygen gas than is required for saturation. Suppose that to 100 of hydrogen gas we add 100 of oxygen, and that 80 measures remain after detonation. The diminution will have been 120 measures; and, of these, two thirds, or 80 measures, are hydrogen. Hence the inflammable gas, under examination, must contain 20 *per cent.* of some other gas, which is most probably nitrogen. In this way, we determine the proportions of hydrogen and nitrogen in any mixture composed of the two gases only.

(f) The diminution of hydrogen and oxygen gases, by the union of their bases, may be shown also by their slow combustion. Fill a tall jar with oxygen gas, and fill also, with hydrogen gas, a bladder furnished with a stop-cock, and with a long brass pipe bent like the letter S, and drawn out to a fine point (plate iv. fig. 41.) On pressing the bladder, a stream of gas will issue from the pipe, which may be set on fire, and brought cautiously under the tall inverted jar of oxygen gas. By this contrivance, the stream of hy-

drogen gas will be burnt in a confined portion of oxygen gas ; and, on continuing the combustion a sufficient length of time, the water will be seen to rise gradually within the jar. On the first impression of the heat, indeed, a quantity of gas will escape from the jar, which will render it difficult to ascertain what degree of absorption has actually taken place. But this loss may be prevented, by using a jar with a neck at the top, to which a compressed bladder is firmly tied. The expanded air, instead of escaping through the water, will now fill the bladder at the top ; and, when the experiment has closed, and the vessels have cooled, it may be ascertained, by pressing out the gas from the bladder, what quantity of oxygen gas has been consumed.

The same experiment may be more accurately and elegantly made, with the assistance of an apparatus, which I have described in the Philosophical Transactions for 1808. The description cannot be understood without the plate, which is there given, and which has been copied into the Philosophical Magazine, vol. xxxii. and Nicholson's Journal, vol. xxi. The fact may, also, be shown by substituting, for the bladder (*c*, fig. 41,) a small gazometer, containing a measured quantity of hydrogen gas. Let the bent pipe be screwed on the cock of the gazometer ; and over its open end, placed perpendicularly, invert a jar of oxygen gas. This jar must be provided at the top with a metallic conductor, screwed into a brass cap, as represented in fig. 41 ; which shows also the level of the water within the jar, attained by means of a syphon. After noting the height of the water within, let a rapid succession of electric sparks be passed between the two conductors ; and, on opening the cock at this instant, the stream of oxygen gas will be inflamed. The end of the pipe must then be so far depressed, that the cement of the brass cap may not be melted by the flame ; and the outer surface of the top of the vessel should be kept cool. When the gas is first lighted, the oxygen gas will be suddenly expanded ; but, presently, a rapid diminution will go on, till the water rises above the end of the pipe and extinguishes the flame. If pure oxygen gas be employed, it will be found, after the experiment, uninjured in its quality, and will support the combustion of burning bodies as well as before.

When the above experiment is made, with the substitution of common air for oxygen gas, a diminution takes place, but much less considerable, *viz.* not amounting to one 6th of the original bulk of the gas.

(*g*) When a stream of hydrogen gas is burned under a tube, 18 or 24 inches long, a musical sound is produced. The experiment may be made in the following manner :

Into a glass bottle are put iron filings and sulphuric acid, diluted with five or six parts of water ; and a cork is fitted into the neck, through which a glass tube is passed, having its upper extremity drawn out to a capillary bore.* By setting fire to the hydrogen

* The success of this experiment seems to me to depend greatly on the attention paid to employing a tube with a capillary bore ; at least, whatever may

gas,* which escapes from this extremity, a continued current or jet of flame is produced, which is allowed to pass into a tube either of glass, earthen-ware, or metal. If the tube be not too large, the flame becomes smaller as it is depressed; and when the tube covers the flame to a considerable depth, very clear sounds are produced. But, on the contrary, if the tube be too narrow, the flame will be extinguished; and, in proportion as the tube is enlarged, the sound diminishes: so that there is a certain limit at which it totally ceases. The same happens when the tube is too long. The sounds may be raised at pleasure, by either using tubes of various figures or dimensions, or made of different substances.†

(h) In a memoir lately read to the National Institute of France, M. Biot announces the important fact, that a mixture of hydrogen and oxygen gases may be made to explode by mechanical compression. A mixture of these two gases was introduced into a strong metallic syringe, furnished with a glass bottom, and a sudden stroke given to the piston. An extremely brilliant light appeared, accompanied with a loud detonation; and the glass bottom was forcibly driven out. The repetition of this experiment, it is obvious, must be attended with considerable difficulty and danger.‡

The combustion of hydrogen and oxygen gases is successfully applied to the purpose of exciting an intense heat by the blow-pipe. The peculiar construction of the apparatus cannot be understood without a plate, which may be seen in the *Annales de Chimie*, tom. xlv. or in the 14th volume of the Philosophical Magazine. It may be sufficient here to state, that the gases are contained each in a separate gas-holder; that they are expelled by the pressure of a column of water obtained by lengthening the pipe *b*, fig. 36; and that their mixture does not take place, till they nearly reach the aperture of the pipe, at the extremity of which they are inflamed. This last precaution is of considerable importance, because a violent and dangerous explosion would otherwise happen.

be the reason, the sound is, I think, less apparent in proportion to the larger diameter of the opening from which the inflamed gas is escaping. The fact itself has been denied by some, but I think incautiously. The reason of the sound taking place, appears to be owing to the continual vibration excited in the tube, by the perpetual conjunction of the hydrogen with the atmospheric oxygen, to constitute water; by which a partial vacuum is momentarily produced, and which is as rapidly filled up by the access of the external air. It is a singular circumstance attending this experiment, that although if we hold the tube *externally* by the hands, the vibration is not destroyed, and consequently the sounds continue; yet if we plunge another smaller tube within the upper opening of that in which the hydrogen is burning, the sound is instantly suspended. Another fact appears to be, that some tubes will not produce the sound at *either* extremity, and others only at *one*. Whatever this may depend on, it is not unreasonable to suppose, that its failure in the cases, in which the fact has been denied, may have arisen from using such *incompatible* tubes. C.

* The gas must not be inflamed, till it has been produced for some time, and has expelled all the common air of the bottle; otherwise an explosion will happen, and the bottle will be burst, with some danger to the operator.

† See Nicholson's Journal, 8vo. i. 129, and iv. 23.

‡ See Nicholson's Journal, xii. 212.

To guard the more effectually against this accident, it is advisable to affix a valve, opening outwards, in the pipe proceeding from each gas-holder, just before the junction of the two.*

3. *Hydrogen gas has an unpleasant smell.*†

4. *Though inflammable itself, it extinguishes burning bodies.*—Bring an inverted jar, filled with this gas, over the flame of a candle; and suddenly depress the jar, so that the lighted wick may be wholly surrounded by the gas. The candle will immediately be extinguished.

5. *It is fatal to animals.*—This may be shown by confining, in the gas, a mouse, or other small animal.‡

6. *It is considerably lighter than atmospherical air.*—One hundred cubic inches, the barometer being 30 inches, and the thermometer 60°, weigh, according to Kirwan, 2.613 grains; according to Lavoisier, 2.372 grains; and, according to Fourcroy, Vauquelin, and Seguin, 2.75 grains. The recent determination of Sir H. Davy§ is, that 100 cubic inches at 30.5 barometer, and 51° Fahrenheit, weigh 2.27 grains. Messrs. Biot and Arago assign to it the specific gravity of 0.07321.

(a) Let a jar, filled with this gas, stand, for a few seconds, with its open mouth upwards. On letting down a candle, the gas will now be found to have escaped.

(b) Place another jar of the gas inverted, or with its mouth downwards. The gas will now be found to remain a short time in the jar, being prevented from escaping upwards by the bottom and sides of the vessel.

* Such is the propensity to degrade, instead of fostering, the genius of America in scientific pursuits, amongst the philosophers of Europe, and especially those of Great Britain, that an acknowledgment can scarcely be there expected for any discovery or improvement in the new world! Who that knows the origin of what is called *Hadley's Quadrant*, (invented by Godfrey of this city,) and other inventions amongst us, can hesitate to admit the truth of this remark! Who would not imagine that the above mentioned combination of oxygen and hydrogen gases in combustion for the purpose of exciting an intense heat, was of European invention! A reference, however, to the *Philosophical Magazine*, 14th vol. as above quoted, will at once point at the real author of this important aid to chemical research. The paper there given by Tilloch, and the plate accompanying it, are extracted from Mr. Hare's paper read before the Chemical Society of Philadelphia, and published under its particular order many years ago. We have lately seen this apparatus slightly modified, puffed off with all the parade of science, in Great Britain, without the slightest acknowledgment to the just claims of Mr. Hare. The subsequent improvement Mr. Hare's blow-pipe received from Mr. Cloud of this city, and of Professor Silliman of Yale College, are equally overlooked, together with the extensive series of experiments entered into by the last named gentleman; and yet Professor Silliman has undoubtedly forestalled many of the brilliant experiments lately published by Dr. Clarke, in the annals of philosophy! I am happy to observe that Professor Silliman has ably vindicated Mr. Hare's claim, together with his own, from foreign invasion, in a late number of the *Eclectic Repertory of Philadelphia*. C.

† It may admit of some doubt whether *perfectly pure* hydrogen gas has any smell. Certainly the smell perceived, diminishes in proportion to the care we take in procuring it. C.

‡ It seems to be negatively fatal, by preventing the access of oxygen to the lungs, rather than from any positively deleterious property possessed by it. C.

§ *Phil. Trans.* 1810.

(c) Fill, with hydrogen gas, a bladder furnished with a stop-cock; and adapt to this a common tobacco pipe. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles. These bubbles, instead of falling to the ground, like those commonly blown by children, will rise rapidly into the air. On this property of hydrogen gas, is founded its application to the raising of balloons.

(d) The experiment may be varied by filling the bladder with a mixture of two parts of hydrogen gas and one of oxygen gas. Bubbles, blown with this mixture, take fire on the approach of a lighted candle, and detonate with a loud report. It is proper, however, not to set them on fire, till they are completely detached from the bowl of the pipe; otherwise the contents of the bladder will be exploded, with considerable danger to the operator.

In this place a property of hydrogen gas may be described, which it possesses in common with all other aëriform bodies, *viz.* a tendency to diffusion through any other elastic fluid, with which it may be brought into contact. Common or inelastic fluids are capable of remaining in contact with each other for a long time without admixture. Thus if we half fill a wine glass with spirit of wine tinged with any colouring ingredient, and then, by means of the dropping tube, fig. 15, introduce under it a quantity of water, the spirit floats on the water, and the two surfaces remain perfectly distinct, provided we carefully avoid agitation or unequal changes of temperature. But this is not the case with elastic fluids or gases, which, it has been discovered by Mr. Dalton,* penetrate each other, and become thoroughly mixed under all circumstances. The fact, with respect to hydrogen and oxygen gases, may be proved by a very simple apparatus.

Provide two glass vials, each of the capacity of about an ounce measure, and also a tube open at both ends, 10 inches long and one 20th inch bore. At each end, the tube is to be passed through a perforated cork, adapted to the necks of the vials. Fill one of the bottles with hydrogen gas, and the other with oxygen gas; place the latter on a table with its mouth upwards, and into this insert the tube secured by its cork. Then, holding the hydrogen bottle with its mouth downwards, fit it upon the cork at the top of the tube. The two bottles, thus connected, are to be suffered to remain in this perpendicular position. After standing two or three hours, separate the vials, and apply a lighted taper to their mouths, when it will almost certainly occasion an explosion in each. The hydrogen gas, though nearly 14 times lighter than the oxygen, must, therefore, have descended through the tube from the upper into the lower vial; and the oxygen gas, contrary to what might have been expected from its greater weight, must have ascended through the tube, and displaced the lighter hydrogen.

Experiments of this kind, it has been shown by Mr. Dalton, may be extended to all the other gases; but to prove the effect, tests of a different kind are necessary, which require a previous knowledge

* Manchester Memoirs, vol. i. new series.

of the properties of these gases. They tend to establish the conclusion, *that a lighter elastic fluid cannot remain upon a heavier without admixture.*

CHAPTER VI.

OF THE COMPOSITION, DECOMPOSITION, AND PROPERTIES OF WATER.

SECTION I.

Synthesis, or Composition, of Water.

IN chap. v. sect. v. it was stated, that oxygen and hydrogen gases, when fired over water, in the proper proportion, wholly disappear. To ascertain the nature of the product thus formed, however, the experiment must be repeated over mercury, in a similar manner, by means of the detonating tube (pl. ii. fig. 28). When this is done repeatedly, it is found that the product of the combustion is that well known fluid, water, which is thus proved to be composed of two elementary ingredients. The water, produced in this mode, is not, however, to be considered as a compound of the two gases, but only of their bases; for the light and caloric, which constituted the gases, escape, in considerable part, during the combustion. Every gas, it must be remembered, has at least two ingredients; the one, gravitating matter, which if separate, would probably exist in a solid or liquid form; the other, an extremely subtile fluid, termed caloric.* In the example before us, caloric (and perhaps electricity and light) is a common ingredient both of hydrogen and oxygen gases; but the two differ in having different bases. The basis of the one is called hydrogen, of the other oxygen; and water may, therefore, be affirmed to be a compound, not of hydrogen and oxygen *gases*, but of hydrogen and oxygen. This may be proved in two modes, by synthesis, *i. e.* by joining together

* I have before objected to the broad and sweeping clause so universally maintained, of gases necessarily depending on the combination of caloric, for their peculiar state of cohesion. This is a point by no means proved, by any thing satisfactory, at least to my mind; and if we take Dr. Henry's words in their real meaning, we shall be disposed to think that he is not himself satisfied of its truth. "Every gas," says he, "has at least two ingredients; the one, gravitating matter, which, if separate, would probably exist in a solid or liquid form," &c. but we must not in science admit mere probability for fact. Nay, indeed, I think it might be shewn, that even probability is against it; for all the assertions made on this point, appear to be solely founded upon experiments on the vapour of water, whose anomalies ought to prevent us from drawing any certain conclusions from it, as to other substances. C.

its two elementary ingredients ; and by analysis, in other words, by separating the constituent parts of water, and again exhibiting them in a distinct form.

I. Fill, with hydrogen gas, a bladder, furnished with a stop-cock and bent pipe (fig. 41, *e*), as in the last chapter. Then pour into a shallow earthen dish as much quicksilver as will about half fill it, and invert over this a glass bell, full of common air and perfectly dry. Expel the hydrogen gas through the pipe ; light the stream, and bring it under the glass bell, by raising this, and depressing it into the mercury, as soon as the inflamed gas is introduced. A portion of air will escape, at first, in consequence of the rarefaction. As the combustion continues, water will form, and will condense on the sides of the glass. This water is produced by the union of hydrogen with the oxygen contained in atmospheric air.

II. Those persons who are not possessed of a sufficient quantity of quicksilver to repeat the above experiment, may substitute the following : procure a large glass globe, capable of holding three or four quarts, and having two openings, opposite to each other, which may be drawn out for a short distance, like the neck of a retort. In-flame the stream of hydrogen gas, and introduce it into the centre of the globe. The rarefied and vitiated air will ascend through the aperture of the globe, and a constant supply of fresh air will be furnished from beneath. By this combustion, a quantity of water will be generated, which will be condensed on the inner surface of the vessel.

III. A simple and ingenious apparatus, less costly than any other, intended for the purpose of exhibiting the composition of water, is made by Mr. Cuthbertson of London. It is described and figured in Nicholson's *Journal*, 4to. vol. ii. p. 235 ; or in the *Philosophical Magazine*, vol. ii. p. 317* ; and also in plate iv. of this work, fig. 33 and 34.

In using this apparatus, however, instead of two glass receivers for the oxygen and hydrogen gases, standing inverted in a trough of water, I employ a couple of gazometers ; and with this alteration, the experiment is more easily managed, as well as more striking. The apparatus thus modified, consists of a large glass receiver or bottle *a* (pl. iv. fig. 34), with an opening at the bottom, into which is cemented a piece of brass, perforated with two holes. This brass piece is represented of a larger size in fig. 33 ; the aperture *a* conveying the oxygen gas, and *b* the hydrogen. Before commencing the experiment, the cock *c*, fig. 34, is screwed, by means of a collar-joint,† to the cock *b* of the gazometer, fig. 35, containing oxygen gas ; and to the cock *d*, by the same means, is affixed another gazometer, filled with hydrogen gas.

* In the same volume of the *Philosophical Magazine*, an interesting account may be consulted of the principal experiments on the composition of water, accompanied by neat and perspicuous engravings of the apparatus employed in them.

† See pl. v. fig. 47 ; and the corresponding description of the structure of this joint, in the explanation of the plates at the end of the work.

When it is intended to ascertain, accurately, the proportions of gases consumed and of water generated, the receiver *a* previously weighed, is first exhausted by an air pump, with which it may be connected by the female screw at *c*. The quantity of common air left in the receiver may be determined, by enclosing a gauge within it. If the additional expense be not deemed an objection, it is advisable, that after exhausting the receiver, oxygen gas should be admitted; its contents be exhausted a second time; and again renewed by fresh oxygen from the gazometer, the quantity of which may be observed by the graduated scale. The receiver being thus filled with oxygen gas, and accurately closed by a cock at *c*, a succession of sparks is to be passed, from the prime conductor of an electrical machine, between the platina knob of the bent wire within the receiver, and the point of the brass cone. While the sparks are transmitted, the cock *d* is to be opened. A stream of hydrogen gas will immediately issue from the aperture at the point of the cone, and will be inflamed by the electric spark, as represented fig. 33. The cock *e* is now to be opened, and the size of the flame of hydrogen gas moderated by partly shutting the cock *d*. As the volume of hydrogen gas consumed is double that of the oxygen; and the pipe, which transmits it, is of less diameter than that conveying the latter, about twice the pressure is required to expel the hydrogen. This is given, by lessening, in that proportion, the weight of the counterpoises (*ee*, fig. 35) of the gazometer containing hydrogen.

During the combustion, the moveable vessel *e*, fig. 35, of each gazometer descends; and, by observing the graduated scales, it will be seen that the hydrogen vessel falls twice as quick as that which holds the oxygen gas. It is necessary to keep the receiver *a* cool by means of wet cloths; and, when this is done, the water, which is produced will form into drops on the inside of the receiver, and collect at the bottom. At the conclusion of the experiment, the receiver is to be again weighed, and the increase noted. The quantity of gases consumed is to be observed, and their actual weight computed, by means of the table given in the Appendix. It will be found, that the weight of water produced is very nearly to that of the two gases expended; that is to say, for every hundred grains of water generated in the receiver, 88.3 grains of oxygen gas, and 11.7 grains of hydrogen gas (equal by measure to about 250 cubic inches of the former, and 500 of the latter), will have disappeared from the gazometers.

IV. By firing repeated portions of a mixture of oxygen and hydrogen gases over mercury, a sensible quantity of water will at last be produced.

Of the Proportion of the Elements of Water.

The precise determination of the proportions of oxygen and hydrogen in water, is a problem of great importance, not only on account of the fact itself, but of its influence on the general theory of chemistry. The results of almost all the earliest experiments

tended to prove, that water is a compound of 85 parts by weight of oxygen, and 15 of hydrogen. These numbers were afterwards corrected by Fourcroy, &c. to 85.7 of oxygen, and 14.3 of hydrogen; and in 1805 it was shown, by Humboldt and Gay Lussac, that the quantity of aqueous vapour, which gases always contain, being subtracted, it is a nearer approximation to truth to state the proportions at 87.4 and 12.6. It is admitted, on all hands, that water is formed by the union of two volumes of hydrogen gas, and one volume of oxygen gas. The greatest deviation from those numbers that has ever been contended for, is, that 100 measures of oxygen gas combine with 197 of hydrogen.* A difference, however, so difficult to ascertain, on account of its minuteness, may be neglected; and it may be safely assumed, that the general statement of one volume of oxygen to two of hydrogen is correct.

In determining the proportion of the elements of water, every thing will depend, therefore, on the precision with which the specific gravities of oxygen and hydrogen gases are ascertained. Taking the results of Biot and Arago as accurate (viz. 1.10359 for oxygen gas, and 0.07321 for hydrogen gas), the proportion of the elements of water must be as those numbers; and 100 grains must be composed of

Oxygen	88.286
Hydrogen	11.714

100.

These proportions scarcely differ from those assigned by Berzelius (81 An. Ch. 25), viz.

Oxygen . .	88.246	. .	750.77	. .	100
Hydrogen . .	11.754	. .	100.	. .	13.33
	<hr/>		<hr/>		<hr/>
	100.		850.77		113.33

If then we admit, with Mr. Dalton, that water is compounded of an atom of oxygen united with an atom of hydrogen, the relative weights of these atoms will be the same as the relative weights of oxygen and hydrogen, ascertained to form water, viz. for oxygen very nearly 7.5, and for hydrogen 1. Or if, with Dr. Wollaston

* The above statement on the proportion of the elements of water, will serve to show, how erroneously we often reason on presumed facts. Lavoisier, who drew many of his most important deductions from his experiments on water, determines most unequivocally the proportions of its elements to be 15 grains of hydrogen and 85 of oxygen. In his controversy with Mr. Kirwan, then, a firm supporter of the existence of phlogiston, he tells us, "one of the points of the modern doctrine, which appears the most firmly established, is the formation, the decomposition, and recomposition of water, and how can it be possible to doubt this, when we see by burning together 15 grains of inflammable gas and 85 of vital air, the product is *exactly* 100 grains of water," &c. (Essay on Phlogiston, &c. by R. Kirwan, p. 16.) yet we find it afterwards modified by succeeding philosophers, until we now find it to consist of about 88½ oxygen, and 11½ of hydrogen. If then such an error, on either side, existed in respect to the experiments of Lavoisier, how can we with propriety bow with humble deference to his doctrines! In the last sentence of the above paragraph, there is a looseness of expression (in "*may be neglected*") as connected with chemical facts, that I should scarcely have suspected in so accurate a philosopher as Dr. Henry.—C.

and others, we denote the atom of oxygen by 10, the atom of hydrogen will bear to 10 the same ratio that 1 bears to 7.5, viz. it will be denoted by 1.327. It should be observed, that Mr. Dalton has deduced the relative weight of the atom of oxygen to be to that of hydrogen as 7 to 1.* But this determination is founded on the results of Humboldt and Gay Lussac, and not on the more recent, and probably more correct ones of Biot and Arago.

It must be allowed, however, to be possible, though it is a much less probable view of the subject, that water may be a compound of two atoms of hydrogen with one of oxygen, which would double the weight of the atom of oxygen, and make it 15, the number assumed by Sir H. Davy. But hitherto we have no evidence that oxygen and hydrogen unite in any other proportion, than that constituting water; for whatever excess we employ of the one gas, or of the other, the surplus invariably remains without alteration. Now it admits of being proved to be consistent with mechanical principles, that the most energetic combination of any two elements is that, in which they are united particle to particle. Until, therefore, the contrary can be established, we may assume, with Mr. Dalton, that water is a binary compound of 1 atom of oxygen, and 1 atom of hydrogen: and, adding the weights of these atoms together ($7.5 + 1$), an atom of water will weigh 8.5. The same proportions, expressed by different numbers, as proposed by Dr. Wollaston, will make the relative weight of an atom of water $10.000 + 1.327 = 11.327$; the only difference in this way of stating the fact, being, that oxygen, instead of hydrogen, is expressed by the decimal unit.

SECTION II.

Analysis, or Decomposition, of Water.

THE analytic experiments on water are of two kinds: 1st, Such as present us with one of its ingredients only, in a separate and distinct form; 2dly, Such as present us with its two component principles, the hydrogen and oxygen, mixed together in the state of gas.

I. Of the first kind are the following:

1. Procure a gun-barrel, the breech of which has been removed, so as to form a tube open at each end. Fill this with iron wire, coiled up in a spiral form. To one end of the barrel adapt a small glass retort, partly filled with water, and to the other a bent glass tube, the open end of which terminates under the shelf of the pneumatic cistern. Let the barrel be placed horizontally (or rather with that end, to which the retort is fixed, a little elevated) in a furnace which has two openings in its body opposite to each other. (Pl. iv. fig. 40.) Light a fire in the furnace; and, when the gun-barrel has become red-hot, apply a lamp under the retort. The steam of the water will pass over the red-hot iron, and will be de-

* New System, p. 275.

composed. Its oxygen will unite with the iron; and its hydrogen will be obtained in the form of a gas. This is the readiest and cheapest mode of procuring hydrogen gas, when wanted in considerable quantity.

2. The same experiment may be repeated; substituting an earthen tube for a gun-barrel, and weighing the iron wire accurately, both before and after the experiment. The iron will be found to have gained weight very considerably; and, if attention be paid to the weight of the water that escapes decomposition, by an addition to the apparatus (fig. 40, *e*), and to the weight of the gases obtained, it will be found, that the weight gained by the iron, added to that of the hydrogen gas, will make up exactly the weight of the water that has disappeared. From experiments of this kind, conducted with the utmost attention to accuracy, as well as from synthetic experiments, it appears, that water is compounded of 85 *per cent.* oxygen, and 15 hydrogen, by weight, very nearly. But as hydrogen gas is eleven times lighter than common air, the proportion of gases, by volume, required to form water, is about two of hydrogen to one of oxygen gas. By the decomposition of every hundred grains of water, therefore, the iron employed gains 85 grains, and becomes oxidized; and 15 grains (equal to about 500 cubical inches) of hydrogen gas are obtained.

3. Water may be decomposed, in a similar apparatus, over charcoal instead of iron. The results, however, are different in this case, as will appear from a subsequent section.

4. Another mode of effecting the decomposition of water yet remains to be mentioned, in which not the hydrogen, but the oxygen, is obtained in a gaseous state. This is by the action of living vegetables; either entire, or by means of their leaves only. Fill a clear glass globe with water, and put into it a number of green leaves, from almost any tree or plant. A sprig or two of mint will answer the purpose perfectly well. Invert the glass, or place it, with its mouth downwards, in a vessel of water. Expose the whole apparatus to the direct light of the sun, which will then fall on the leaves surrounded by water. Bubbles of air will soon begin to form on the leaves, and will increase in size, till at last they rise to the top of the vessel. This process may be carried on as long as the vegetable continues healthy; and the gas, when examined, will prove to be oxygen gas, nearly pure. In this experiment, the hydrogen combines with the plant, to the nourishment and support of which it contributes, while the oxygen is set at liberty.

II. The processes, by which the elementary parts of water are separated from each other, and are both obtained in an aëriiform state as a mixture of hydrogen and oxygen gases, are dependent on the agency of electricity.

1. The first of these experiments requires for its performance the aid of a powerful electrical machine. This fact was the discovery of a society of Dutch chemists; and the principal circumstance, in the experiment, is the transmission of electrical shocks, through a confined portion of water. The apparatus employed, in

this experiment of Messrs. Dieman and Van Troostwyk, is a glass tube, about one 8th of an inch diameter, and 12 inches long, one of the ends of which is sealed hermetically, a gold wire being inserted at this end, and projecting about an inch and a half within the tube. About the distance of five 8ths of an inch from the extremity of this, another wire is to be fixed, which may extend to the open end of the tube. The tube is next to be filled with distilled water, and to be placed inverted in a vessel of the same. When thus disposed, electrical shocks are to be passed between the two ends of the wire, through the water; and, if these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and will ascend till the upper part of the wire is uncovered by the water. As soon as this is effected, the next shock that is passed will set fire to the air, and the water will rise again in the tube, a very small quantity of gas remaining. Now, as hydrogen and oxygen gases, in a state of admixture, are the only ones that are capable of being inflamed by the electric shock; and as there is nothing in the tube, besides water, that can afford them in this experiment, we may safely infer, that the evolved hydrogen and oxygen gases arise from decomposed water.

2. An improved apparatus, exhibiting the same experiment, with less trouble to the operator, has been invented by Mr. Cuthbertson, and may be seen described and figured in Dr. Pearson's paper in the Philosophical Transactions for 1797, or in Nicholson's Journal, vols. i. and ii. 4to.

3. The decomposition of water by galvanic electricity is a process singularly adapted to demonstrate the fact in a simple and elegant manner. The manner of conducting it, as well as the results, will be fully explained, when we come to treat of the general principles of electro-chemical science.

SECTION III.

*Properties and Effects of Water.**

I. *Water contains air.*—This may be shown by placing a glass vessel of water under the receiver of an air-pump. During the exhaustion of the receiver, bubbles of air will be seen to ascend very plentifully. Much air escapes also from water, during ebullition, and may be collected by a proper apparatus. The same fact may also be exhibited, by filling a barometer tube, about 32 inches long, sealed at one end with quicksilver, except about four inches, and the remainder with water. On inverting the open end of the tube in quicksilver, bubbles of air will be seen, in a short time, to rise from the water.

The kind of gas, extricated from the water of a spring at a con-

* Whenever, in the course of this work, water is mentioned as an agent in any chemical operation, pure distilled water is to be understood.

siderable distance from the surface, I have made the object of experiment.* From 100 cubic inches of the water, or about $3\frac{1}{2}$ wine pints, 4.76 cubic inches of gas were separated, of which 3.38 were carbonic acid gas, and 1.38 air of the same standard as that of the atmosphere.

It is probable that the proportion of gaseous contents differs in the water of different springs, for Mr. Dalton states the average of his experiments to be about 2 inches from 100 of water, and that the air expelled, after losing 5 or 10 per cent of carbonic acid by the action of lime water, consists of 38 per cent oxygen and 62 nitrogen.†

Every gas is absorbed by water, which has been deprived of all or the greatest part of its air by long boiling. The quantity, however, which water is capable of absorbing, varies considerably with respect to the different gases. Those, of which only a small proportion is absorbed, require violent and long continued agitation in contact with water. The following table has been drawn up by Mr. Dalton from the combined results of his own experiments and mine.

Water absorbs, at the mean pressure and temperature of the atmosphere,

Of carbonic acid gas	its own bulk.
sulphuretted hydrogen	do.
nitrous oxide	do.
olefiant gas	$\frac{1}{8}$.
oxygen gas	$\frac{1}{27}$.
nitrous gas	do.
carburetted hydrogen	do.
carbonic oxide	$\frac{1}{64}$.
azotic gas	do.
hydrogen gas	do.

The principle, on which gases are retained by water, is still a matter of controversy. By Berthollet and the generality of chemists, it is ascribed to the exertion of a chemical affinity between the gas and the water; but it has been suggested by Mr. Dalton (and as appears to me with greater probability) that the fact may be better explained on mechanical principle.‡ A statement of the argument may be seen in Mr. Dalton's "New System of Chemical Philosophy," or in two papers, which I have published in the eighth and ninth volumes of Nicholson's Journal.

II. *Water is contained in the air of the atmosphere, even during the driest weather.*—Expose to the air, in a shallow vessel, a little sub-carbonate of potash or common salt of tartar. In a few days it will have become moist, or *deliquated*. On the same principle, water

* Philosophical Transactions, 1803.

† New System p. 271.

‡ It is to be regretted Dr. H. did not introduce the arguments favourable to this opinion. Were it a mere mechanical principle which operated in this case, there seems very little reason why all the above mentioned gases should be so *unequally* absorbed, since it should, apparently, act on all alike. C.

exposed to the air, in a shallow vessel, disappears, being dissolved by the atmosphere. Saussure states the quantity of water in a cubic foot of air, charged with moisture at 65° of Fahrenheit, to be 11 grains. The quantity of water, that may be extracted from 100 cubical inches of air, at 57° Fahrenheit is 0.35 of a grain; but, according to Clement and Desormes, at 54° Fahrenheit, only 0.236 of a grain can be detached by exposure to muriate of lime. The experiments, both of these chemists and of Mr. Dalton, concur in proving, that at the same temperature equal bulks of different gases give up the same quantity of water to deliquescent salts. The portion of humidity, which they thus abandon, has been called *hygrometric water*. Whether they contain a still farther quantity in a state of more intimate union, and not separable by deliquescent substances, is still undetermined.

III. Several bodies absorb water from the atmosphere, which can scarcely be supposed to have an affinity for it, and again give it up, on the application of a gentle heat. Such are almost all substances in the state of powder; porous paper; and even the filings of metals. Some powders retain the moisture they have absorbed, till a considerable heat is applied.* The nature of this combination is not exactly understood.

There are two different theories of the state, in which water exists in the atmosphere and in other gases. By most writers, it has been considered as united to air by chemical affinity; and, when abstracted by other bodies, (as sulphuric acid, lime, and the whole class of deliquescent salts) the effect has been ascribed to the superior affinity of those bodies for water. Mr. Dalton first took a different view of the subject, viz. that the vapour of water, mixed with air, and other gases, differs in no respect from pure steam, and is subject to the same laws. It constitutes, indeed, in his opinion, a distinct and independent atmosphere, the elastic force of which forms, at different temperatures, different proportions of the elastic force of the whole; for example, at the temperature of 65° Fahrenheit, it gives to air $\frac{1}{30}$ of its elasticity. This theory appears to have much more probability, than that which explains the phenomena by chemical affinity; and it is supported, especially, by the absorption of caloric, which is ascertained to be of the same amount, in spontaneous as in forced evaporation.

Instruments for measuring the degree of moisture of the air are called *hygrometers*. They consist, for the most part, of some substance, such as a human hair or a fine slip of whalebone, which is elongated by a moist atmosphere, and shortened by a dry one. The extreme points are attained by placing it, first in air artificially dried, and then in air rendered as humid as possible. The degree of expansion or contraction is rendered more sensible by connecting it with an axis, which moves a circular index, like the finger of a clock. Mr. Leslie, by a slight modification of his differential thermometer, makes it serve the purpose of an hygrometer; for if one of the balls be covered with silk, and then moistened with wa-

* Berzelius, 79 An. Chim. 118.

ter, the rate of evaporation will be shown by the degree of cold produced, as indicated by the descent of the liquid in the opposite leg of the instrument. The drier the air, the quicker will be the evaporation, and the greater the effect in moving the liquid within the instrument.

IV. *Water enters into combination with various solid bodies, and entirely loses its fluid form.*—In many instances, it unites only in a definite proportion; and it is retained by so powerful an affinity, as not to be separated by a very high temperature. Such compounds are termed *hydrates*. The pure alkalis, potash, and soda, retain, for example, even after fusion, about $\frac{1}{3}$ their weight of water, which can only be separated by some body having a stronger affinity for the alkali. In all hydrates, at least one atom of water must be present, or it must be contained in them in such quantity, as to bear the proportion of at least 8.5 to the weight of the atom with which it is united. If, for example, the weight of the atom of potash be 48, as Sir H. Davy supposes, we cannot have a true chemical compound of water and potash, in which the former bears to the latter a less proportion than that of 8.5 to 48. And if, in any instance, water is obtained from a compound in a proportion less than that of the weight of the atom of water, to the weight of the atom of the body with which it is associated, we may take for granted that it is held mechanically and accidentally, and not as a true chemical constituent. Such appears to be the nature of the union of water with certain neutral salts (common salt for example) which contain only 1 or 2 per cent. of their weight of water.

V. *Water dissolves a great variety of solid bodies.*—The substances, on which it exerts this effect, are said to be soluble in water; and there are various degrees of solubility. See chap. i. and the table in the Appendix.

VI. *During the solution of bodies in water, a change of temperature ensues.*—In most instances, an absorption of caloric (in other words, a production of cold) is attendant on solution, as in the examples given in chap. iii. sect. 2. But, in other cases, caloric is evolved, or heat is produced. Thus, common salt of tartar, during solution in water, raises the temperature of its solvent; and caustic potash, in a state of dryness, does the same still more remarkably. Both carbonated and pure potash, however, when crystallized, observe the usual law, and absorb caloric during solution. Now as their difference, in the crystallized and uncrystallized state, depends chiefly on their containing in the former, but not in the latter, water chemically combined, we may infer, that the cold, produced during the solution of salts, is occasioned by the conversion of the water, which exists in these bodies, from a solid to a liquid form.

VII. *During the solution of salts in water, a quantity of air is disengaged.*—This air was partly contained mechanically in the salt, and partly in the water. That it does not arise entirely from the former source, is proved by varying the experiment in the following manner. Let an ounce or two of sulphate of soda be put into a vial, and pour on this as much water as will completely fill the bottle. The air contained in the pores of the salt will be thus

disengaged; but only a small portion of the salt will be dissolved, agreeably to the principle laid down, chap. ii. 7. Let the vial be shaken, and the whole of the salt will disappear; a fresh portion of air being liberated during solution. The air, that now appears, is extricated from the water, in consequence of the affinity between the water and the salt being stronger than that between the water and the air. It is, therefore, a case of single elective affinity.*

VIII. *During the solution of bodies, the bulk of water changes.*—Take a glass globe, furnished with a long narrow neck, (commonly termed a matras, see fig. 4,) and put into it an ounce or two of sulphate of soda. Then, add as much water as will fill the globe, and about three 4ths of the neck. This should be done with as little agitation as possible, in order that the salt may not dissolve, till required. Mark, by tying a little thread, or by a scratch with a file, the line where the water stands; and then agitate the matras. The salt will dissolve; air will be set at liberty; and, during the solution, the water will sink considerably below its level. The contraction of bulk is owing to the diminution of temperature; and, when the water has regained its former temperature, it will also be found, that its bulk is increased by the addition of salt. The Bishop of Landaff observed, that water exhibits a manifest augmentation of bulk, by dissolving only the two thousandth part of its weight of salt; a fact sufficiently decisive against that theory, which supposes pores in water capable of receiving saline bodies without an augmentation of volume.

IX. *Water has its solvent power increased, by diminishing the pressure of the atmosphere.*—Into a Florence flask, put half a pound of sulphate of soda; pour on it barely a pint of water, and apply heat so as to boil the water. The whole of the salt will be dissolved. Boil the solution for several minutes pretty strongly, so as to drive out the air; and cork the bottle tightly, immediately on its removal from the fire. To prevent more completely the admission of air, tie the cork over with bladder. As the vessel cools, an imperfect vacuum will be formed over the solution; for the steam, which arises during the ebullition, expels the air, and takes its place. The steam is condensed again, when the vessel cools. The solution, when perfectly cold, may be shaken without any effect ensuing, so long as the vessel is kept closely stopped; but, on removing the cork and shaking the vessel, the solution will immediately congeal, and heat will be produced.† This experiment, besides the principle which it is peculiarly intended to illustrate, exemplifies also the general rule laid down, chap. iii. sect. 2. vi. viz. that caloric is always evolved, during the transition of bodies from a fluid

* Does not the above fact tend to corroborate the opinion of gases being retained in water, by a chemical, and not a mechanical cause? It can scarcely be doubted, if the air above mentioned is extricated by the superior affinity of the salt to the water. C.

† The opinion above maintained is so conclusively overthrown by the experiments I have repeated for many years past to my class, on this very subject, that it is unnecessary to dwell upon it. The result of those experiments are detailed in the 6th vol. of the *Annals of Philosophy*, p. 101, to which the reader is referred. C.

to a solid state; and it furnishes a fact exactly the reverse of that in which cold is produced, or caloric absorbed, during the solution of salts.

X. It is unnecessary to add any thing to what has been already said in a former section, respecting the combination of caloric with water constituting steam; or to the history of the phenomena attending its conversion into ice; except that, during the latter change, its bulk is enlarged in the proportion of nine to eight, and that, in consequence of this expansion, water, during congelation, is capable of bursting the strongest iron vessels; and becomes specifically lighter. Hence, ice swims always on the surface of the water.*

It is remarkable, that this enlargement of the bulk of water begins long before its temperature has descended to the freezing point, viz. at about 40° Fahrenheit. Let a thermometer bulb, and part of its tube, having a wide bore, be filled with water, tinged with a little litmus, which may be introduced by the same means as those already directed for filling with quicksilver. Immerse the thermometer in water of the temperature of 40° ; and, when the included water may be supposed to have attained the same degree of heat, remove the instrument successively into water of the temperature of 36° and 32° . At each immersion, the water will rise in the tube. Bring its temperature again to 40° , and it will descend to the same point as before. Place it in water of 50° , and it will again be expanded. Precisely similar effects, therefore, appear to result, in these experiments, from two opposite causes; for the bulk of water is alike increased by reducing or raising its temperature. It is contended, however, by Mr. Dalton, that, in the apparent expansion by a lower temperature, there is a deception, arising from the contraction of the glass, which must lessen the capacity of the bulb, and force the water up the stem. The question is not yet decided; and is still contested by Mr. Dalton against the experiments of Count Rumford and of Dr. Hope. The former philosopher now contends, that water is of the greatest density at 36° of Fahrenheit, or 4° above its freezing point.†

* It might be said, that ice floats on the surface of *boiling* water: such is the extraordinary expansion, and consequent diminution of specific gravity, which it undergoes. It may admit of a question, whether the vessels which burst during frost, are broken by the conversion of the water into ice. I am rather disposed to consider the effect as taking place, during the passage of the water from the temperature of 40 to the freezing point: for it is generally the case, I believe, that the leaden pipes of our houses, are only burst in one small point, around which the metal is found to be gradually pushed out, so as to be at the edge of the opening not thicker than a piece of paper; but if the effect resulted during the conversion of the water into ice; as this is more extended and immediate in its change, so we ought to expect to find the pipe rent throughout its length. C.

† The experiments in favour of the expansion of water at a temperature below 40° , appear to me to be too strong, to permit a doubt of the fact. Some late and very ingenious experiments on this subject will be found in the *Annals of Philosophy* for May last, by Mr. G. O. Sym. Although perhaps the exact point of the greatest density of water, is not perfectly established; yet, whenever we are certified of this, would it not be the most appropriate degree from which to estimate the specific gravity of bodies? C.

CHAPTER VII.

ON THE CHEMICAL AGENCIES OF COMMON AND GALVANIC
ELECTRICITY.

THAT branch of natural science, which comprehends the phenomena of Galvanism, and the general principles under which they are arranged, is only of recent origin. It was not till the year 1791, that Galvani, an Italian philosopher, being engaged in a course of experiments on animal irritability, observed accidentally the contractions, which are excited in the limbs of frogs, by applying a conductor of electricity between a nerve and a muscle. The theory which he framed to account for this phenomenon was, that the different parts of an animal are in opposite states of electricity, and the effect of the metal is merely to restore the equilibrium. The analogy, however, was afterwards shown to be without foundation, by Volta, who excited similar contractions by making a connection between two parts of a nerve, between two muscles, or between two parts of the same muscle; but to produce the effect, two different metals were found to be essential. Hence he was led to infer that, by the contact of different metals, a small quantity of electricity is excited; and to the agency of this electricity, first upon the nerves, and through their mediation on the muscles, he ascribed the phenomena in question.

Several years elapsed, during which the action of galvanic electricity on the animal body, and the discussion of its cause, occupied the attention of philosophers. Early in 1800, the subject took a new turn, in consequence of the discovery by Signor Volta of the Galvanic Pile;* a discovery which has furnished us with new and important instruments of analysis, capable, if any such there are, of leading to a knowledge of the true elements of bodies. From this period, discoveries have multiplied with a rapidity and to an extent, which surpass any thing before known in the history of science; and the facts are now become so numerous, that an arrangement and classification of them seem to be preferable to an historical detail in the order of time. The method, which appears to me best calculated to give a distinct view of the subject, is to describe,

I. The construction of galvanic apparatus, and the circumstances essential to the excitement of this modification of electricity:

II. The facts, which establish its identity with the electricity excited by ordinary processes:

III. The agency of the electric or galvanic fluid in producing chemical changes:

IV. The theory, by which these changes, in the present state of our knowledge, are best explained: And

* Philosophical Transactions, 1800, or Philosophical Magazine, vii. 289.

V. The hypotheses, which have been framed to account for the origin of the electricity, excited by galvanic arrangements.

SECTION I.

Of the Construction of Galvanic Arrangements.

FOR the execution of ordinary electricity, it is well known that a class of substances are required, called *electrics*, by the friction of which the electric fluid is accumulated, and from which it may be collected by a different class of bodies, termed *non-electrics* or *conductors*. When friction, for example, is applied to the glass cylinder or plate of an electrical machine, that part of the glass, which is in contact with the rubber, attracts the electric fluid from it, as well as from all other conducting bodies, with which the rubber is connected. The glass regaining instantly its natural state, repels the electric fluid, which is received by the prime conductor, placed for that purpose. All then that is effected, by the action of the machine, is a disturbance of the natural quantity of electricity in bodies, or a transfer of it from some to others, in consequence of which, while the latter acquire a redundance, the former become proportionally deficient in their quantity of electricity.

The conditions necessary to the excitement of galvanic electricity are altogether different; for the class of bodies, termed *electrics*, have now no longer any share in the phenomena. All that is required is the simple contact of different conducting bodies with each other. Conductors of electricity have been divided into *perfect* and *imperfect*, the former comprehending the metals, plumbago and charcoal, the mineral acids, and saline solutions; the latter, or *imperfect*, alcohol and ether, sulphur, oils, resins, metallic oxides, and compounds of chlorine.

The least complicated galvanic arrangement is termed a **SIMPLE GALVANIC CIRCLE**. It consists of three conductors, two of which must be of the one class, and one of the other class. In the following Tables, constructed by Sir H. Davy, some different simple circles are arranged in the order of their powers, the most energetic occupying the highest place.

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

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

Solution of sulphur and potash, of potash, of soda.	Copper, Silver, Lead, Tin, Zinc, Other Metals, Charcoal.	Nitric acid, Sulphuric acid, Muriatic acid, Any solutions containing acid.
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In explanation of these Tables, Sir H. Davy observes, that in all cases when the fluid menstrea afford oxygen, those metals which have the strongest attraction for oxygen, are those which form the positive pole. But when the fluid menstrea afford sulphur to the metals, the metal which, under the existing circumstances, has the strongest attraction for sulphur, determines the positive pole. Thus, in a series of copper and iron plates, introduced into a porcelain trough, the cells of which are filled with water or with acid solutions, the iron is positive and the copper negative; but when the cells are filled with solution of sulphuret of potash, the copper is positive and the iron negative. When one metal only is concerned, the surface opposite the acid is negative, and that in contact with solution of alkali and sulphur, or of alkali, is negative.*

The powers of simple galvanic circles are but feeble; but they may be made sufficiently apparent by the following experiments.

1. When a piece of zinc is laid upon the tongue, and a piece of silver under it, no sensation is excited, so long as the metals are kept apart; but, on bringing them into contact, a metallic taste is distinctly perceived. In this case we have an example of the arrangement of two perfect conductors (the metals) with one imperfect one (the tongue, or rather the fluids which it contains). The metallic taste arises, in all probability, from the excitement of a small quantity of electricity by the contact of the metals, and its action on the nerves of the tongue.†

2. A piece of zinc, immersed under water which is freely exposed to the atmosphere, oxidizes very slowly; but when placed in the same situation, in contact with a piece of silver, its oxidation is much more rapid. By immersing iron and silver (also in contact with each other) under diluted muriatic acid, the action of the acid upon the iron is considerably increased; and hydrogen gas is evolved from the water, not only where it is in contact with the iron, but where it touches the silver. These facts explain, why, in the sheathing of ships, it is necessary to use bolts of the same metal which forms the plates; for if two different metals be employed,

* El. of Chem. Phil. p. 148

† It rather depends, I should apprehend, on the small quantity of oxyd formed, which being soluble in the saliva, imparts the metallic taste of the solution. G.

they both oxidate or rust very speedily, in consequence of their forming with the water of the ocean, a simple galvanic circle.*

Of compound Galvanic Circles or Batteries.

Galvanic batteries are formed by multiplying those arrangements, which compose simple circles. Thus if plates of zinc and of silver, and pieces of woollen cloth of the same size as the plates and moistened with water, be piled upon each other (fig. 77, pl ix), in the order of zinc, silver, cloth; zinc, silver, cloth; and so on, for twenty or more repetitions, we obtain a galvanic battery termed, from its discoverer, the *Pile of Volta*. The power of such a combination is sufficient to give a smart shock, as may be felt by grasping in the hands, which should be previously moistened, two metallic rods, and touching with these the upper and lower extremities of the pile. The shock may be renewed at pleasure; until, after a few hours, the activity of the pile begins to abate, and finally ceases altogether.

The metals, composing a galvanic battery, may be more conveniently arranged in the form of a trough, a happy invention of Mr. Cruickshank. In a long and narrow wooden trough, made of baked wood, grooves are cut, opposite to and at the distance of between $\frac{1}{3}$ and $\frac{2}{3}$ of an inch from each other; and into these are let down, and secured by cement, square plates of zinc and copper, previously united together by soldering. (See figs. 37 and 78.) The space, therefore, between each pair of plates, forms a cell for the purpose of containing the liquid, by which the combination is to be made active. The advantage of this contrivance, over the pile, is partly that it is much more easily put in order; but, besides this, it is a more efficient instrument. When constructed in the way which has been described, it affords an example of a galvanic combination of the *first kind*, formed by two perfect and one imperfect conductor. But it admits of being modified, by cementing, into the grooves, plates of one metal only, and filling the cells, alternately, with two different liquids, as diluted nitric acid and solution of sulphuret of potash. In this case, we have a battery of the *second order*, formed by the repetition of one perfect and two imperfect conductors. For all purposes of experiment, the first kind of arrangement is universally preferred.

Another modification of the apparatus, which may be called the *Chain of Cups*, was proposed by Volta at the same time that he communicated his invention of the Pile; and from the recent ex-

* The same explanation will probably account for the deterioration of watches and time pieces, the pivots of whose wheels, lubricated with oil, play in sockets of another metal;—hence then all the requisites of galvanic action are present; and an oxydation of the most oxydable must ensue. This can only be remedied, by causing the pivots of the wheels to play in sockets of the *same* metal: Hence probably the superiority of such watches, whose pivots play in rubies, &c. where galvanic action does not take place, rather than from any greater excellence in point of workmanship.—C.

periments of Mr. Children,* it appears to be a very useful and powerful one. It consists of a row of glasses (see fig. 75), such as wine glasses or small tumblers, for the purpose of containing any fluid that may be selected. Into each of these glasses is plunged a plate of zinc and another of copper, each not less than an inch square, which are not to touch each other. The plates of different cups are connected by metallic wires or arcs, in such a manner that the zinc of the first cup communicates with the copper of the second; the zinc of the second with the copper of the third; and so on through the whole row. The shock is felt on dipping the fingers of one hand into the fluid of the first cup, and those of the other hand into the last of the series. The superiority of this arrangement consists in both surfaces of each metallic plate being exposed to the action of the liquid; whereas, by soldering the plates together, one of the surfaces of each is protected from the liquid, and contributes nothing to the effect. The common trough has lately been made to combine this advantage, by dividing it into cells, not by plates of metal but by partitions of glass. Into each of these cells, filled with the proper liquid, a plate of each metal is introduced, but not so as to touch each other. A communication is then made, by a metallic arc, between the zinc plate of each cell and the copper one of the next, precisely as in the chain of cups. More lately the troughs themselves have been made of earthen ware, and the partitions of the same material; the apparatus being completed, in other respects, in the manner already described.

The size of the plates has been varied from one or two inches to several feet. For ordinary purposes, plates of two inches square are sufficient; but for the repetition of Mr. Davy's experiments, not less than 100 pairs of plates, each four inches square, are required.† The enlargement of the size of the troughs, so as to contain this number, would be extremely inconvenient; and we may therefore combine the power of several troughs, by uniting the zinc end of the one with the copper end of the other, by the intervention of a metallic wire, or by an arc of silver or zinc.

It may be sufficient to add, in general terms, that every combination, which is capable of forming a simple galvanic circle, may, by sufficient repetition, be made to compose a battery. The combinations, also, which are most active in simple circles, are observed to be most efficient in compound ones. The foregoing tables of Mr. Davy express, therefore, the powers of compound as well as of simple arrangements.

To construct a battery of the first order, it is essential that a fluid be employed, which exerts a chemical action upon one of the metals. Pure water, entirely deprived of air, appears to be inefficient. In general, indeed, the galvanic effect is, within certain limits, proportional to the rapidity with which the more oxidable

* Philosophical Transactions, 1809, page 32.

† Some useful information respecting the number and size of plates, adapted to different purposes, is given by Mr. Singer in Nicholson's Journal, vol. xxiv. page 174.

metal is acted upon by the intervening fluid. The fluid generally used is nitric acid, diluted with 20 or 30 times its weight of water. Mr. Children recommends a mixture of three parts fuming nitrous acid, and one sulphuric, diluted with thirty parts of water. Directions, also, respecting the best kind and density of acids, for producing galvanic electricity, are given by Mr. Singer. From his experiments it appears, that acid of different densities is required for different purposes. The best wire melting charge is formed with 10 gallons of water, five pounds of nitric acid, and half a pound of muriatic acid.

The power of the apparatus has been found to be increased, when insulated by non-conductors; and when surrounded by an atmosphere of oxygen gas; not sufficiently, however, to make it necessary to resort to either of these expedients in ordinary cases. Oxygen gas disappears in this process, when carried on under a receiver; and, after all the oxygen is absorbed, the effect ceases, and is renewed by introducing a fresh portion.* When the cells are filled with diluted nitric acid, the apparatus continues active, even under the exhausted receiver of an air-pump, or in an atmosphere of carbonic acid or nitrogen gases. But if the cells be filled with water only, all action is suspended, by placing it under any of these circumstances. Hence it appears that the oxidation of one or both of the metals, composing the trough, is essential to the excitement of galvanic electricity.

SECTION II.

On the mutual Relation of Electricity and Galvanism.

Is the influence, it may now be inquired, which is called into action in a way so different from that employed for the excitation of ordinary electricity, identical with it or of a different kind? This question will be decided by examining whether any of those phenomena, which are occasioned by the agency of the electric fluid, are produced also by that of galvanism; and we shall find the following striking resemblances.

1. The sensation, produced by the galvanic shock, is extremely similar to that which is excited by the discharge of a Leyden jar. Both influences, also, are propagated through a number of persons, without any perceptible interval of time.

2. Those bodies, which are conductors of electricity, are also conductors of the galvanic fluid, as the metals, charcoal, and a variety of liquids. Again, it is not transmitted by glass, sulphur, and the whole class of electrics, which do not convey ordinary electrici-

* Hence it happens that a small Voltaic pile, under a large tumbler or bell glass, standing in water will serve as a very good eudiometer. The water rises in the glass as the oxygen is removed. The process is however too slow for common employment.—C.

ty. Among liquids, those only are conductors of electricity and galvanism, which contain oxygen as one of their elements.*

3. The galvanic fluid passes through air and certain other non-conductors, in the form of sparks; accompanied with a snap or report; and, like the electric fluid, it may be made to inflame gunpowder, phosphorus, and mixtures of hydrogen and oxygen gases. It has lately been found, also, by Mr. Children, that in the Voltaic apparatus there is, what is called in electricity, a *striking distance*. With a power of 1250 pairs of four inch plates, he found this distance to be one 50th of an inch, the thickness of a plate of air, through which the galvanic discharge is able to pass in the form of a spark. Increasing the number of plates, the striking distance will be greater; and the reverse when it is diminished. It is also increased by rarefying the air, through which the spark is transmitted.

4. The Voltaic apparatus is capable of communicating a charge to a Leyden jar, or even to a battery. If the zinc end of a pile (whether it be uppermost or the contrary) be made to communicate with the inside of a jar, it is charged positively. If circumstances be reversed, and the copper end be similarly connected, the jar is charged negatively.† The shocks do not differ from those of a jar or battery, charged to the same intensity by a common electrical machine.

5. Galvanism, even when excited by a single galvanic circle only (such as a piece of zinc, a similar one of copper, and a piece of cloth moistened with a solution of muriate of ammonia), distinctly affects the gold leaf of the condensing electrometer. If the zinc end be uppermost, and be connected directly with the instrument, the electricity indicated is positive; if the pin of the electrometer touch the copper, the electricity is negative. A pile consisting of sixty combinations produces the effect still more remarkably.‡

6. The chemical changes produced by galvanic and common electricity, so far as they have hitherto been examined, are precisely similar. These will form the subject of the following section.

SECTION III.

On the Chemical Agencies of Electricity and Galvanism.

THE effects of the electric or galvanic fluids, in producing chemical decomposition, cannot be described, without introducing to the reader the names of several substances, with which, in the pre-

* Cruickshank, in Nicholson's 4to. Journal, iv. 258.

† Cuthbertson's Practical Electricity and Galvanism, page 261. Volta, in Nicholson's Journal, 8vo. i. 140. Van Marum, in Philosophical Magazine, xii. 162.

‡ Nicholson, 8vo. i. 139, and ii. 281; Cuthbertson, page 264.

sent state of his knowledge, he may be supposed to be unacquainted. This difficulty is unavoidable; for it is impossible to explain the general laws of electro-chemical action, without a variety of particular instances. In general, however, it will be found that a minute acquaintance with the bodies, which are brought in illustration, is by no means essential; and that it is sufficient to consider them as composed simply of two ingredients, which are in opposite electrical states, and are subject to the laws of electrical attraction and repulsion.

The most simple chemical effect, produced alike by the agency of electricity and galvanism, is the *ignition* and *fusion* of *metals*. When a piece of watch-pendulum wire is placed in the circuit of a common electrical battery, containing not less than three or four square feet of coating, at the moment of the discharge the wire becomes red-hot; but continues so only for a few seconds, no longer, indeed, than if it had been ignited in any other way.* The same effect may be produced by making a piece of wire the medium of communication between the opposite extremities of a galvanic trough; but, in this case, the heat continues sensibly longer, than when it is excited by an electrical explosion. Indeed a platina wire may be kept ignited *in vacuo*, for an unlimited time, by Voltaic electricity.† Water, surrounding a wire so placed, may be made to boil briskly.

When the power of an electrical battery is increased, metallic wires, by transmitting the discharge through them, may be melted and dispersed in the form of smoke, or of an impalpable powder lighter than air. The galvanic discharge, also, is capable of fusing metallic wires; but being less violent, it does not scatter their particles to a distance. Even wire from the most infusible of the metals, platina, acquires a white heat, and melts into globules.

With a still more powerful electrical battery (one for example containing about 18 square feet) metallic wires are not only melted, but undergo absolute *combustion*. Lead and tin wire emit a yellow light, and copper and silver a green one. If the experiment be made on wire confined in a glass receiver, which contains a measured quantity of air, the bulk of the air, and its proportion of oxygen, are both found to be diminished.‡ The metals are converted into oxides of different colours; lead, tin, and zinc, into white oxides; platina, gold, silver, and copper, into oxides of a dark colour. The experiment may be pleasingly varied by passing the discharge through wires, stretched over panes of glass or sheets of paper, at a small distance from their surface. The metallic oxide which is produced is forcibly driven into the glass or paper;

* On the quantity of coated surface required for igniting different lengths of wire, the reader may consult Mr. Cuthbertson's book, page 161, &c.

† From whence are we to derive the heat and light apparent in this case, by any theory of combustion or ignition hitherto promulgated? C.

‡ Cuthbertson, page 199.

and produces beautiful figures, varying in colour with the metal employed.*

The combustion of metals may be effected, also, by galvanic electricity; but for this purpose the form of very thin leaves is preferable to that of wire. The plates, composing the galvanic trough, should, for this purpose, be not less than four inches square, the larger, indeed, the better; and several troughs should be joined together, so as to form an aggregate of not less than 100 or 150 pairs of plates. The galvanic influence is to be conveyed by wires brought from each extremity of the arrangement, and placed in contact with the opposite surfaces of the leaf. For the protection of the fingers, the wires should be inclosed in glass tubes. When thus exposed, the metals burn, or rather deflagrate, with great brilliancy.

Gold emits a very vivid white light, inclining a little to blue, and leaves an oxide, whose colour verges towards that of mahogany. Copper presents similar phenomena.

The flame of silver is a vivid green, somewhat like that of a pale emerald, and the light is more intense than that of gold. Lead gives a vivid light of a dilute blueish purple. Tin a light similar to that of gold; and zinc a blueish white flame fringed with red.† In all these cases, provided the power be sufficiently strong, the deflagration is kept up, for some time, without intermission.

But a much more remarkable action is exerted by the electric and galvanic fluids, in disuniting the elements of several combinations. One of the first discoveries of the chemical agency of the pile was its power of decomposing water. Two pieces of any metallic wire are thrust through separate corks, which are fitted into the open ends of a glass tube in such a way, that the extremities of the wires, when the corks are in their places, may not be in contact, but may be at the distance from each other of about a quarter of an inch (see fig. 77, *a*). If the parts of the wire, which project from without the tube, be made to communicate, the one with the zinc or positive end, and the other with the copper or negative end, of a galvanic battery, a remarkable appearance takes place. The wire, connected with the zinc or positive end of the pile or trough, where it is in contact with the water, if of an oxidable metal, is rapidly oxidized; while from the negative wire a stream of small bubbles of gas arises. But if the wires employed be of a metal, which is not susceptible of oxidation, such as gold or platina, gas is then extricated from both wires, and, by a simple contrivance, may be separately collected. The apparatus for this purpose is shown by fig. 76, where the wires *p* and *n*, instead of being introduced into a straight tube, are inclosed in a syphon, and terminate before they reach the end, in which a small hole is to be ground. When a stream of galvanic electricity is made to act upon water thus con-

* Cuthbertson, page 226, and Wilkinson's Elements of Galvanism, in the 9th plate of which these appearances are represented.

† Philosophical Magazine, xi. 284, and xv. 96.

finer, oxygen gas is found, at the close of the experiment, in the leg connected with the positive end of the battery, and hydrogen gas in that connected with the negative end; and in the proportions which, by their union, compose water. At an early period of the inquiry, it was found, however, by Mr. Cruickshank, that the water surrounding the positive wire became impregnated with a little acid; and that around the negative wire with a little alkali. If instead of water, we employ a metallic solution, the metal is revived round the negative wire *n*, and no hydrogen gas is liberated.

The gases constituting water, it was afterwards discovered by Sir H. Davy, may be separately produced from two quantities of water, not immediately in contact with each other. The fact is of peculiar importance, from its resemblance to other more recent ones, which have led that distinguished philosopher to the discovery of the general laws of electro-chemical action. Two glass tubes (*p* and *n*, pl. ix. fig. 79), about one third of an inch diameter and four inches long, having each a piece of gold wire sealed hermetically into one end and the other end open, were filled with distilled water, and placed inverted in separate glasses, filled, also, with that fluid. The two glasses, *a* and *b*, were made to communicate, either by dipping the fingers of the right hand into one glass, and those of the left into the other, or by interposing fresh animal muscle, or a living vegetable, or even moistened thread, as shown at *c*. The gold wires, projecting from the sealed ends of these tubes, were then connected, the one with the positive, the other with the negative end of the trough. Gas was immediately evolved from both wires. At the close of the experiment, in the tube *p* oxygen gas was found; in the negative tube *n* hydrogen. The proportions by measure were, as nearly as possible, those which result from the decomposition of water, viz. two of hydrogen to one of oxygen gas.* Now if these gases arose, as they necessarily must, from the decomposition of the same portion of water, that portion of water must have been contained either in the tube *p* or in the tube *n*. In the former case, the hydrogen gas, found after the process in *n*, must have passed invisibly from *p* to *n*, through the intermediate substance *c*. Or, if the water was decomposed in *n*, then the reverse process must have happened with respect to the oxygen; and it must have been transmitted, in a like imperceptible manner, from *n* to *p*. Facts of this kind, evincing the transference of the elements of a combination to a considerable distance, through intervening substances, and in a form that escapes the cognizance of our senses, however astonishing, it will appear from the sequel, are sufficiently numerous and well established.

Different chemical compounds require, for the disunion of their elements, galvanic arrangements of various powers and intensities. The decomposition of water is easily effected by a series of fifty pairs of plates, each one or two inches square.† But for those which

* Nicholson's Journal, 4to. iv. 276.

† An infinitely less power than this is sufficient, although the effect is proportionally small. I have frequently decomposed water with six or eight plates of only about one square inch. C.

remain to be described, instruments of much greater power are necessary.

The apparatus, employed in the masterly experiments of Sir H. Davy, which have laid the groundwork of this new field of science, was extremely simple. In cases, where liquid substances were operated upon, he employed occasionally the agate cups *p* and *n*, fig. 80, each of which was capable of holding about sixty grains of water. They were connected together, as shown in the figure at *a*, by the fibres of a peculiar flexible mineral called amianthus; and into each was inserted a platina wire; the bent extremity of which is seen, in each figure, projecting above the cup. When the vessels were in actual use, the wire of *p* was connected with the zinc or positive end of a powerful galvanic series; and that of *n* with the copper or negative extremity. For the agate cups two hollow gold cones were occasionally substituted (*p* and *n*, fig. 81), the wire projecting from *p* being connected with the positive, and that from *n* with the negative end of a trough or series of troughs. Solid bodies were submitted to the galvanic influence, either by immersing small pieces of them in the gold cones; or, at other times, by making the cups themselves of the substance intended to be decomposed. Or if it was desirable to preserve them from contact with water, they were laid on a small insulated dish of platina, with the inferior surface of which, immediately under the substance used, a wire from one end of the battery was connected, while the substance itself was made to communicate by another wire, with the opposite extremity of the apparatus.

When the gold cones were both filled with a solution of sulphate of potash (a salt composed of potash and sulphuric acid), after exposure, during a sufficient time, to a powerful galvanic arrangement, pure potash was found in the negative cone *n*, and sulphuric acid in the positive cone *p*. The decomposition was even quite complete; for the liquid in *n* contained no acid, and that in *p* no alkali.

The experiment was repeated with several other neutral salts;* and with the invariable result, that the acid collected in the positive cone, and the alkali in the negative one. Strong solutions, or those in which the salt bore a considerable proportion to the water, were more rapidly acted upon than weak ones. Metallic salts were, also, decomposed. The acid appeared, as before, in the positive cone, and the metal was deposited, sometimes with a little oxide, in the negative one.

Salts, which are either insoluble, or very sparingly soluble, in water, had their elements disunited in the following manner. Cups were constructed of them, precisely resembling the gold cones, which, as the salts were hard and compact in their texture, was easily effected. These, after being filled with water, were connected, by platina wires, with the opposite ends of a galvanic battery,

* Minute directions for exhibiting the transfer of acid and alkali, by means of a power not exceeding thirty pairs of two inch plates, are given by Mr. Singer. (Nicholson's Journal, xxiv. 178.)

the vessels themselves, communicating as before, by means of moistened amianthus. At the conclusion of the experiment, sulphuric acid (when the cups were made of sulphate of lime) was found in the positive cup, and lime water in the negative one. Sulphate of strontites, fluato of lime, and sulphate of barytes were decomposed, though less easily, by the same expedient. In all these cases the acid element was found at the positive side, and the earthy one at the negative side of the arrangement.

These facts evidently point out a transference of the elements of combinations from one electrified vessel or surface to another differently electrified. But the principle is made much more apparent by a little variation of the experiment. Thus, if solution of sulphate of potash be electrified in the positive cone *p*, water alone being contained in *n*, after a sufficient continuance of the electrical action *p* will be found to contain diluted sulphuric acid; and the potash will be discovered in the water of *n*. The alkali must necessarily, therefore, have passed, in an imperceptible form, along the connecting amianthus from the vessel *p* to the vessel *n*. Reversing the experiment, and filling *n* with solution of sulphate of potash, the alkali remains in this cone, and the acid is transferred to the opposite side *p*. In one experiment, in which nitrate of silver was placed in the positive cup, and pure water in the negative one, the whole of the connecting amianthus was covered with revived silver.

In the farther prosecution of the inquiry, Sir H. Davy succeeded in discovering a still more extraordinary series of facts. When an intermediate vessel (*i*, fig. 82) was placed between the positive and negative cups *p* and *n*, and was connected with both of them by moistened amianthus, it was found that acids may actually be made to pass from *n* to *p*, through the intermediate solution in *i*, without combining with it. Thus, solution of sulphate of potash being put into the negative cup *n*, solution of pure ammonia into *i*, and pure water into *p*, in half an hour sulphuric acid was found in the water of the positive cup, to have reached which it must have been transferred from *n* through the intermediate solution of ammonia. Muriatic acid, also, from muriate of soda, and nitric acid from nitrate of potash, were transferred from the negative to the positive side through an interposed solution of alkali. And contrariwise, alkalis and metallic oxides were transmitted from the positive to the negative side, through intervening solutions of acids.

It is necessary, however, that the solution, contained in the intermediate vessel *i*, should not be capable of forming an insoluble compound with the substance intended to be transmitted through it. Thus sulphuric acid, in its passage from sulphate of potash in the negative cup, through the vessel *i* containing a solution of pure barytes, is detained by the barytes, and falls down in the state of an insoluble compound with that earth.

Bodies, the composition of which is considerably more complicated, are, also, decomposed by galvanic electricity. Thus from certain minerals, containing acid and alkaline matter in only very minute proportion, these ingredients are separately developed. Ba-

salt, for example, (a kind of stone which, in 100 grains, contains only $3\frac{1}{2}$ grains of soda and half a grain of muriatic acid,) gave, at the end of ten hours, evident traces of alkali round the negative, and of acid round the positive wire. A slip of glass, also, negatively electrified in one of the gold cones, had soda detached from it, and sustained a loss of weight.

It may now be understood, why, by the agency of galvanism on water, alkali appears at the negative and acid at the positive wire. The fact was, for some time, not a little perplexing to Sir H. Davy; till, at length, he ascertained that all water, however carefully distilled, contains neutral salts in a state of solution.* From these impurities, the alkaline and acid elements are separated, agreeably to a law, which has already been explained. In the same way, also, the muriatic acid and alkali are accounted for, which some chemists have obtained by galvanizing what was before considered as pure water; a fact which has been urged in proof of the synthetical production of both those bodies. Absolutely pure water, it has been demonstrated by Sir H. Davy, yields nothing but hydrogen and oxygen gases.

All the effects of galvanic arrangements, in producing chemical decompositions, it has been found, may be obtained by ordinary electricity. Its adaptation to this purpose was first successfully attempted by Dr. Wollaston.† The apparatus, which he employed, was similar to that already represented, (fig. 77, a,) excepting that the wires, instead of being exposed to the fluid, contained in the tube, throughout their whole length, were covered with wax, and the points only were laid bare. Or (what was found to answer still better) the wires were enclosed in capillary tubes, which were sealed at their extremities, and then ground away, till the points alone were exposed. The conducting wires, thus arranged, were then introduced into a tube, or other vessel containing the liquid to be operated on, and were connected, the one with the positive, the other with the negative, conductor of an electrical machine, disposed for positive and negative electricity.‡ When solution of sulphate of copper was thus electrized, the metal was revived round the negative pole. On reversing the apparatus, the copper was re-dissolved, and appeared again at the other wire, now rendered negative.

When gold wires, from $\frac{1}{700}$ to $\frac{1}{1500}$ of an inch in diameter, thus inclosed, were made to transmit electricity, a succession of sparks afforded a current of gas from water. When a solution of gold in

* If such be the fact, what dependance can be placed on chemical analysis? Can we suppose the presence of such neutral salts will not often modify the results of the most accurate inquirer? And are we incapable of detecting such substances by any tests in our possession? I must confess, I would rather suspect the accuracy of Sir H. Davy's researches, than fully acquiesce in the above assertion. Whence or how did Sir H. Davy obtain his *absolutely pure water*, of which Dr. H. speaks at the conclusion of the paragraph? C.

† Philosophical Transactions, 1801.

‡ See Cuthbertson's Practical Electricity.

nitro-muriatic acid was passed through a capillary tube; the tube then heated to drive off the acid; and afterwards melted and drawn out, it was found that the mere current of electricity, without sparks, evolved gas from water.

Sir H. Davy has since proved that by a similar apparatus, solution of sulphate of potash is decomposed, potash appearing at the negative, and sulphuric acid at the positive pole.*

SECTION IV.

Theory of the Changes produce / by Galvanic Electricity.

A FACT of considerable importance in explaining the phenomena that form the subject of the last section, was discovered several years ago by Mr. Bennett, and has since been confirmed by the experiments of Volta and Davy. Different bodies, it is found, acquire, when brought into contact either by their whole surfaces or by a single point, different states with respect to their quantities of electricity. The best method of performing the experiment is to take two discs or plates, the one of copper, the other of zinc, each about four inches diameter, and furnished with an insulating glass handle; to apply them for an instant to each other by their flat faces; and afterwards, to bring them separately into contact with the insulated plate of the condensing electrometer. The instrument indicates, by the divergence of its gold leaves, the electricity acquired by each of the plates, which in the zinc plate is shown to be positive, and in the copper plate negative.†

It had been established, also, by Sir H. Davy, in 1801, that when a galvanic arrangement of *the second kind* is constructed, by alternating metallic plates with strata of different fluids, alkaline solutions always receive electricity *from* the metal, and acids on the contrary transmit it *to* the metal. When an arrangement, for example, is made of water, tin, and solution of potash, the current of electricity is from the tin to the alkali. But, in an arrangement of nitric acid, tin, and water, the circulation of electricity is from the acid to the tin. If then the alkali, after having acquired electricity from the metal, could be suddenly separated from the combination, there can be no doubt that it would be found in a positive state. For the contrary reason, the acid, having given electricity to the metal, must, if it could be detached, be found negative.

Still more satisfactory evidence has been since obtained of the electrical state of the acids and alkalis, by examining what kind of electricity they impart to an insulated metallic plate. Various dry acids, being touched on an extensive surface by a plate of copper insulated by a glass handle, the copper was found after contact to

* Philosophical Transactions, 1806.

† Volta, in Nicholson's Journal, 8vo. i. 136. Wilkinson, ii. 40, 50, 131. Cuthbertson, 267.

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

Now, if the common laws of electrical attraction and repulsion operate, as there is every reason to believe they must, among bodies so constituted, it will follow that hydrogen, the alkalis, metals, and oxides, being positively electrified, will be repelled by surfaces which are in the same state of electricity as themselves, and will be attracted by surfaces that are negatively electrified. And, contrariwise, oxygen, and the acids, (in consequence of the oxygen they contain,) being in a negative state, will be attracted by positive surfaces and repelled by negative ones.

To apply this theory to the simplest possible case, the decomposition of water, the hydrogen of this compound, being itself positively electrified, is repelled by the positive wire and attracted by the negative one; while, on the contrary, oxygen, being negative, is repelled by the negative wire, and attracted by the positive one.* In the case of neutral salts, the negative acid is attracted by the positive wire; and the positively electrified alkali by the negative wire.

* Ingenious as is this theory, there are certainly difficulties attending it that have not yet been surmounted. It gives us no explanation, where (whatever may be the electric states of hydrogen and oxygen in their gaseous form) the water is decomposed; whether at the positive or negative pole, at both equally, or at some intermediate point. The experiments of Dr. Wollaston prove, I think, that by common electricity, water is decomposed at *both* poles, and both equally evolve its constituent gases. If galvanism is merely a modification of electricity, I can scarcely hesitate to believe that the decomposition of water in this case occurs equally at both poles; yet since we find oxygen, apparently, only at the positive, and hydrogen at the negative end; the question is, what has become of the hydrogen at the positive, or of the oxygen at the negative? We are too apt to regard the operations before us as the result of simple affinity, when probability would more readily establish it, as of a compound nature. Whether such be the case, in the process under consideration, I shall not presume to affirm, although I believe it to be so. And I think we are guided to somewhat of an explanation, by referring to the experiments of Mr. Milner, on ammonia, &c. in which he found that nitrogen and hydrogen do not combine, unless the *fully formed* nitrogen meets the attenuated hydrogen in its *nascent* or *forming* state. We have perhaps equal reason to believe that oxygen will not combine with fully formed hydrogen, although it probably may combine with it in its nascent state. I presume, then, that as by common electricity, both gases are evolved together at each pole; yet as they meet in a fully formed state, the oxygen cannot combine with the hydrogen, to reproduce a portion of water. A double action is nevertheless continually progressing; whilst the oxygen of the one pole (say the positive) and the hydrogen of the other mutually escape, (and are those collected in the experiment,) the nega-

Thus then a power has been discovered, superior in its energy to chemical affinity, and capable either of counteracting it, or of modifying it according to circumstances. The chemical attraction between two bodies may be destroyed, by giving one of them an electrical state opposite to its natural one; or the tendency to union may be increased, by exalting the natural electrical energies.

All bodies, indeed, that combine chemically, so far as they have hitherto been examined, have been found to possess opposite states of electricity. Thus copper and zinc are in opposite states to each other; so are gold and mercury; sulphur and metals, acids and alkalis. By bringing two bodies into the same electrical state, which were before capable of union, we destroy their tendency to combination. Thus zinc or iron, when negatively electrified, will not unite with oxygen. Even after combination, it is thought by Sir H. Davy not improbable, that bodies may still retain their peculiar states of electricity. If oxygen prevail, in any compound, over the combustible or positive base, the compound is negative, as in certain metallic oxides. But the combustible ingredient may be in such proportion, as to predominate, and to give to the compound a positive energy. When precise neutralization is attained, bodies that had before exhibited electrical effects are deprived of this property.

It is an interesting question, but one which can scarcely be determined in the present state of the science, whether the power of electrical attraction and repulsion be identical, as Sir H. Davy has suggested, with chemical affinity; or whether it may not rather be considered, like caloric, as a distinct force, which only modifies that of chemical attraction? On the former hypothesis, two bodies, which are naturally in opposite electrical states, may have these states sufficiently exalted, to give them an attractive force superior to the cohesive affinity opposed to their union; and a combination will take place, which will be more or less energetic, as the opposed forces are more or less equally balanced. Again, when two bodies, repellent of each other, act upon a third with different degrees of the same electrical energy, the combination will be determined by the degree. Or, if bodies, having different degrees of the same electrical energy with respect to a third, have likewise different energies with respect to each other, there may be such a

tive, but fully formed oxygen meets the *nascent* positive hydrogen, and re-constitutes a portion of water, equal to half the amount of that decomposed. There is certainly no reason why this extraordinary agent should be incapable of re-uniting elements into the same form, from which it had the instant before separated them, for common electricity does the same; indeed we know that it is also accomplished by galvanic action; and we must remember that it now meets them under a totally different state of existence. The various experiments of Davy related in the text, of the separation and transmission of the component parts of bodies, invisibly, and even across fluids, capable by their affinity, under ordinary circumstances, of retaining them, I think are highly favourable to the truth of this hypothesis. Nor can the distance of the wires, or their being placed in different vessels, at all militate against it, when the above referred-to experiments are properly considered. C.

balance of attracting and repelling forces as to produce a triple compound.

This hypothesis, it is remarked by Sir H. Davy, agrees extremely well with the influence of *mass*, which has been so well illustrated by Berthollet; for many particles, acting feebly, may be equal in effect to fewer acting more powerfully. Nor is it at all contradictory to the observed influence of caloric over chemical union; for an increase of temperature, while it gives greater freedom of motion to the particles of bodies, exalts also their electrical energies. This Sir H. Davy ascertained with respect to an insulated plate of copper and another of sulphur, when heated below 212° Fahrenheit; and at a still higher temperature these bodies, as is well known, combine with the extrication of heat and light, the usual accompaniments of intense chemical action.

On the supposition that electricity is a force, which only modifies the action of chemical affinity, we may regard it, when it promotes combination, as producing this effect by counteracting cohesive attraction. When it impedes combinations, or destroys those which are already formed, it probably acts as a force co-operating with elasticity.

SECTION V.

Theory of the Action of the Galvanic Pile.

Two theories have been framed to account for the phenomena of the Galvanic Pile, and of all similar arrangements. The first, originating with Volta, was suggested by the fact, which may be considered, indeed, as fundamental to it—that electricity is excited by the mere contact of different metals. When a plate of copper and another of zinc are made to touch by their flat surfaces, as was stated in the last section, the zinc, after separation, exhibits positive electricity, and the copper negative. It is natural, therefore, to conclude that a certain quantity of electricity has moved from the copper to the zinc. On trying other metals, Volta found that similar phenomena take place; and by a series of experiments he was led to arrange their powers in the following order, it being understood that the first gives up its electricity to the second; the second to the third; the third to the fourth, and so on.

Silver.
Copper.
Iron.
Tin.
Lead.
Zinc.

The metals, then, have been denominated by Volta, from this property, *motors* of electricity; and the process, which takes place,

electro-motion, a term since sanctioned by the adoption of it by Sir H. Davy.

It is on this transference of electricity from one body to another by simple contact, that Volta explains the action of the instrument discovered by himself, and of all similar arrangements. The interposed fluids, on his hypothesis, have no effect as chemical agents in producing the phenomena, and act entirely as conductors of electricity. Without disputing, however, the accuracy or value of the facts which suggested his theory, it is sufficient for its refutation that it is irreconcilable with other phenomena; and especially with the observation, that the chemical agency of the liquids, on the more oxidizable metal of galvanic arrangements, is essential to their sustained activity. It has been proved, indeed, that the phenomena begin and terminate with the oxidation; and that the energy of the pile bears a pretty accurate proportion to the rapidity of the process. Hence it seems, on first view, an obvious inference, that the oxidation of the metal is the primary cause of the evolution of electricity in galvanic arrangements. It has been proved, however, that it is not necessary to the excitement of electricity, that the amalgam should be oxidated; for the machine continues to act when inclosed in hydrogen gas or carbonic acid; and the electric column of M. de Luc is composed of dry substances.

But though the chemical agency of the fluids which are employed is now admitted, on all hands, to be essential to the excitement of this kind of electricity, yet it is by no means universally agreed that we are to consider it as the first in the order of phenomena. It has been suggested by Sir H. Davy, as a correction of the theory of Volta, that the electro-motion, occasioned by the contact of metals, is the primary cause of the chemical changes; and that these changes are in no other way efficient, than as they restore the electric equilibrium. To explain this, let us suppose that in any three pairs of plates of a galvanic trough, the zinc plates $z\ 1$, $z\ 2$, $z\ 3$, (fig. 78,) are in the state of positive, and the copper plates $c\ 1$, $c\ 2$, $c\ 3$, in that of negative electricity. The liquid, in any cell after the first, will be in contact, on the one side, with positively electrified zinc, and on the other with negatively electrified copper. And if the elements composing the fluid be themselves in different states of electricity, the negatively electrified element will be attracted by the zinc, and the positively electrified element by the copper. Thus when solution of muriate of soda in water is the fluid, the oxygen and the acid will pass to the zinc or positive plate, and the alkali to the copper one; while the hydrogen, having no affinity for copper, escapes. The electric equilibrium will be restored, but only for a moment; for, as the interposed fluid is but a very imperfect conductor of electricity, the zinc and copper plates will, by their electromotive power, again assume their states of opposite electricity; and these changes will go on, as long as any muriate of soda remains undecomposed. In a Voltaic arrangement, therefore, the electrical energies of the metals with respect to each other, or to the substances dissolved in water, are the causes disturbing.

the equilibrium; and the chemical changes are the causes that restore it.

No theory of the galvanic pile, however, can be considered as complete, that does not account for the accumulation of electricity at the zinc end of the apparatus. On the theory that the oxidation of the zinc is the source of the evolved electricity, the fact has been ingeniously explained by Dr. Bostock. He takes it for granted that the electric fluid has an affinity for hydrogen; and supposes that the electricity, evolved at the surface of the first zinc plate, is carried, united to hydrogen, through the fluid of the cell to the opposite copper plate. Here the hydrogen and electricity separate; the former flies off in the state of gas, and the latter passes outwards to the next zinc plate. Being in some degree accumulated in this plate, it is disengaged by the action of the fluid in a more concentrated state than before. And in the same manner, by multiplying the number of pairs, it may be made to exist, in the zinc end of the pile, in any assignable degree of intensity.

On this theory, the electricity evolved is actually *generated* by the chemical action of the interposed fluids on every zinc plate of the series; and its accumulation is the aggregate of what is thus evolved. The concentration, which takes place at the zinc end of the arrangement admits, however, of being explained by the hypothesis of Volta, especially as modified by Sir H. Davy. Taking the first cell as an example, the fluid interposed between the positive zinc plate z 1, fig. 78, and negative copper plate c 2, being itself a conductor of electricity, must in time produce an equilibrium between these two plates; but this can only be done by the passage of a certain quantity of electricity across the fluid. The absolute quantity of electricity, will, therefore, be diminished in the first pair, and increased in the second. In like manner, the second zinc plate will give up part of its electricity to the third copper plate, and the second pair of plates will be deprived of part of its electricity. The electricity, thus lost by the second pair, it will regain from the first pair of plates. By multiplying, in this way, the number of plates, every successive pair, as we advance in the series, has a tendency to diminish the quantity of electricity in the first; and to have its own state of electricity proportionally exalted.

When a communication is made between two extremities of a series, for example between z^3 or its contiguous cell, and c^1 , the opposite electricities tend to an equilibrium. The third pair gives up a share of its electricity to the first; and the intermediate pair, being placed between equal forces, remains in equilibrio. Hence, in every galvanic arrangement, there is a pair of plates at the centre, which is in its natural state of electricity. The effect of such a communication must necessarily be to reduce the pile to a state of inactivity, if there did not still exist some cause sufficient to destroy the equilibrium. On the hypothesis of Volta, this can be nothing else than the property of electro-motion in the metals, which originally produced disturbance.

Such are the hypotheses that have been framed to explain the phenomena of the Voltaic pile. In the present state of the science,

neither of them is entitled to be received as altogether satisfactory; and I have stated them rather with the view of exciting than of satisfying inquiry.* On the theory of galvanic electricity, it only remains to point out its difference from the electricity developed by ordinary processes; and to explain the different effects, which are produced by varying the size of the plates in galvanic arrangements.

Though the identity of common and galvanic electricity appears to be sufficiently established, yet in some of their phenomena, which have already been described, there is a considerable difference. To explain these, it was long ago suggested by Mr. Nicholson,† that the electricity, excited by the common machine, is developed in much smaller quantity, but in a higher state of concentration or intensity, than the electricity of galvanism. Hence, its velocity is much more rapid; and hence it readily passes through plates of air and other non-conductors, that are scarcely permeable by galvanic electricity. By virtue of the same property it disperses the metals in the form of smoke; while the utmost effect of a Voltaic arrangement is to melt them into globules. By doubling the quantity of galvanic electricity, also, we ignite only a double length of metallic wire, and the ignition is more permanent; but the intensity of common electricity is such, that by doubling its quantity we ignite four times the length of wire, and the effect is little more than momentary.‡

The comparative quantities of electricity evolved by the common machine and by a Voltaic apparatus, have been made a subject of calculation by Mr. Nicholson. A pile consisting of 100 half crowns, with the same number of pieces of zinc, produces, he found, 200 times more electricity than can be obtained, in an equal time, from a 24 inch plate machine in constant action. Van Marum has, also, observed, that a single contact of a Leyden jar or battery with a Voltaic pile charges it to the same degree, as six contacts with the prime conductor of a powerful machine.

It might naturally be expected that a proportion would be observed between the quantity of surface composing galvanic arrangements, and their power of action; and such, with some limitation, is the fact. With plates of the same size, the effect, generally speaking, is proportional to the number. But by enlarging the size, without increasing the number, neither the shock nor the power of decomposing water and other imperfect conductors, is proportionally increased. A remarkable proof of this is, that Mr. Children's great battery of 20 double plates, 4 feet by 2, had no

* The reader, who wishes to pursue the subject, may consult an essay by the author, in the 35th vol. of Nicholson's Journal, p. 259; Mr. De Luc's papers, vol. 32, p. 271, and vol. 36, p. 97; Mr. Singer on the Electrical Column, vol. 36, p. 373, and his work on Galvanic Electricity; Dr. Bostock's Essay in Thomson's Annals, iii. 32; Sir H. Davy's chapter on Electrical Attraction and Repulsion, in his Elements of Chem. Philos. p. 125; and the 1st vol. of Gay Lussac and Thénard's Researches.

† See his Journal, 4to. iv. 244.

‡ Cuthbertson, page 278.

more effect on the human body, or in decomposing water, than a battery containing the same number of small plates. On the contrary, to obtain a great increase of effect in the combustion of metals, it is necessary to enlarge considerably the size of the plates. Thus 100 plates of four inches square produce, in this way, an incomparably greater effect, than the same surface divided into four times the number.

The effect of multiplying the number of plates, it has already been observed, is, that we obtain electricity of a higher intensity, and it was supposed by Volta* that the proportion is, as nearly as can be judged, an arithmetical one. If, for example, we have a certain intensity with 20 pairs, it should be doubled by 40, trebled by 60, and so on. It has been shown, however, by Sir H. Davy,† that by increasing the number of plates, the quantities of gas, evolved from water, were nearly as the squares of the numbers. By a sufficient increase, the most astonishing effects may be produced. Thus the combination belonging to the Royal Institution, which contains 2000 double plates, each having a surface of 32 square inches, when in action, melts platina, as easily as wax is melted by a candle, and fuses quartz, the sapphire, lime, and magnesia. By enlarging the size, without increasing the number, it has also been shown that we gain, not in intensity, which remains exactly the same, but in quantity. Now, for the combustion of metals what we principally want is a large quantity of electricity; for as they are perfect conductors, it finds a ready passage through them even when of low intensity. On the contrary, to find its way through fluids and other imperfect conductors, it must be evolved in a high state of concentration. The facts, therefore, accord sufficiently well with the explanation, to entitle it to be received as a probable hypothesis.

CHAPTER VIII.

ALKALIS.

THE alkalis, in their pure state, are the products of chemical operations, which will be described in the sequel. They are distinguished by the following

General Qualities.

The properties, common to all the three alkalis, may be shown by those of a solution of pure potash.

(a) The alkalis change vegetable blue colours, as that of an infusion of violets, to green.

(b) They have an acrid and peculiar taste.

* Nicholson's Journal, 8vo. i. 139.

† Elements of Chem. Philos. p. 155.

- (c) They serve as the intermedia between oils and water.
- (d) They corrode woollen cloth; and, if the solution be sufficiently strong, reduce it to the form of a jelly.
- (e) They are readily soluble in water.
- (f) The two fixed alkalis unite with water, and form solid *hydrates*.

SECTION I.

Pure Potash and pure Soda.

ART. 1.—*Their Preparation and General Qualities.*

To prepare pure potash, dissolve any quantity of American or Dantzic pearl-ash in twice its weight of boiling water, and add the solution, while hot, to an equal weight of fresh quicklime, slaked with six times its weight of hot water. Boil the mixture in an iron kettle, and continue stirring during half an hour. Then separate the liquid alkali, either by filtering through calico or by subsidence; and boil it to dryness in a silver dish. Pour, on the dry mass, as much pure alcohol as is required to dissolve it; put the solution into a bottle, and let the insoluble part settle to the bottom. Then decant the alcoholic solution of potash; and distil off the alcohol in an alembic* of pure silver, furnished with a glass head. Pour the alkali, when in fusion, upon a silver dish, and, when cold, break it into pieces, and preserve it in a well-stopped bottle. If the distillation of the alcohol be not carried so far, the alkali will shoot, on cooling, into regular crystals, containing 53 per cent of water.

From the electro-chemical researches of Sir H. Davy, it appears that potash is not completely deprived of carbonic acid, by any process hitherto employed for its preparation.† Probably the method suggested by Darcet, of removing the last portions of carbonic acid from an alkaline liquor by solution of barytes, after the full action of lime, would be found effectual.

In the same mode may pure soda be prepared, substituting the carbonate of soda for the pearl ash.

These alkalis have the following properties:

- (a) They powerfully attract moisture from the atmosphere, or deliquesce.
- (b) They readily dissolve in water, and produce heat during their solution if the fused alkalis be employed; but the crystallized alkalis generate cold, when dissolved.
- (c) They are not volatilized by a moderate heat, and hence have been called fixed alkalis.

* The figure of an alembic may be seen in pl. i. fig. 2.

† Philosophical Transactions, 1808, 355.

(d) When melted with silex, in proper proportions and by a sufficient heat, they form glass.

Hydrated Alkalis.

It is necessary to observe that the alkalis, even after being kept some time in fusion, contain a quantity of water in the state of combination; in other words, are *hydrates*. This discovery appears to be due to Darcet, who has established his claim very satisfactorily.* Various proportions of water and alkali have been assigned to these compounds. Bethollet, in the 2d vol. of the *Mémoires d'Arcueil*, states that 100 parts of solid potash contain $13\frac{1}{2}$ parts of water; but Sir H. Davy† has raised it as high as from 17 to 19 per cent; and Gay Lussac and Thenard allow about one fifth of water in solid potash.‡ One possible source of fallacy is, that if the alkali contain soda, the proportion of water will appear too great; because that alkali combines with more water than potash. If, as Mr. Dalton suspects, the hydrate of potash be a compound of 1 atom of potash + 1 atom of water, its atom should weigh 56.5; and it ought to be composed of

$$\begin{array}{rcl} 84.9 \text{ potash} & \} & \text{or} \quad \{ 84 \\ 15.1 \text{ water} & \} & \{ 16 \\ \hline 100 & & 100 \end{array}$$

And it is remarkable, that, according to the theoretical view of Berzelius, potash, to become a hydrate, requires a quantity of water containing precisely as much oxygen, as exists in the alkali united with potassium; that is, 100 parts of the hydrate should contain 16.15 of water.§

There is also considerable difference in the statements respecting *Hydrate of soda*. Berard makes it contain 18.86 per cent of water; Darcet 28; and Sir H. Davy from 23 to 25.|| If the atom of soda weigh as Mr. Dalton supposes, 28, and if the hydrate consist of 1 atom of soda + 1 atom of water, the atom of hydrate of soda should weigh 36.5, and the hydrate should be composed of

$$\begin{array}{r} 76.7 \text{ soda} \\ 23.3 \text{ water} \\ \hline 100. \end{array}$$

In these instances, the theoretical view, and the best practical result, confirm each other.

It is often of importance to know the quantity of real alkali, contained in solutions of different specific gravities. The following Tables have been constructed by Mr. Dalton from his own experiments, conducted with great attention to accuracy.

* 71 Ann. de Chim. 202.

† Elements, p. 326.

‡ Here we have another proof of the imperfection of analysis, and, of consequence, how careful we should be, of implicitly relying on any hypothesis built on so imperfect a foundation.—C.

§ 82 Ann. de Chim. p. 11.

|| Phil. Trans. 1811.

1. *Table of the Quantity of Real Potash in watery Solutions of different Specific Gravities.*

Atoms of Potash Water.	Potash per cent. by weight.	Potash per cent. by measure.	Specific Gravity.	Congeeing point.	Boiling point.
1+ 0	100	240	2.4	unknown.	unknown.
1+ 1	84	185	2.2	1000°	red heat.
1+ 2	72.4	145	2.0	500°	600°
1+ 3	63.6	119	1.88	340°	420°
1+ 4	56.8	101	1.78	220°	360°
1+ 5	51.2	86	1.68	150°	320°
1+ 6	46.7	75	1.60	100°	290°
1+ 7	42.9	65	1.52	70°	276°
1+ 8	39.6	58	1.47	50°	265°
1+ 9	36.8	53	1.44	40°	255°
1+10	34.4	49	1.42		246°
	32.4	45	1.39		240°
	29.4	40	1.36		234°
	26.3	35	1.33		229°
	23.4	30	1.28		224°
	19.5	25	1.23		220°
	16.2	20	1.19		218°
	13	15	1.15		215°
	9.5	10	1.11		214°
	4.7	5	1.06		213°

2. *Table of the Quantity of Real Soda in watery Solutions of different Specific Gravities.*

Atoms of Soda Water.	Soda per cent. by weight.	Soda per cent. by measure.	Specific Gravity.	Congeeing point.	Boiling point.
1+0	100	230?	2.30?	1000°	unknown.
1+1	77.8	156	2.	500°	red hot.
1+2	63.6	118	1.85	250°	600°
1+3	53.8	93	1.72	150°	400°
1+4	46.6	76	1.63	80°	300°
1+5	41.2	64	1.56		280°
1+6	36.8	55	1.50		265°
	34	50	1.47		255°
	31	45	1.44		248°
	29	40	1.40		242°
	26	35	1.36		235°
	23	30	1.32		228°
	19	25	1.29		224°
	16	20	1.23		220°
	13	15	1.18		217°
	9	10	1.12		214°
	4.7	5	1.06		213°

ART. 2.—*Analysis of the two fixed Alkalis.*

Though it had long been conjectured* that the fixed alkalis are not simple or elementary bodies, yet no distinct evidence had been obtained of their nature, until, in the year 1807, it was furnished by the splendid discoveries of Sir H. Davy. From the facts which have been stated in a former section respecting the powers of electrical decomposition, it appeared to that philosopher a natural inference, that the same powers, applied in a state of the highest possible intensity, might disunite the elements of bodies, which had resisted all other instruments of analysis. If potash, for example, were an oxide, composed of oxygen united to an inflammable base, it seemed to him probable, that when subjected to the action of opposite electricities, the oxygen would be attracted by the positive wire and repelled by the negative. At the same time, the reverse process might be expected to take place with respect to the combustible base, the appearance of which might be looked for at the negative pole.

In his first experiments, Sir H. Davy failed to effect the decomposition of potash, owing to his employing the alkali in a state of aqueous solution, and to the expenditure of the electrical energy in the mere decomposition of water. In his next trials, the alkali was liquefied by heat in a platina dish, the outer surface of which, immediately under the alkali, was connected with the zinc or positive end of a battery consisting of 100 pairs of plates, each six inches square. In this state, the potash was touched with a platina wire proceeding from the copper or negative end of the battery; when instantly a most intense light was exhibited at the negative wire, and a column of flame arose from the point of contact, evidently owing to the development of combustible matter. The results of the experiment could not, however, be collected, but were consumed immediately on being formed.

The chief difficulty in subjecting potash to electrical action is, that in a perfectly dry state it is a complete non-conductor of electricity. When rendered, however, in the least degree moist by breathing on it, it readily undergoes fusion and decomposition, by the application of strong electrical powers. For this purpose, a piece of potash, weighing from 60 to 70 grains, may be placed on a small insulated plate of platina, and may be connected, in the way already described, with the opposite end of a powerful electrical battery, containing not less than 100 pairs of six inch plates. On establishing the connection, the potash will fuse at both places where it is in contact with the platina. A violent effervescence will be seen at the upper surface, arising, as Sir H. Davy has ascertained, from the escape of oxygen gas. At the lower or negative surface, no gas will be liberated; but small bubbles will appear, having a high metallic lustre, and being precisely similar in visible characters to quick-silver. Some of these globules burn with an explo-

* See Philosophical Magazine, xxxii. 18, 62.

sion and bright flame; while others are merely tarnished, and are protected from farther change by a white film, which forms on their surface.*

This production of metallic globules is entirely independent of the action of the atmosphere; for Sir H. Davy finds that they may be produced *in vacuo*.

Pure soda gives similar results; but its decomposition demands a greater intensity of action. The quantity of soda should not exceed 15 or 20 grains; and the distance between the platina surfaces must be reduced from $\frac{1}{4}$ to $\frac{1}{8}$ or $\frac{1}{10}$ of an inch. The metal from soda does not, like that from potash, continue fluid at the temperature of the atmosphere; but speedily becomes solid, and bears a considerable resemblance to silver. When the electrical power is much increased, globules of the metal fly with great velocity through the air, in a state of vivid combustion, producing beautiful jets of fire.

To preserve these new substances, it is necessary to immerse them immediately in pure naphtha, a fluid which will be described in a subsequent part of the work. If they are exposed to the atmosphere, they are rapidly converted back again into the state of pure potash or pure soda.† To prevent their oxidation still more effectually, Mr. Pepys has proposed to produce them under naphtha; and has contrived an ingenious apparatus for this purpose, which is described in the 31st volume of the Philosophical Magazine, page 241.

When the globules, obtained either from potash or soda, are exposed to the action of air over mercury in graduated glass tubes, an absorption of oxygen happens; and a crust of alkali is formed on the surface, which defends the interior from farther change. When heat is applied to the globules similarly confined, a rapid combustion ensues, attended with a brilliant white flame. The globules are found, after the experiment, converted into a white substance; which is potash when we have used those from potash, and soda when the globules from soda have been employed. In this process, oxygen is absorbed, and the weight of the alkali produced is found to exceed that of the globules consumed.

When either of these substances is thrown into water, a rapid disengagement of hydrogen gas takes place; and the oxygen of the water, uniting with the globules, regenerates alkali.

Nothing then can be more satisfactory than the evidence, fur-

* For the repetition of this experiment, very useful practical directions may be found in a paper by Mr. Singer—Nicholson's Journal, xxiv. 174.

† Even in the purest naphtha, these metallic substances soon become decomposed, or covered with a soapy matter. If the quantity obtained is any way considerable, the best method of preserving them is to put them into a small vial, pressing the mass down tightly, and securing with a cork covered with wax. After the small portion of oxygen in the vial is absorbed, no further change will take place. I have thus preserved some, now nearly eighteen months. C.

nished by these experiments, of the nature of the fixed alkalis. By the powerful agency of opposite electricities, each of them is resolved into oxygen and a peculiar base.* This base, like other combustible bodies, is repelled by positively electrified surfaces, and attracted by negative ones; and hence its own natural state of electricity must necessarily be positive. Again, by uniting with oxygen, these bases are once more changed into alkali, either slowly at ordinary temperatures; or with heat and light, if their temperatures be raised. We have the evidence, therefore, both of analysis and synthesis, that each of the fixed alkalies is a compound of oxygen with a peculiar inflammable basis.

But in what class of combustible bodies are we to arrange the alkaline bases? Some properties, common to both, have influenced Sir H. Davy to place them among the metals, with which they agree in opacity, lustre, malleability, conducting powers as to heat and electricity, and in their qualities of chemical combination. The only property, which can be urged against this arrangement, is their extreme levity, which even exceeds that of water. But when we compare the differences, which exist among the metals themselves, this will scarcely be considered as a valid objection. Thus tellurium, which no chemist hesitates to consider as a metal, is only about six times heavier than the base of soda, while it is four times lighter than platina; thus forming a sort of link between the old metals and the bases of the alkalis.

In giving names to the alkaline bases, Sir H. Davy has adopted that termination, which, by common consent, has been applied to other newly discovered metals, and which, though originally Latin, is now naturalized in our language. The base of potash he has called POTASSIUM, and the base of soda SODIUM; and these names have met with universal acceptance among chemical philosophers.

It is not, however, by electrical means only that the decomposition of the fixed alkalis has been accomplished. Soon after Sir H. Davy's discoveries were known at Paris, Messrs. Gay Lussac and Thenard† succeeded in their attempts to decompose both the fixed alkalis, without the aid of a Voltaic apparatus, and merely by the intervention of chemical affinities. Their process, though it affords the alkaline bases of less purity, yields them in much larger quantity than the electrical analysis, *viz.* to the amount of nearly 400 grains by one operation. It consists in bringing the alkalis into contact with intensely heated iron, which, at this temperature, attracts oxygen more strongly than the alkaline base retains it.

The apparatus, used for obtaining potassium, differs very little from that which is commonly employed to decompose water by

* The proportions of oxygen and base in each will be found at the end of the the articles Potassium and Sodium.

† Annales de Chimie, lxx. 325, or Memoires d'Arcueil, ii. 299.

means of iron.* It consists of a common gun-barrel curved, and drawn out, at one end, to rather a smaller diameter, as represented in the 9th plate, fig. 83, c. To one end is adapted an iron tube *a*, of the capacity of two cubic inches, for containing the potash. At the bottom of this tube is a small hole, through which the potash gradually flows. To the opposite end of the gun-barrel a tube of safety *e* is to be cemented; and into this a sufficient quantity poured, either of mercury or naphtha. Into the gun-barrel, $2\frac{1}{2}$ parts of very clean iron turnings are to be introduced, and pushed on to the bent part *c*. The tube, carefully luted, is then to be placed in a small furnace nine or ten inches in diameter, and provided with a pair of double blast bellows, the pipe from which is shown at *f*. The next step is to insert the tube *a* in its place, after having put into it $1\frac{1}{2}$ parts of pure potash, deprived of as much water as possible by previous fusion. The whole apparatus should be perfectly dry, clean, and impervious to air.

A strong heat is now to be excited in the furnace *d*; and while this is doing, the tube containing the potash, as well as the opposite end of the barrel, should be kept cool by ice. When the barrel has attained a white heat, the potash in *a* may be melted by a small portable furnace. It will then flow, through the small hole, upon the iron turnings. A considerable quantity of hydrogen gas will be evolved by the decomposition of that portion of water, which the potash retains even after fusion, and which has been shown to exceed 13 *per cent*. When the production of this gas slackens, we may remove the small furnace from beneath the tube *a*, and increase the heat in the furnace *d*, in order to restore to the iron turnings at *c* the temperature proper for decomposing more potash. These operations may be repeated, alternately, till no more gas is produced; but last of all, the heat in the furnace should be strongly raised, in order to drive off some of the potassium, which strongly adheres to the iron turnings.

When the furnace is quite cold, the safety tube *e* is to be removed, and its place supplied by an iron plug. If the end of the gun-barrel, projecting from this side of the furnace, has been kept

* Hachette in Philosophical Magazine, xxxii. 89; and Mr. E. Davy, ditto. page 276. Ample details respecting the preparation of potassium are also given in the 1st vol. of Gay Lussac and Thenard's *Recherches Physico-Chimiques*; and a simple and ingenious apparatus, for procuring this metal, is described by Mr. Tennant in the *Phil. Trans.* for 1814. (*)

(*) This method is to put the potash and iron turnings together into a gun-barrel about a foot and a half long, and covered with a lute composed of Stourbridge clay, partly in its natural state, and partly previously baked. Into the mouth of the gun-barrel another iron tube about 8 inches long is to be put, perforated at the lower extremity, and having its upper end projecting about an inch beyond the gun-barrel. The mouth of the gun-barrel is shut by another tube which slips over it. The mouth of it is filled by a perforated cork, through which there passes a bent glass tube, having in it a drop of mercury. This apparatus being exposed to a strong heat for an hour in a smith's forge, the potassium is found perfectly pure in the upper perforated iron tube. *Annals of Philosophy*, 6, 139. C.

Another method is described by Dr. Hamel in the 5th vol. 349, of the *An. of Philos.* C.

carefully cooled during the experiment, the metal will be found adhering to it, in the form of brilliant laminæ. In order to extract it, the gun-barrel is to be cut at the commencement of the part which has been kept cool, where the greatest quantity will be found. Another portion will be found close to the plug, and this adheres so slightly to the gun-barrel, that the least effort serves to detach it. It is even partly oxidized by the air, which gains access during the cooling of the furnace; and when the whole is covered with naphtha, the oxidized part is detached in laminæ, exposing a white and brilliant metallic surface.

The *potassium*, which is condensed nearest the furnace, must be detached by a sharp chisel, and in the largest pieces we can possibly break off; for if it be in small molecules, it inflames in the air, even at very low temperatures. In the middle of the gun-barrel we shall find an amalgam of potassium and iron, which becomes green on exposure to the air, the potassium returning to the state of potash.

When the iron turnings were very clean, the potash very dry and pure, and the whole apparatus free from foreign matters, the metal produced differed very little from that obtained by a Voltaic battery. Its lustre, ductility, and malleability were similar. Its point of fusion and specific gravity, however, were a little higher; for it required nearly 130° Fahrenheit, to render it perfectly fluid, and was to water as 796 to 1000 at 60° Fahrenheit. This Sir H. Davy ascribes to contamination with a minute proportion of iron. The affinities, indeed, by which the decomposition is produced, he supposes to be those of iron for oxygen, of iron for potassium, and of potassium for hydrogen.

Charcoal, it has been asserted by Curaudau* may be employed, also, for the decomposition of the alkalis. To ensure success in the process, great attention, it appears, is necessary to the manipulations, which are fully described in the memoir of the inventor. The fact sufficiently explains an observation of Professor Woodhouse.† A mixture of half a pound of soot and two ounces of pearl-ash, was exposed for two hours in a covered crucible to an intense heat. When the mixture became cold it was emptied upon a plate, and a small quantity of water poured upon it, when it immediately took fire. This could only be owing to the conversion of part of the potash into potassium.

ART. 3.—*Potassium.*

I. The base of potash, at 60° Fahrenheit, exists in small globules, which possess the metallic lustre, opacity, and general appearance of mercury; so that when a globule of mercury is placed near one of potassium, the eye can discover no difference between them. At this temperature, however, the metal is only imperfectly fluid; at 70° it becomes more fluid; and at 150° its

* Nicholson's Journal, xxiv. 37.

† Ibid, xxi. 290.

fluidity is so perfect, that several globules may easily be made to run into one.

By reducing its temperature, potassium becomes, at 50° Fahrenheit, a soft and malleable solid, which has the lustre of polished silver. At about the freezing point of water, it becomes hard and brittle, and exhibits, when broken, a crystallized texture, which, in the microscope, seems composed of beautiful facets of a perfect whiteness and high metallic splendour.

To be converted into vapour, it requires a temperature approaching that of a red heat; and, when the experiment is conducted under proper circumstances, it is found unaltered after distillation.

II. Potassium is a perfect conductor both of electricity and of heat.

III. Its specific gravity at 60° Fahrenheit, making some allowance for unavoidable errors in the experiment, is as 6 to 10, the latter number being assumed as that of water. Gay Lussac and Thénard make it between 8 and 9, and Bucholz 8.76; but they probably operated on a less pure substance. Even in its solid form, it swims in naphtha, whose specific gravity is about $7\frac{1}{2}$ to 10. The most recent statement of its specific gravity, by Sir H. Davy, fixes it between 8 and 9.

IV. Its combustibility has already been noticed. At the temperature of the atmosphere, it absorbs oxygen slowly; but if heated nearly to redness, or to its point of vaporization, it burns with a brilliant white flame and a very intense heat.

V. It appears to be susceptible of different degrees or stages of oxidizement. 1stly, By heating it to a point, below what is necessary for its inflammation, either in common air or oxygen gas; or, (which is still better,) by confining it, for some days, in an empty phial loosely corked, a substance is formed of a bluish grey colour, softer than wax, and readily fusible. This substance takes fire in oxygen gas, or even common air, at about 70° Fahrenheit, and acts on water, giving out hydrogen, but in less quantity than is extricated by potassium.

2. The second oxide is potash, which is most effectually produced by the action of potassium on water.

3. Potassium, gently heated on a platina tray in oxygen gas, gives, for the result of its combustion, an orange coloured fusible substance. It is necessary to protect the platina from its action, by dipping the tray, before the experiment, into muriate of potash melted by heat. The precise nature of this compound was first explained, and its properties examined, by Gay Lussac and Thénard. It is fusible at a lower heat than hydrate of potash, and crystallizes in laminæ by cooling. When thrown into water, oxygen gas is evolved, and the substance passes, by this loss of oxygen, to the state of potash. Oxygen gas is, also, separated, by heating it strongly on a platina tray coated with muriate of potash; and a grey vitreous substance remains, which Sir H. Davy considers as absolutely pure potash. Almost all bodies, that have an attraction for oxygen, decompose this orange oxide, and reduce it to

the state of potash, which, in some cases, combines with the new compound. Charcoal, for example, with the excess of oxygen in the orange substance, forms carbonic acid; and this acid, uniting with the potash that is produced, composes carbonate of potash.

VI. The action of potassium on water is attended with some beautiful phenomena. When it is thrown upon water exposed to the atmosphere, or when it is brought into contact with a drop of water, it decomposes the water with great violence; an instantaneous explosion is produced with a vehement flame; and a solution of pure potash is the result. The hydrogen gas, which is disengaged, appears to dissolve a portion of potassium; for, on escaping into the air, it forms a white ring of smoke, gradually enlarging as it ascends, like the phosphuretted hydrogen gas.

When water is made to act on the base of potash, atmospheric air being excluded, there is much heat and noise, but no luminous appearance; and the gas evolved is pure hydrogen. It is of importance to remember that each grain of potassium, by acting on water, detaches about 1.06 cubic inch of hydrogen gas.

If a globule of the base of potash be placed on ice, it instantly burns with a bright flame, and a deep hole is made in the ice filled with a fluid which is found to be a solution of potash.

The production of alkali, by the action of water on potassium, is most satisfactorily shown, by dropping a globule of the metal upon moistened paper, which has been tinged with turmeric. At the moment, when the globule comes into contact with the paper, it burns, and moves rapidly as if in search of moisture, leaving behind it a deep reddish brown trace, and acting upon the paper, exactly like dry caustic potash.

So strong, indeed, is the affinity of potassium for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when carefully purified, and disengages, from both these fluids, hydrogen gas.

On naphtha colourless and recently distilled, potassium has very little power of action; but in naphtha, which has been exposed to the air, it soon oxidates, and alkali is formed, which unites with the naphtha into a brown soap, that collects round the globules.

VII. When thrown into the liquid mineral acids, the base of potash inflames, and burns on the surface; or, if kept beneath the surface, its effects are such as may be explained by its affinity for oxygen. In concentrated sulphuric acid, a white saline substance is formed, which is probably concentrated sulphuric acid surrounded by sulphur. At the same time a gas escapes which has the smell of sulphureous acid mixed with hydrogen gas. In nitrous acid, nitrous gas is disengaged, and nitrate of potash formed. In oxymuriatic acid gas, it burns vividly with bright scintillations, and muriate of potash is generated.

VIII. Potassium readily combines with the simple combustibles. To unite it with sulphur or phosphorus, it must be melted with these bodies under naphtha.

The *phosphuret of potassium* requires for its fusion a stronger heat than either of its constituents. It is of the colour of lead;

and, when spread out, has a lustre similar to polished lead. By exposure to the air, or by rapid combustion, it forms phosphate of potash. Besides this, there is, also, a chocolate coloured compound of potassium and phosphorus; so that it is probable these two bodies unite in different proportions, the lead coloured compound consisting of 2 atoms of metal + 1 of phosphorus; and the chocolate of 1 atom of metal + 1 of phosphorus.

When potassium is fused with sulphur, in a vessel filled with the vapour of naphtha, a rapid combination ensues, accompanied with heat and light,* and a disengagement of sulphuretted hydrogen. The result is a grey substance not unlike artificial sulphuret of iron.

IX. With mercury, potassium gives some extraordinary and beautiful results. The combination is very rapid, and is effected by merely bringing them into contact at the temperature of the atmosphere.† The amalgam, in which the potassium is in least proportion, seems to consist of about 1 part in weight of basis and 70 of mercury. It is very soft and malleable; but by increasing the proportion of potassium, we augment, in a proportional degree, the solidity and brittleness of the compound.

The compound of mercury and potassium may be obtained by an easy and simple process, first pointed out by Berzelius. Mercury, to the depth of a line, is put into a glass capsule, two inches in diameter, with a flat bottom. On this a solution of pure potash is poured; an iron wire connects the mercury with the negative pole of a galvanic arrangement, which needs not contain more than 20 pairs of plates; and a spiral platina wire, from the positive pole, is immersed in the solution, and kept within about a line from the surface of the mercury. In six hours, the effect is observable, and in 24 is very distinct; for, in that time, more than 1200 grains of mercury will be rendered solid by combination with potassium. Unfortunately, this combination cannot be so decomposed, as to obtain the potassium in a separate state.

In this state of division, potassium appears to have its affinity for oxygen considerably increased. By a few minutes' exposure to the air, potash is formed which deliquesces, and the mercury is left pure and unaltered. When a globule is thrown into water, it produces a rapid decomposition and a hissing noise; potash is formed; pure hydrogen disengaged; and the mercury remains free.

The fluid amalgam of potassium and mercury dissolves all the metals; and in this state of union, mercury even acquires the power of acting on platina.

Potassium unites, also, with gold, silver, and copper; and, when the compounds are thrown into water, this fluid is decomposed, potash is formed, and the metals are separated unaltered.

X. Potassium reduces all the metallic oxides when heated with

* From whence do they arise?—Here is no oxygen for decomposition! C.

† I have tried this experiment several times, but never found the combination a very rapid one. C.

them, even of those metals which most powerfully attract oxygen, such as oxides of iron. In consequence of this property, it decomposes and corrodes flint and green glass by a very gentle heat; potash is generated with the oxygen taken from the metal, which dissolves the glass and exposes a new surface. At a red heat even the purest glass, formed merely of potash and silex, is acted upon. The alkali in the glass seems to give up a part of its oxygen to the potassium, and an oxide of potassium results, with a less proportion of oxygen than is necessary to constitute potash. The silex, also, it is probable, is partly de-oxidized.

From this summary of the action of potassium, it appears that all the most remarkable effects which it exhibits, are connected with its affinity for oxygen, which is sufficiently energetic to enable it to take oxygen from all other bodies. Hence the application of potassium to any substance is the best test of its containing oxygen, which, if present, it cannot fail to detect.

It was important to determine the proportions in which potassium and oxygen combine, when potash is regenerated. This Sir H. Davy investigated by two different processes. The one consisted in ascertaining how much oxygen gas disappears by the action of a given quantity of potassium; the other how much hydrogen is disengaged from water by a known weight of the same substance. Dividing the bulk of the hydrogen gas by 2, he learned the quantity of oxygen which had been taken from the water.

The coincidence of results, obtained by these different methods, is remarkable. By the action of potassium on oxygen gas, it appeared, on an average, that

$$\text{Potash consists of } \left\{ \begin{array}{l} 86.1 \text{ potassium,} \\ 13.9 \text{ oxygen.} \end{array} \right.$$

100

By the agency of water, the proportions differed only by a small fraction, so that we may state in round numbers that the base is to the oxygen as six to one, or that

$$\text{Potassium is composed of } \left\{ \begin{array}{l} 86 \text{ potassium,} \\ 14 \text{ oxygen.} \end{array} \right.$$

100

Subsequent experiments, however, have made some change necessary in these numbers. Gay Lussac and Thenard found, that 100 parts by weight of potassium take 19.945 of oxygen from water; and Sir H. Davy, by the action of 8 grains of potassium on water, obtained, on an average, $9\frac{1}{2}$ cubic inches of hydrogen gas, showing that $4\frac{3}{4}$ cubic inches ($= 1.61$ grains) of oxygen had combined with the metal. Berzelius investigated the composition of potash, by exposing an amalgam of potassium and mercury, containing known proportions of those metals, to water; saturating the potash with muriatic acid; and determining its weight by the mu-

riate of potash formed.* The following table shows the proportions of potassium and oxygen in 100 grains of potash, as deduced from these different authorities. One hundred grains of potash contain,

	Potassium.	Oxygen.
According to Sir H. Davy	83.2	16.8
———— Gay Lussac	83.37	16.63
———— Berzelius	82.97	17.03

If deduced from the atomic theory, the true proportions should be 85 of potassium to 15 oxygen, numbers very near those originally obtained by Sir H. Davy. It is probable, indeed, that sources of inaccuracy may exist in the experiments, sufficient to account for this small deviation from theory; and that potash is a compound of 1 atom of potassium weighing 42.5 with 1 atom of oxygen weighing 7.5. Hence the weight of the atom of potash will be 50; and an atom of water (8.5) being added, the atom of hydrate of potash will weigh 58.5.

It is doubtful whether the grey compound, (mentioned in § v.) be a true *sub-oxide of potassium*, or merely a mixture of potash with potassium. If the former, it must consist of two atoms of potassium (85) with one atom of oxygen (7.5) = 92.5. But the latter view of its nature is the most probable one.

The composition of the orange oxide cannot be assigned, from the quantity of oxygen, absorbed in the experiments, by which it is produced; for in eight results, obtained by Gay Lussac and Thénard, there is not a sufficient agreement to decide this point. It seems probable that the oxygen, which converts potassium into this substance, is twice that which converts it into potash; and that the orange oxide consists of 1 atom of potassium = 42.5, + 2 atoms of oxygen = 15, which would make the weight of the atom of orange oxide 57.5

Potassureted Hydrogen Gas.

This name I would propose for the solution of potassium in hydrogen gas, which, it has already been stated, results from the action of potassium on water, and, as appears from Sir H. Davy's experiments, may be formed, directly, by heating the metal in hydrogen gas. A large portion of potassium is thus dissolved; but the greater part precipitates on cooling.

This gas is spontaneously inflammable in the atmosphere; burns with a very brilliant light, which is purple at the edges; and throws off dense vapours of potash. It loses its inflammability by keeping; is heavier than hydrogen gas; and is very dilatable by electricity. Beside the gas, which is spontaneously combustible, there is also, according to Sementini, another compound of potassium and hydrogen, which is not possessed of this property, and probably contains a less proportion of the combustible metal.

* 80 An. de Chim. 245.

Gay Lussac and Thenard * have succeeded, also, in forming a solid compound of potassium and hydrogen. The process consists in heating the metal in hydrogen gas; and the only difficulty is to regulate the heat, for a high temperature decomposes the compound. The flame of a spirit lamp, applied to potassium, in a retort filled with hydrogen gas, occasions an absorption of the gas, and the formation of a solid *hydruret of potassium*.

The colour of this substance is grey; it is destitute of metallic lustre; and is infusible. It is not inflammable, either in air or in oxygen gas, at common temperatures; but burns vividly at a high one. When strongly heated in a close vessel, it is totally decomposed; all the hydrogen it contains is liberated in the state of gas; and the potassium remains. When brought into contact with heated mercury, hydrogen gas is evolved, and an amalgam of potassium and mercury is produced.

Nitrogen gas has not, at any temperature, any action on potassium.

ART. 4.—Sodium.

The base of soda agrees, in many of its properties, with the base of potash, and exerts on several bodies a precisely similar action, except that the results are compounds of soda instead of potash. Thus with nitric acid it affords nitrate of soda; with oxymuriatic acid, muriate of soda. In this place, therefore, I shall describe only such of its properties as are peculiar to and characteristic of it.

I. SODIUM, at common temperatures, exists in a solid form. It is white, opaque; and, when examined under a thin film of naphtha, has the lustre and general appearance of silver. It is exceedingly malleable, and much softer than any of the common metallic substances. When pressed upon by a platina blade with a small force, it spreads into thin leaves; and a globule of $\frac{1}{10}$ th or $\frac{1}{12}$ th of an inch in diameter is easily spread over a surface of a quarter of an inch. This property is not diminished, by cooling it to 32° Fahrenheit. Several globules, also, may, by strong pressure, be forced into one; so that the property of *welding*, which belongs to platina and iron at a strong heat only, is possessed by this substance at common temperatures.

II. It is lighter than water. As near as can be determined, its specific gravity is as 0.9348 to 1.

III. It is much less fusible than the base of potash. At 120° Fahrenheit, it begins to lose its cohesion, and it is a perfect fluid at about 180° . Hence it readily fuses under heated naphtha.

IV. Its point of vaporization has not been ascertained; but it remains fixed, in a state of ignition, at the point of fusion of plate glass.

V. When SODIUM is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white

* Recherches, 1. 176.

crust of soda, which deliquesces more slowly than that formed on potassium.

VI. It combines with oxygen, slowly and without luminous appearance, at all common temperatures. When heated, the combination becomes more rapid; but no light is emitted till it becomes nearly red hot. The flame which it then produces is white, and it sends forth bright sparks, exhibiting a very beautiful effect. In common air, it burns with a similar colour to charcoal, but of much greater splendor.

VII. When thrown into water, it produces a violent effervescence and a loud hissing noise; it combines with the oxygen of the water to form soda; and hydrogen gas is evolved, which does not, however, as in the case of potassium, hold any of the alkaline base in solution. Neither can sodium be made to dissolve in hydrogen gas, by being heated in contact with it.

When thrown into hot water, the decomposition is more violent, and in this case a few scintillations are generally observed at the surface fluid; but this is owing to small particles of the base, which are ejected from the water, sufficiently heated to burn in passing through the atmosphere.

VIII. Its action on alcohol, ether, volatile oils, and acids, is similar to that of potassium; but with nitric acid a vivid inflammation is produced.

IX. Sodium appears to be susceptible of different degrees of oxydation. 1st. When it is fused with dry soda, a partition of oxygen takes place between the alkali and the metal. A deep brown fluid is produced, which becomes a dark grey solid on cooling. This substance is capable of attracting oxygen from the atmosphere, and of decomposing water, by which it is again converted into soda. The same *oxide of sodium* is formed, by fusing this metal in tubes of plate glass.

It is of a greyish colour, destitute of lustre, brittle, and gives hydrogen when acted on by water, but less than an equal weight of sodium. It may, however, be doubted, whether this is a compound of sodium and oxygen, or merely a mixture of the metal with soda.

2d. The second oxide of sodium (or first, if the one which has been just described be only a mechanical mixture) is *soda*. It may be formed by burning sodium, in a quantity of air containing just oxygen enough to convert the metal into alkali. It is of a grey colour; of a vitreous fracture; and requires a strong red heat for its fusion. Water is absorbed by it with violence, and converts it into *hydrate of soda*.

3d. The orange oxide of sodium may be formed, by burning the metal with an excess of oxygen. It is of a deep orange colour, very fusible, and a non-conductor of electricity. When acted on by water, its excess of oxygen escapes, and it becomes soda. It deflagrates with most combustible bodies.

X. There is scarcely any difference between the visible phenomena attending the action of the base of soda, and that of potash on sulphur, phosphorus, and the metals. The sulphuret of sodium

has a deep grey colour; the phosphuret resembles lead. Added to mercury in the proportion of $\frac{1}{40}$ th, it renders that metal a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat. The amalgam seems, like that of potassium, to form triple compounds with other metals, and even with iron and platina, which remain united with the mercury, when it is deprived of the new metal by the action of air.

The proportions in which this base unites with oxygen to form soda were investigated by the methods already described in the article potassium. The results of Sir H. Davy; of Gay Lussac and Thenard; and of Berzelius, are given in the following table:

	Sodium.	Oxygen.
Per Davy (1807) 100 soda contain	77.7	22.3
— Ditto (1811)	74.6	25.4
— Gay Lussac	74.63	25.37
— Berzelius*	74.29	27.71

The proportions that would best accord with the atomic theory, are 77.5 of sodium to 22.5 of oxygen; for this last number agrees with the weight of three atoms of oxygen. And on the supposition that soda is a compound of 1 atom of sodium + 1 atom of oxygen, by dividing 77.5 by 3 we should obtain the weight of the atom of sodium, viz. 25.8. In this case the atom of soda would weigh 33.3, and the atom of hydrate of soda 41.8. The number, assumed by Dr. Wollaston to represent sodium, (oxygen being 10) is 29.1; and soda will, therefore, be denoted, on his scale, by $29.1 + 10 = 39.1$.

SECTION II.

Pure Ammonia.

ART. 1.—*Preparation and Qualities of Ammonia.*

I. Ammonia, in its purest form, subsists in the state of a gas. In order to procure it, one of the following processes may be employed.

(a) Mix together equal parts of muriate of ammonia and dry quicklime, each separately powdered; and introduce them into a small gas bottle or retort. Apply the heat of a lamp; and receive the gas, that is liberated, over mercury.

(b) To a saturated solution of ammonia in water, or the pure liquid ammonia, in a gas bottle, apply the heat of a lamp; and collect the gas, as in a.

II. This gas has the following properties:

(a) It has a strong and very pungent smell.

(b) It immediately extinguishes flame; and is fatal to animals. Before, however, a candle is extinguished, by immersion in this gas, the flame is enlarged, by the addition of another, of a pale yellow colour, which descends from the mouth to the bottom of the jar. If the flame of the candle be only in part immersed in the gas, this yellowish flame rises a few lines above the other.

(c) It is lighter than atmospheric air. Hence a jar filled with this gas, and placed with its mouth upwards, is soon found to change its contents for common air, which, being heavier, descends, and displaces the ammoniacal gas. By the recent experiments of Messrs. Allen and Pepys,* undertaken at the desire of Sir H. Davy, 100 cubic inches of ammonia weigh 18.18 grains, barometer 30° , thermometer 60° . According to Gay Lussac, its specific gravity is to that of common air as 0.596 to 10; and hence (taking 100 cubic inches of air at 30.5 grains) 100 cubic inches of ammonia weigh 18.17 grains. Mr. Dalton assumes, that at a mean temperature and pressure, 100 cubic inches weigh 18.6 grains; and hence that its specific gravity is 6, air being 10. It does not appear that in any of these trials, the gas was artificially dried. To effect its desiccation, potash or quicklime are best adapted, for dry muriate of lime absorbs it rapidly.

(d) Ammoniacal gas is not sufficiently inflammable to burn when in contact with common air. But, when expelled from the extremity of a pipe, having a small aperture surrounded by oxygen gas, it may be kindled, and it then burns with a pale yellow flame, the products of its combustion being water and nitrogen gas.

(e) Ammoniacal gas may be decomposed by transmitting it through a red hot porcelain tube, which should be either well glazed internally, or covered externally with a lute. It has been ascertained by Thenard,† that when any of the five following metals are enclosed in the tube, they promote the decomposition of ammonia in the order set down, viz. iron, copper, silver, gold, and platina: iron being most effectual, and platina least. Iron, after the process, is found to be rendered brittle, and copper still more so. The gas obtained always consists of 3 parts hydrogen by measure, and 1 nitrogen. None of the metals is either increased or diminished in weight; and they can only, therefore, act as conductors of heat. Yet it is singular that iron decomposes a much larger quantity than platina, and at a lower temperature.

(f) It has been asserted by Guyton, that ammoniacal gas is reduced to a liquid state at 70° below 0 of Fahrenheit; but it may be questioned whether the drops of liquid, which he observed, were any thing more than the watery vapour, which the gas always contains, condensed by the cold, and saturated with ammonia.‡

* Philosophical Transactions, 1808, page 39.

† 85 Ann. de Chim. 61.

‡ This is the most probable explanation, and it is equally probable, that it is this watery vapour, that in condensation gives off its latent heat, from whence the increased temperature arises in procuring the aqua ammoniacæ. C.

(g) Ammonia is rapidly absorbed by water. A drop or two of water being admitted to a jar of this gas, confined over mercury, the gas will be immediately absorbed, and the mercury will rise, so as to fill the whole of the jar, provided the gas be sufficiently pure. Ice produces the same effect, in a still more remarkable manner. From Sir H. Davy's experiments, it appears that 100 grains of water absorb 54 grains of ammoniacal gas, or 190 cubic inches. Therefore a cubic inch of water takes up 475 cubic inches of the gas. More recently he has stated that at 50° Fahrenheit, water absorbs 670 times its bulk, and acquires the specific gravity .875.*

Alcohol, also, absorbs several times its bulk, and affords a solution of ammonia in alcohol, which possesses the strong smell, and other properties, of the gas.

(h) Water, by saturation with this gas, acquires its peculiar smell; and constitutes what has been called liquid ammonia; or, more properly, solution of pure ammonia in water. The method of effecting this impregnation will be described hereafter; and processes will be given for obtaining the solution of ammonia in considerable quantity, which cannot conveniently be accomplished by the method described in experiment *e*. This solution again yields its gas on applying heat. (See I. *b*.)

The strength of a solution of ammonia is influenced by two circumstances, the temperature of the liquid, and the pressure on its surface, for ammonia is not retained in water without external force. The intervals of temperature, required to double the force of ammoniacal vapour, were ascertained by Mr Dalton to increase in ascending. When mixed with common air, its elasticity is not altered; thus when ammoniacal gas of 15 inches force is mixed with a given volume of air, the air is doubled in bulk.

Solutions of ammonia, when mixed with water, were found by Sir H. Davy, not to be sensibly condensed; and, therefore, if the quantity of ammonia in a solution of given specific gravity be determined, it is easy to calculate the quantity in solutions of other densities. The two following Tables, it may be observed, do not exactly agree in their results, the quantity of ammonia, in solutions of the same density, being from 15 to 20 per cent. less in Mr. Dalton's Table than in Sir H. Davy's. The numbers in the latter, marked with an asterisk, were found by experiment, and from these the others were deduced.

* Elements of Chem. Phil. p. 268.

Sir H. Davy's Table of the Quantities of Ammoniacal Gas in Solutions of different Densities (Temp. 50° Fahrenheit's Barometer, 29.8).

100 parts of Specific Gravity.		Of Ammonia.	100 parts of Specific Gravity.		Of Ammonia.
.8750*	contain	32.5	.9435	contain	14.53
.8875		29.25	.9476		13.46
.9000		26.	.9513		12.40
.9054*		25.37	.9545		11.56
.9166		22.07	.9573		10.82
.9255		19.54	.9597		10.17
.9326		17.52	.9619		9.60
.9385		15.88	.9692*		9.50

Mr. Dalton's Table of the Quantities of Ammonia in Solutions of different specific Gravities.

* Specific Gravity.	Grains of Ammonia in 100 water-grain measures of liquid.	Grains of Ammonia in 100 grains of liquid.	Boiling point of the liquid in degrees of Fahrenheit.	Volume of gas condensed in a given volume of liquid.
850	30	35.3	26°	494
860	28	32.6	38°	456
870	26	29.9	50°	419
880	24	27.3	62°	382
890	22	24.7	74°	346
900	20	22.2	86°	311
910	18	19.8	98°	277
920	16	17.4	110°	244
930	14	15.1	122°	211
940	12	12.6	134°	180
950	10	10.5	146°	147
960	8	8.3	158°	116
970	6	6.2	173°	87
980	4	4.1	187°	57
990	2	2.	196°	28

ART. 2.—*Electrical Analysis of Ammonia.*

(1) Ammoniacal gas is decomposed by electricity. Into a glass tube, having a conductor sealed hermetically into one end (fig. 29), and standing inverted over mercury, pass about one tenth of a cubic inch of ammoniacal gas; and transmit through it a succession of electrical discharges from a Leyden jar. The arrangement of the apparatus for this purpose, is shown in fig. 84, pl. ix. and is describ-

ed in chap. v. sect. 1. When two or three hundred discharges have been passed, the gas will be found to have increased to almost twice its original bulk, and to have lost its property of being absorbed by water. Mix it with a quantity of oxygen gas, equal to between one third and one half of its bulk, and pass an electric spark through the mixture. An explosion will immediately happen; and the quantity of gas will be considerably diminished. Note the amount of the diminution by firing; divide it by 3; and multiply the product by 2. The result shows the quantity of hydrogen gas in the mixed gases which have been generated by electricity; for two measures of hydrogen are saturated by one of oxygen gas.

Suppose, for example, that we expand 10 measures of ammonia 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. Dividing 20 by 3 we have 6.66, which multiplied by 2 gives 13.32 measures of hydrogen gas from 10 of ammonia. Deducting 13.32 from 18, we have 4.68 for the nitrogen gas contained in the product of electrization. Therefore 10 measures of ammonia have been destroyed, and expanded into

13.32 measures of hydrogen gas,
4.68 ———— nitrogen gas.

According to the above proportions, 100 cubic inches of ammonia, which weigh about 18 grains, if they could be decomposed by electricity, would give about 133 cubic inches of hydrogen weighing 3.5 grains, and 46 of nitrogen weighing 14.4 grains, in all 17.9 grains, or one tenth of a grain less than the ammonia decomposed. Mr. Dalton obtained 185 measures of gas by decomposing 100 measures of ammonia; and, by comparing the products with the original gas, he finds that the weight of the former rather exceeds that of the latter; thus,

		Grains.	
100 measures of ammonia \times sp. gr.		.6 =	.60
produce {	51.8 nitrogen, which \times sp. gr.	.967 =	50.09
	133.2 hydrogen, which \times sp. gr.	.08 =	10.05
			<hr/> 60.74

The excess of $\frac{1}{10}$ ths of a grain in 60 he considers as too small to affect the conclusion, and as arising from unavoidable inaccuracies in some of the data.

It is contended by Gay Lussac and Thenard, and the probable accuracy of their result is admitted by Sir H. Davy,* and by Dr. Wollaston, that 100 measures of ammonia are resolvable, by analysis, into 300 of hydrogen and 100 of nitrogen. This proportion is consistent with the theory of combination in definite volumes.

* Elements of Chem. Phil. p. 269.

There is, however, considerable difficulty in ascertaining the precise amount of the gases evolved from ammonia; for if either the gas itself, or the mercury which confines it, contain any moisture, the product of gas, resulting from its decomposition, will exceed what it ought to be. The problem is one of great importance to the atomic theory, because from the proportion of the elements of ammonia, is deduced the weight of the atom of nitrogen. This will differ considerably, according to the statement, which we may adopt, of the amount of gases obtained by decomposing ammonia; their proportion to each other; and the exact specific gravities of hydrogen and nitrogen gases. From the data supplied by Mr. Dalton, it appears reasonable to believe that the weight of nitrogen in ammonia is to that of hydrogen nearly as 5 to 1, and the atom of nitrogen will, therefore, be represented by 5, and that of ammonia by $5 + 1 = 6$. On the scale of Dr. Wollaston, nitrogen is represented by 17.54; which, with 3 proportions of hydrogen, ($1.32 \times 3 = 3.96$) gives 21.5 for the equivalent of ammonia.

(2) In the Philosophical Transactions for 1809, I have described a property of ammonia, which forms the basis of a very easy and quick mode of analyzing that alkali. When mingled with oxygen gas it may be inflamed by the electric spark, precisely like a mixture of hydrogen and oxygen gases. To obtain accurate results, however, it is necessary to use less oxygen at first, than is sufficient to saturate the whole hydrogen of the alkali. This is easily calculated. If, for example, we take 10 measures of ammonia, we must use less oxygen than will saturate 13 or 14 measures of hydrogen gas, the quantity which exist in 10 of ammonia; and which require about 7 of oxygen gas. It will be advisable, therefore, not to add above 4 or 5 of oxygen. The whole (suppose 15) will probably, after firing, be reduced to about 9. To the remaining gas admit 4 or 5 measures more of oxygen; and, on passing the electric spark again, a second explosion will happen, with a diminution of about 6 measures. But, in the first explosion, the whole of the oxygen disappears, and it must therefore have saturated a quantity of hydrogen equal to 10 measures; besides which, two thirds of the second diminution ($6 \div 3 \times 2 = 4$) measures are owing to the condensation of hydrogen. Hence the whole hydrogen is $10 + 4 = 14$. The nitrogen, the whole of which exists in the product of the first detonation, is first ascertained by deducting from it (*viz.* from 9 in the present instance) the second quantity of hydrogen (4) which gives 5 for the nitrogen. These numbers may not, perhaps, be exactly obtained by experiment; and they are given merely as a general illustration of the process.

By experiments of this kind, I have determined that 100 measures of ammonia require, for saturating the hydrogen which they contain, between 67 and 68 of pure oxygen gas, and afford

Of hydrogen gas about 136 measures,
nitrogen gas 47 measures.

The results of this analysis furnish a good example of the condensation of the elements of gases which takes place on chemical union; and if we could, by any means, permanently condense a mixture of 136 measures of hydrogen with 47 of nitrogen into 100 measures, the new gas would constitute ammonia. Simple admixture of these gases, however, even in the same proportions which are obtained by analyzing ammonia, is not sufficient to generate this alkali. The caloric, with which the hydrogen and nitrogen are respectively combined, opposes, by its elasticity, an obstacle to their union, and places them beyond the sphere of their mutual attractions. If these elements are presented to each other when one or both are deprived of part of their caloric, combination then takes place; and the composition of the volatile alkali is proved synthetically, as in the following experiment.

When iron filings, moistened with water, are exposed to nitrogen gas confined over mercury, the gas, after some time has elapsed, acquires the smell of volatile alkali. In this case, the iron decomposes the water and seizes its oxygen; while the hydrogen, at the moment of its liberation, unites with nitrogen and composes ammonia. This state of condensation, or absence of the quantity of caloric necessary to bring it into a gaseous form, has been called the nascent state of hydrogen; and the same term has been applied to the bases of other gases when in a similar state.

ART. 3.—*On the Presence of Oxygen in Ammonia; and on the Amalgam of Mercury and Ammonia.*

Beside the hydrogen and nitrogen which, it has already been stated, are obtained by decomposing ammonia, it has been conjectured by Sir H. Davy that this alkali contains, also, a small proportion of oxygen, not exceeding seven or eight parts in the hundred. The arguments, which he has brought in favour of this opinion, are derived chiefly from the following facts.

1. When he decomposed ammonia by electricity, the gases produced fell short, by nearly one eleventh, of the weight of the ammonia employed; in other words, 100 grains of ammonia gave only about 91 grains of permanent gases. To obtain this result, however, several precautions are necessary, which are fully stated by Mr. Davy in the Philosophical Transactions for 1809, page 460.

2. By repeatedly transmitting ammoniacal gas (previously deprived, by passing it through a tube surrounded by a freezing mixture, of as much water as possible) over red-hot iron wire, the metal became superficially oxidized, and gained a very slight increase of weight. It is proper, however, to state that a similar experiment was made by Mr. Berthollet, junior, with different, or at least with equivocal, results. Besides, a very minute addition of oxygen might be furnished to the iron by the decomposition of a small portion of water, which ammoniacal gas, in common with all other gases, contains; and which would scarcely be separated from it by the temperature of a freezing mixture. No sufficient proof, in-

deed, has been established by the subsequent experiments of Sir H. Davy ; by my own, directed to the same object ; or by those of any other person, that oxygen exists as an element of ammonia, or that any products can be obtained by its decomposition, beside hydrogen and nitrogen gases.

It must be acknowledged, however, that the indirect evidence, in favour of the presence of oxygen as an element of ammonia, which is furnished by other experiments of Sir H. Davy, is much stronger than that derived from the results of its analysis. These experiments even go so far as to suggest that ammonia may, like the fixed alkalis, be an oxide of a peculiar metal, or at least of some compound containing the elements of a metal. And, as hydrogen and nitrogen alone are obtained by the electrical analysis of ammonia, it will follow that the metal in question is either a compound of those two bases, or a component part of one of them. If this should be established, we shall obtain proof of a fact of the greatest novelty and curiosity, *viz.* the existence of a metal or a metallic oxide, whose natural state is that of an aëriform fluid.

To understand the general outline of these experiments, it may be necessary to premise, that whenever mercury, after combination with another substance, retains in a great measure its characteristic properties, and forms what has been called an *amalgam*, we infer that the change has been produced by its union with a metal ; for the metals are the only bodies which are capable of amalgamating with quicksilver. Now it was found by M. M. Berzelius and Pontin of Stockholm, that when mercury, negatively electrified in the Voltaic circuit, is placed in contact with solution of ammonia, it gradually expands to four or five times its dimensions, and becomes a soft solid, which, at 70° or 80° Fahrenheit, has the consistence of butter. At the freezing temperature, it becomes firmer, and forms a crystallized mass, in which small shining facets appear. By this combination, it is very remarkable that mercury gains an addition of only about one twelve thousandth part of its weight ; and yet has its specific gravity so much decreased, that from being between 13 and 14 times heavier than water, it becomes only three times heavier. Its colour, lustre, opacity, and conducting powers remain unimpaired.

An easier mode of forming this amalgam, Sir H. Davy found, is to employ mercury united with a minute quantity of potassium, sodium, or barium. A compound of this sort, placed in contact with a solution of ammonia, enlarges to eight or ten times its bulk, and becomes a soft solid, which may be preserved a much longer time than the amalgam made by electrical powers, and which even changes very slowly under water.

When this amalgam is exposed to the atmosphere, oxygen is absorbed ; ammonia is reproduced ; and the quicksilver is recovered in its metallic form. When thrown into water, ammonia is also regenerated, and quicksilver separated, hydrogen gas being at the same time evolved. It appears, then, that in the formation of the amalgam, mercury combines with one or more of the elements of ammonia, and that in the subsequent oxidation of what is thus ac-

quired by the ammonia, consists the process of regenerating alkali. In this view of the subject, there certainly appears great reason to believe that oxygen is one of the constituents of ammonia; but the facts are not sufficiently simple to furnish incontrovertible evidence, and their explanation is still attended with considerable obscurity.

On the supposition that the unknown substance, which amalgamates with the mercury, is of a metallic nature, Sir H. Davy proposed for it the name AMMONIUM. All attempts to detach it from this combination, and to exhibit it in a separate form, have hitherto failed; and it still remains an object of farther investigation. One great difficulty consists in procuring the amalgam free from water, of which it always contains enough to furnish oxygen, and to regenerate alkali. The amalgam, which appears to be most free from adhering moisture, is that of potassium, mercury, and ammonium in a solid state; but even this amalgam gave on distillation nothing but hydrogen gas, beside a small proportion of ammonia. The quantity of matter, added to the mercury, in the formation of the amalgam, Sir H. Davy estimates at only $\frac{1}{12000}$ th.

Gay Lussac and Thenard* have also made a great number of experiments on this amalgam, from which they infer that it is a compound of mercury, hydrogen, and ammonia; and that mercury, to become the amalgam, absorbs 3.47 times its bulk of hydrogen gas, and 4.22 or 8.67 times its bulk of ammoniacal gas. The increased levity of the mercury, they are of opinion, may be explained by the lightness of the elements with which it combines, and by their being retained by so feeble an affinity, as to produce very little condensation. This view of the subject has been opposed by Berzelius on theoretical grounds, for a statement of which the reader may consult the 77th vol. of *Annales de Chimie*, p. 79. In the present state of the inquiry, new facts seem to be wanting to determine the nature of this singular compound.

ART. 4.—*Action of Potassium on Ammonia.*

When potassium is melted in ammoniacal gas, it is changed into an olive green fusible substance; the ammonia almost entirely disappears; and is replaced by a volume of hydrogen, precisely equal to that, which the same quantity of potassium would have disengaged from water. To effect this combination, in the way recommended by Gay Lussac and Thenard, a bent glass tube is employed, into which, when filled with perfectly dry mercury, a known quantity of ammoniacal gas is admitted, and a determinate weight of potassium is then passed through the mercury, by means of a bent iron wire. Care must be taken to shake off from the potassium, and from that part of the tube which contains the gas, all the adhering globules of mercury; otherwise they interfere with the result. The part of the tube, which contains the potassium, is next gently heated by a spirit lamp; the metal enters

* *Recherches*, i. 72.

into fusion, and is covered with a thin crust, which soon disappears; the brilliant surface of the metal then is exposed; it absorbs much ammoniacal gas, and, in a few instants, is transformed into the olive-green substance. It is necessary, at this period, to remove the lamp; and indeed the regulation of the heat, which can only be learned by experience, occasions considerable variety in the results, and in the quantity of ammonia which disappears. When the gas is used in sufficient quantity, all the potassium is changed into the olive compound; and it absorbs from 100 to 136 times its volume of alkaline gas.

When the olive-coloured substance is gradually heated in a glass vessel, in contact with hydrogen gas, it enters into a kind of ebullition; much gas is disengaged; and the mercury descends rapidly in the tube. When the tube is not heated beyond a cherry red, nothing but ammonia is disengaged. But when this degree of heat is exceeded, hydrogen and nitrogen are obtained, in the proportions required to form ammonia, viz. 3 to 1. In all cases, the residue is blackish, and is found to have lost its fusibility. Only three-fifths, however, of the ammonia which has disappeared, can be attained by heat, either in the form of alkaline gas or of its elements.

When the olive-coloured substance is brought into contact with water in close vessels, great heat is excited, and the only products are potash and ammoniacal gas, the latter in exactly the same quantity which was originally absorbed, except a few hundredth parts, which are absorbed by the moist potash. The only caution, necessary to obtain this result, is not to use more water than is absolutely necessary.

Precisely similar phenomena occur, when sodium is heated in ammoniacal gas; the sodium is transformed into an olive-green substance; ammonia is absorbed, and hydrogen is evolved, in exactly the same quantity as by the action of an equal weight of sodium on water.

The experiments of Sir H. Davy on the olive-coloured compound agree, in the main, with those of Gay Lussac and Thenard. By distillation *per se*, he obtained some undecomposed ammonia, and hydrogen and nitrogen gases, in the proportion by volume of $2\frac{1}{2}$ of the former to 1 of the latter. He examined the residue of its distillation with much attention; and describes it to be a black, shining, opaque, and brittle substance, highly inflammable when exposed to air at the ordinary temperature. When submitted by itself to distillation at a strong heat, in a platina tube (which was done with the expectation that nitrogen gas only would have been evolved), a mixture of gases was obtained, consisting of only one fifth nitrogen, and four fifths hydrogen, without any ammonia; and potash remained in the tube.

Though these facts cannot be easily explained, except on the supposition that nitrogen is an oxide; yet (as is candidly acknowledged by Sir H. Davy),* in processes so delicate and complicated,

* If the same candour was more generally exhibited by Chemical experimentalists, it is probable much benefit would result to the science.—C.

and involving such numerous data, we cannot be certain that every source of fallacy has been avoided, and every circumstance observed and reasoned upon.*

CHAPTER IX.

EARTHS.

THE term earth was, till lately, employed to denote "a tasteless, inodorous, dry, brittle, and uninflammable substance, not more than five times heavier than water." This definition, however, was rendered imperfect by the discovery, that certain earths have a strong taste, and are readily soluble in water, which yet possess the other characters of earthy bodies. Some of the earths were therefore removed from this class, and arranged among the alkalis. The classification, however, which appears to me most eligible, is that which divides them into *earths* simply, and *alkaline earths*; the latter partaking of the characters both of earths and alkalis. The alkaline earths are Barytes, Strontites, Lime and Magnesia. The earths are Silex, Alumine, Zircon, Glucine, and Yttria.†

Until the important æra of Sir H. Davy's discoveries, the earths were, with respect to the state of our knowledge, simple or elementary bodies. Many conjectures, it is true, had been formed respecting their nature; and, among these we find that their being composed of oxygen and a metallic base had been suggested as a probable theory.‡ Led by the analogy arising from his experiments on the alkalis, Sir H. Davy, however, was the first to demonstrate what had before been only imagined; and to disunite, by the agency of strong electrical powers, the constituent principles of several of this class of bodies.

In this part of the investigation, difficulties were encountered, which demanded great perseverance and more complicated processes. The affinity of the earthy bases for oxygen appears considerably to surpass that of the metals composing potash and soda; and it was found that simple exposure to the opposite electricities was not adequate to the separation of the principles, which compose the earths; or, at least, that the effect was too indistinct to furnish satisfactory evidence of their nature. Sir H. Davy was, therefore, induced to electrify the earths, as he had formerly ope-

* Among the singular changes produced in bodies by chemical action, none are more extraordinary than in the combination of nitrogen and hydrogen, to form ammonia. Here, two gases unabsorbable, inodorous, tasteless, possessing no alkaline properties, and incapable of uniting separately to the acids; form a compound possessed of all the above mentioned properties, in which they are deficient, and occupying a bulk very inferior to that of the original elements. C.

† The Augustine of Tromsdorff has been shown, by Berthollet, to be merely Phosphate of Lime. Nicholson's Journal, 8vo. vii. 117.

‡ The reader may consult a history of opinions respecting the earths, in a note to Mr. Davy's paper, Philosophical Transactions, 1808.

rated on potash, in contact with the oxides of known metals; with the expectation that the metallic base of the earth would unite with the metal contained in the oxide he employed, and form an alloy. Thus a mixture of barytes and red oxide of mercury might be expected to yield an alloy of mercury with the metallic base of barytes; and such, in fact, was the result of the experiment; for a solid amalgam adhered to the negative wire, which, when thrown into water, evolved hydrogen, leaving pure mercury, and a solution of barytes. Mixtures of lime, strontites, or magnesia with oxide of mercury, gave similar amalgams, from which the respective alkalis were regenerated by the action of air or water; but the quantity obtained was too minute for investigation.

On the suggestion of Professor Berzelius of Stockholm, the earths were next electrified negatively in contact with mercury itself; and in this way amalgams were obtained from barytes, strontites, lime, and magnesia. These compounds of mercury with the metallic base of the earths decomposed water, and the earth, which had afforded them, was regenerated. Under naphtha, they might be preserved for a considerable time; but at length they became covered with a white crust of the regenerated earth.

To procure quantities of these amalgams sufficient for distillation, the earths were slightly moistened, and mixed with one third of red oxide of mercury: the mixture was then placed on a plate of platina, a cavity was made in the upper part of it to receive a globule of mercury of from 50 to 60 grains in weight, and the whole was covered with a thin film of mercury; lastly, the plate was made positive, and the mercury negative, by a proper communication with a battery of 500 pairs.

From these amalgams, the mercury was separated by distilling in small tubes of glass filled with the vapour of naphtha. Considerable difficulties, however, attended these operations, and after all, Sir H. Davy could, in no case, be absolutely certain, that there was not a small quantity of mercury in combination with the metals of the earths.

The proportion of oxygen and metal has not yet been ascertained in any of the earths; but the evidence from analysis of their composition is perfectly satisfactory, the inflammable base appearing uniformly at the negative surface in the Voltaic circuit, and the oxygen at the positive surface.

The decomposition of the other earths, alumine, silex, zircon, and glucine, was not effected by the same means, that had been applied successfully to the alkaline earths. Combinations of potash and alumine, and of potash and silex, were electrified, with the hope that the bases of these earths would be obtained in the state of an alloy with potassium. Soda and zircon were similarly treated. In all these cases, the phenomena indicated that some portion of the several earths had been decomposed; but in too minute a quantity to examine the properties of their bases.

Lastly, potassium, amalgamated with about one third its weight of mercury, was electrified negatively under naphtha, in contact with the four earths, which were last enumerated. The potassium

generated was thrown into water, and the alkali produced saturated with acetic acid. Now if any metal had thus been obtained from the earths, it would exist in the form of an alloy with potassium; both metals would be oxydized by the water; the potassium would reproduce potash, and the other metal the earth which gave it origin, which earth would be dissolved by the solution of potash, and would reappear on adding an acid. The general tenor of the results gave great reason to conclude that alumine, silex, glucine, and zircon, are, like the alkaline earths, metallic oxides.

SECTION I.

Barytes.

Barytes may be obtained in a state of purity, by the calcination of its carbonate or nitrate, in a manner which will be hereafter described. (See chap. xi. sect. 4. art. iv.) It exhibits, when pure, the following properties.

I. Barytes, in a pure form, has a sharp caustic taste; changes vegetable blue colours to green; and serves as the intermedium between oil and water. In these respects, it bears a strong resemblance to alkalis.

II. When exposed to the flame of the blow-pipe on charcoal, it melts; boils violently; and forms small globules, which sink into the charcoal. After being kept in fusion in a crucible during ten minutes, it still, according to Berthollet, contains 9 *per cent.* of water; from theory it should contain 10.59 per cent. This, however, is true only of barytes which has been obtained from the carbonate, by a process to be described hereafter. Barytes, procured by decomposing the nitrate of that earth, is not fusible, and appears to contain little if any water.*

III. If a small quantity of water be added to recently prepared barytes, it is absorbed with great rapidity; prodigious heat is excited; and the water is completely solidified, a sort of hard cement being obtained. A little more water converts this mass into a light bulky powder; and, when completely covered with water, the barytes is dissolved. Boiling water should be employed for this purpose; unless sufficient temperature has been produced, by the sudden addition of the whole quantity necessary for solution.

IV. When the solution, prepared with boiling water, is allowed to cool slowly, it shoots into regular crystals. These have the form of flattened hexagonal prisms, having two broad sides, with two intervening narrow ones; and terminated, at each end, by a quadrangular pyramid. They lose, according to Bucholz, half their weight of water in a red heat; the barytes then continues fused, and parts with no more water, though still combined with the proportion above stated. Mr. Dalton, from his experiments,

* Nicholson's Journal, xxiii. 281.

infers that the crystals contain 30 barytes and 70 water per cent. which would make them consist of 1 atom of barytes + 20 atoms of water.

V. The crystals are so soluble, as to be taken up, when heated, merely by their own water of crystallization. When exposed to a stronger heat, they swell, foam, and leave a dry white powder, amounting to about 47 parts from 100 of the crystals. This again combines with water with great heat and violence. At 60° of Fahrenheit, an ounce measure of water dissolves only 25 grains of the crystals, *i. e.* they require for solution, $17\frac{1}{2}$ times their weight of water. Exposed to the atmosphere, they effloresce, and become pulverulent.

VI. When added to spirit of wine, and heated in a spoon over a lamp, they communicate a yellowish colour to its flame.

VII. The specific gravity of this earth, according to Fourcroy, is 4, but Hassenfratz states it at only 2.374. The former account, however, is the more probable. All its combinations have considerable specific gravity; and hence its name is derived, *viz.* from the Greek word βαρύς, signifying heavy. The weight of its atom Mr. Dalton states at 68, but this number is probably too low.

VIII. Barytes does not unite with any of the alkalis.

Of the base of barytes, or barium.—The base of barytes was obtained by Mr. Davy by distilling its amalgam, obtained in the following manner. A quantity of native carbonate of barytes was made into a paste with water, and placed on a tray of platina; a cavity was made in the paste to receive a globule of mercury, which was rendered negative, at the same time that the platina was made positive by means of a Voltaic battery, containing about 100 double plates. In a short time, an amalgam was formed consisting of mercury and barium. This amalgam was introduced into a little tube made of glass free from lead, which was bent into the shape of a retort, then filled with the vapour of naphtha, and hermetically sealed. Heat was then applied to the tube, till all the mercury was driven off.

The residuum of this distillation was a dark grey metal with a lustre inferior to that of cast iron. At the ordinary temperature of the air it remained a solid; but became fluid at a heat below redness. It did not rise in vapour, till heated nearly to redness, and then acted violently upon the glass.

When exposed to the air, this substance rapidly tarnished, and fell into a white powder, which was barytes. When this process was conducted in a small portion of air, the oxygen was found absorbed; and the nitrogen remained unaltered. A portion of it thrown into water acted upon it with great violence, and sunk to the bottom, producing barytes and evolving hydrogen gas.

The quantities obtained were too minute for an examination either of its physical or chemical qualities. It sunk rapidly in water, and even in sulphuric acid, though surrounded by globules of hydrogen equal to two or three times its volume. Hence it is probable that it cannot be less than four or five times as heavy as water.

It was flattened by pressure, but required considerable force for this effect.

The proportion of the components of barytes Sir H. Davy deduces to be 89.7 barium and 10.3 oxygen per cent. The determination of Berzelius nearly agrees with this, viz.

Barium	89.52	100.00
Oxygen	10.48	11.69
	<hr/>	<hr/>
	100	111.69

Barium, from the experiments of Gay Lussac and Thenard, appears capable of combining with a larger quantity of oxygen than exists in barytes; for, when pure barytes, prepared from the nitrate, was heated in dry oxygen gas, the gas was rapidly absorbed, and the earth became grey, and appeared glazed on its surface.

On the supposition that barytes consists of an atom of barium united with an atom of oxygen, the atom of barium should weigh 64, and that of barytes 71.5. The second oxide probably contains an additional atom of oxygen; and its atom, in that case, will weigh 79.

SECTION II.

Strontites.

I. STRONTITES (called also Strontia, from Strontian in Scotland, the place where it was first discovered) resembles barytes in many of its properties; and all that is included in the first three paragraphs of the last section may be applied, also, to this earth.

II. Like barytes, strontites is readily soluble in boiling water; and the solution, on cooling, affords regular crystals; but the shape of these differs considerably from that of barytic crystals. The crystals of strontites are thin quadrangular plates; sometimes square, oftener parallelograms: not exceeding in length, and not reaching in breadth, a quarter of an inch. Sometimes their edges are plain, but they oftener consist of two facets, meeting together, and forming an angle like the roof of a house. They adhere to each other in such a manner as to form a thin plate, of an inch or more in length, and half an inch in breadth. Sometimes they assume a cubic form.

III. These crystals undergo, by the action of heat, much the same changes as those of barytes; and leave only about 32 per cent. of the dry earth. One part of the crystals requires about $51\frac{1}{2}$ of water at the temperature of 60° for solution, but boiling water takes up half its weight. Mr. Dalton supposes the crystals to consist of 1 atom of strontites and 12 atoms of water.

IV. Boiling alcohol, with the addition of these crystals, burns with a blood red flame.

V. Strontites does not combine with alkalis. Barytes has no affinity for it; for no precipitation ensues, on mixing the watery solutions of the two earths.

From the preceding enumeration of its characters, it appears that strontites differs from barytes in the form of its crystals, which contain also more combined water, and are less soluble than those of barytes; and also in affording, with alcohol, a flame of different colour. These distinctions were deduced by Dr. Hope, from his excellent series of experiments on the two earths.* Other circumstances of distinction, derived from the properties of their respective salts, will be stated hereafter.

Of the base of strontites or strontium.—Strontium may be procured by exactly the same process as barium, substituting the native carbonate of strontites for that of barytes. It was first obtained by Sir H. Davy in 1808, but in very minute quantities. It resembled barium, had not a very high lustre, was difficultly fusible, and not volatile. It was converted into strontites by exposure to air, or by contact with water.

The product of its oxidation, strontites, Sir H. Davy thinks it probable, is composed of 86 strontium and 14 oxygen. In this case, 45 would be nearly the weight of the atom of strontium, and 52.5 that of the atom of strontites.

SECTION III.

Lime.

I. *Its external qualities.*—These may be exhibited in common quicklime, such as is employed for the purposes of building or agriculture. In the same state, it is sufficiently pure for demonstrating its chemical properties; but, when used for purposes of the latter kind, it should be fresh burnt from the kiln. For accurate experiments, it should be prepared by calcining Carara or Parian marble in a crucible for several hours. Its specific gravity is 2.3. It requires an intense heat for its fusion, and is not volatile.

II. *Relation of lime to water.*

(a) Lime absorbs water very rapidly with considerable heat and noise. This may be shown by sprinkling a little water on some dry quicklime. The above mentioned phenomena will take place, and the lime will fall into powder, which has been called *hydrat of lime*. In this compound, the lime is to the water, according to Mr. Dalton, as 23 to 8; according to Davy, as 55 to 17; and to Berzelius, as 100 to 32.1. Some care, however, is necessary in its preparation, lest more water should be added, than is essential to its constitution. It affords a very convenient form of keeping lime,

* See Edinburgh Transactions, vol. iv.

for occasional use in a laboratory; for the hydrat may safely be preserved in glass bottles, which are almost constantly broken by the earth in its perfectly dry state. The hydrat of lime differs from those of barytes and strontites, in retaining its water much less forcibly; for the whole of it may be expelled by a strong red heat.

The degree of heat, produced by the combination of lime with water, is supposed by Mr. Dalton to be not less than 800° , and is sufficient to set fire to some inflammable bodies; and when a large quantity of lime is suddenly slaked in a dark place, even light, according to Pelletier, is sometimes evolved. The caloric, which is thus set at liberty, is doubtless that contained in the water, and essential to its fluidity.* By combination with lime, water passes to a solid state, and probably even to a state of much greater solidity than that of ice. Hence, during this change, it evolves more caloric than during conversion into ice; and hence even ice itself when mixed with quicklime, in the proportion of one to two, enters into a combination which has its temperature raised to 212° . When a sufficient quantity of water has been added to reduce lime into a thin liquid, this is called *milk* or *cream of lime*.

Lime is, in some degree, convertible into vapour by combination with water. When a piece of moistened paper, stained with the juice of the violet, is held in the steam, which arises from lime suddenly slaked, its colour is changed from blue to green. Hence the smell which is perceived during the slaking of lime.

(b) Lime absorbs moisture from the atmosphere, and falls gradually into powder.

(c) Lime is very sparingly soluble in water, *viz.* in the proportion of about 1 to 500; according to Thomson, 1 to 758; to Davy, 1 to 450; and to Dalton, at 60° Fahrenheit, 1 to 778. The experiments of Mr. Dalton tend to establish a curious fact respecting the solubility of lime, *viz.* that it dissolves more plentifully in cold than in hot water.† He has given the following table, the first column of which expresses the temperature of the water; the second, the number of grains of water required to take up one grain of lime; and the third, the number required to dissolve one grain of hydrate of lime.

Temperature.	Grains of water that dissolve 1 gr. of lime.	Grains of water that dissolve 1 gr. of hydrate.
60°	778	584
130°	972	720
212°	1270	952

* If we suppose the ice at 32° , then, to give off 800° of caloric, we must have the ice reduced in temperature about 7 times lower than any hitherto-known reduction of temperature! C.

† In the above diversity of opinion as to a point of fact, we see the difficulty under which all theory must labour—and in the greater solubility of lime, in cold, than in hot water, we equally perceive the defects of our hypotheses. C.

At the freezing point, or nearly so, Mr Dalton thinks it probable that water would take up nearly twice as much lime, as is dissolved by boiling water.

Lime, when thus dissolved, forms what has been termed *lime-water*. This solution tastes strongly of lime, turns vegetable blues to green, and unites with oil, forming an imperfect soap. To prepare the solution, lime is to be slaked to a thin paste, and a sufficient quantity of water afterwards added. The mixture is to be stirred repeatedly, the lime allowed to settle, and the clear liquor decanted for use. It must be preserved in closely stopped vessels, for reasons which will be stated in the chapter on carbonic acid.

(d) Lime does not combine, in any notable proportion, with the alkalis or earths already described.

The base of lime, to which Sir H. Davy has given the name of *calcium*, he has never been able to examine, exposed to air or under naphtha. In the case, in which he was able to distil the quicksilver from its amalgam, to the greatest extent, the tube unfortunately broke whilst warm; and, at the moment that the air entered, the metal, which had the colour and lustre of silver, instantly took fire, and burnt, with an intense white light, into lime.

There appears to be only one compound of calcium and oxygen, viz. lime; and, in this, the oxygen is to the metal, according to Sir H. Davy, as 7.5 to 20. Berzelius electrified lime liquor in contact with mercury, and obtained an amalgam of mercury with calcium. On this, water was made to act; and, from the quantity of lime that was formed, he estimated its composition to be,

Calcium	71.73	. . . .	100
Oxygen	28.27	. . . .	39.4
	<hr/>		<hr/>
	100		139.4

This would make the atom of calcium to weigh 20, and the atom of lime 27.5, and of the hydrate 36.

SECTION IV.

Magnesia.

MAGNESIA possesses the properties of an alkali, but in a considerably less degree than any of the foregoing earths. Its characters are as follow :

When perfectly pure, it is entirely destitute of taste and smell. Its specific gravity is between 2 and 3

II. No heat is excited by the affusion of water, and only a very small proportion, not exceeding a 2000th its weight, of the earth is dissolved. Magnesia appears, however, to have some affinity for water; for when moistened, and afterwards dried, its weight is

found increased in the proportion of 118 to 100. When precipitated by pure potash or soda from any of its salts, it falls down in union with water as a *hydrat*, which, when dried by a very gentle heat, forms some transparent masses. In this state, according to Davy, it contains about $\frac{1}{4}$ of its weight of water; or, according to Berzelius, 100 parts of magnesia absorb from 142 to 144 of water.

III. Magnesia changes to green the blue colour of the violet; but the watery solution of magnesia, when filtered through paper, does not produce a similar effect. In this respect, it differs from lime. It reddens turmeric like the alkalis.

IV. It is not dissolved by liquid alkalis, nor by alkaline earths; and in the dry way, it has no affinity for barytes or strontites.

The base of magnesia, for which Sir H. Davy has proposed the term *magnesium*, is but imperfectly known. In the attempts to distil its amalgams, the metal seemed to act upon the glass, even before the whole of the quicksilver was distilled from it. In one experiment, in which the process was stopped, before the mercury was entirely driven off, it appeared as a solid, having the same whiteness and lustre as the other metals of the earths. It sunk rapidly in water, though surrounded by globules of gas, and produced magnesia. In the air, it quickly changed, becoming covered with a white crust, and falling into a white powder, which proved to be magnesia. This earth, Berzelius states, in round numbers, to consist of 38 or 39 per cent. oxygen, and 61 or 62 magnesium.

SECTION V.

Silex.

I. Siliceous earth, or silex, may be obtained tolerably pure from flints by the following process:—Procure some common gun-flints, and calcine them in a crucible in a low red-heat. By this treatment they will become brittle, and easily reducible to powder. Mix them, when pulverized, with three or four times their weight of carbonate of potash, and let the mixture be fused in a strong red-heat, in a crucible. The materials must bear only a small proportion to the capacity of the crucible; and the heat must at first be very moderate, and slowly increased. Even with this precaution, the mass, on entering into fusion, will be apt to overflow; and must be pressed down as it rises, by an iron rod. When this effervescence has ceased, let the heat be considerably raised, so that the materials may be in perfect fusion during half an hour, and pour the melted mass on a copper or iron dish. We shall thus obtain a compound of alkali and siliceous earth. Dissolve this in water, filter the solution, and pour it into diluted sulphuric or muriatic acid. An immediate precipitation will ensue, and, as long as this continues, add fresh portions of the solution. In precipitating the alka-

line solution of silex, more acid must be used than is sufficient to engage the alkali; and the alkaline liquor must be added to the acid, and not the reverse; for, in the latter case, the precipitate will be glass, and not silex. Let the precipitate subside, pour off the liquor that floats above it, and wash the sediment with hot water, till it comes off tasteless. Then dry it.

Silex, obtained by this process, though pure enough for the following experiments, may still contain a portion of alumine. To separate the latter earth, boil the precipitate with diluted sulphuric acid, to which a little sulphate of potash may be added. The alumine will thus be dissolved; and the silex may be freed from the solution of alum by repeated washings with water. Even silex, however, that has been most carefully washed, still give traces of potash on the application of electro-chemical powers. (Davy.)

II. Siliceous earth, as thus obtained, has the following qualities:

(a) It is perfectly white and tasteless. It is infusible, except by the intense heat of Voltaic electricity. To a certain degree it appears to be volatile, for a filamentous substance, collected from iron furnaces, and resembling amianthus, was found by Vauquelin to be pure silex.

(b) When mixed with water, it does not form a cohesive mass like alumine, and has a dry and harsh feel to the fingers. It retains, when fresh precipitated, about 26 per cent. of water, after being dried at 70° Fahrenheit. But, according to Berzelius, this water is not chemically combined.

(c) It is insoluble in water. Yet, when fresh precipitated, water has the property of retaining in solution about one thousandth of its weight.* That silex, however, is dissolved in water by processes of nature, can scarcely be doubted, when it is considered, that it is found, in considerable quantities, in a crystallized form.

(d) It is not acted on by any acid, except the fluoric. Sulphuric acid poured on this compound, according to Dalton, expels the fluoric acid, but does not unite with the silex. But though the earth itself is not dissolved by acids, yet when first combined with an alkali, it unites with several acids, forming triple salts.† When fresh precipitated, however, Dr. Marcet asserts, that it is sparingly soluble in most acids; and, for this reason, he recommends, in analysis, to precipitate silex by muriate of ammonia, which does not, like the acids, redissolve it.

(e) When prepared in the foregoing manner, and very minutely divided, silex is taken up by a solution of pure potash, or of soda, but not by ammonia. In the aggregated state of flints, however, it is perfectly insoluble in this way by alkaline solutions, an excellent illustration of the principle that a very minute division of solid bodies, by presenting a greater surface to the action of fluids, facilitates solution.

(f) When mixed with an equal weight of carbonate of potash, and exposed to a strong heat in a furnace, it forms a glass, insoluble in water, and identical in all its properties with the glass common-

* See Klaproth's Contributions, vol. i. page 399, 400.

† 81 An. Chim. 239.

ly manufactured. It is owing to the siliceous earth which it contains, that glass is decomposed by the fluoric acid. Glass, however, has occasionally other ingredients, besides the two that have been mentioned.*

(g) With a larger proportion of alkali, as three or four parts to one of silex, this earth affords a compound called, by Dr. Black, *silicated alkali*. This compound, formed by the process which has been just described, is soluble in water, and affords a good example of the total change of the properties of bodies by chemical union; for, in a separate state, no substance whatever is more difficult of solution than silex. The solution of silicated alkali was formerly termed, *liquor silicum*, or *liquor of flints*. Acids seize the alkali, and precipitate the silex, which is even separated by mere exposure to the atmosphere, in consequence of the absorption of carbonic acid by the alkali. Without attention to the circumstances mentioned in speaking of its preparation, glass, and not silex, is separated by acids.†

(h) Barytes, or strontites, and silex combine together, in a manner similar to the union of this earth with alkalis; but the combination has not been applied to any useful purpose.

(i) When a solution of silex in potash is mingled with one of barytes, of strontites, or of lime in water, or of alumine in alkali, a precipitation ensues. Hence silex may be inferred to have an affinity for all these earths, in the humid way. The composition of these precipitates is stated by Mr. Dalton in his System, p. 541.

Base of silex.—In his attempts to obtain the base of silex, or *silicium*, in a state of separation, Sir H. Davy has hitherto been unsuccessful; though the results of his experiments leave little room to doubt that this earth is, like the rest, a metallic oxide.

Berzelius decomposed silex, by fusing it with charcoal and iron in a blast furnace. He obtained an alloy of iron and *silicium*, which, by the action of a diluted acid, gave more hydrogen than the same weight of iron.‡ This process was successfully repeated by Stromeyer, and the properties of the different alloys investigated. He recommends the fusion of 7 parts of iron, 5 of silex, and from $\frac{1}{4}$ to $\frac{8}{10}$ ths of a part of soot. From the results of acting on the alloy by dilute acids, Berzelius infers silex to consist of

Silicium . . .	45.92	. . .	100
Oxygen . . .	54.08	. . .	117.38
	<hr/>		<hr/>
	100.		217.38

* See Guyton Ann. de Chim. vol. 73.

† See Dalton, p. 538.

‡ 81 An. Ch. 179. See also his account of an attempt to analyze silica, in 40 Phil. Mag. 201.

And Sir H. Davy deduces the proportions to be 31 of metal to 30 oxygen. These numbers, however, can be considered in no other light than as approximations; but since, according to recent experiments,* three parts of potassium are required to decompose one of silex, that earth cannot contain much less than half its weight of oxygen. The base, Sir H. Davy now believes not to be a metal, but a substance most resembling *boron*; and like it bearing an analogy to charcoal, sulphur, and phosphorus.†

SECTION VI.

Alumine.

I. *Alumine* may be obtained free from other earths, but still combined with carbonic acid, by precipitating a solution of alum in water by the crystallized carbonate of potash. To secure its complete purification from sulphuric acid, Guyton advises that the precipitate be re-dissolved in nitric acid, that nitrate of barytes be cautiously added to the solution, till it no longer occasions milkiness, and that the alumine be afterwards precipitated, or separated from the nitric acid by heat.‡ Electro-chemical analysis, however, in this as in many other instances, shows the imperfection of the common methods of separating bodies from each other; for the most carefully prepared alumine yields the metals of soda and potash, when negatively electrified in contact with mercury.§ Berzelius, also, found that when alumine is precipitated either from the sulphate or nitrate, it is contaminated with those acids; but not with the muriatic, when thrown down from the muriate of alumine by ammonia.

II. Alumine has the following properties:

1. It is destitute of taste and smell.
2. When moistened with water, it forms a cohesive and ductile mass, susceptible of being kneaded into a regular form. It is not soluble in water; but retains a considerable quantity, and is, indeed, a hydrate, containing, when dried at the temperature of the atmosphere, almost half its weight of water. Even after ignition, alumine has such an affinity for moisture, that it can scarcely be placed on the scale, without acquiring weight. Berzelius found that 100 parts of alumine, after being ignited, gained $15\frac{1}{2}$ from a dry atmosphere, and 33 from a humid one. For full saturation, 100 grains of alumine, he ascertained, require 54 of water.||
3. It does not affect blue vegetable colours.

* Phil. Trans. 1814, p. 67.

† Berzelius has lately attempted to shew that silex acts the part of an acid, in many of its combinations; and hence we are by him, presented with an extensive class of silicates. C.

‡ Annales de Chimie, xxxii. 64.

§ Davy, Philosophical Transactions, 1808.

|| 82 An. Chim. 14.

4. It is dissolved by the liquid fixed alkalis, and is precipitated by acids unchanged. In ammonia, it is very sparingly soluble. It is not soluble in alkaline carbonates.

5. Barytes and strontites combine with alumine, both by fusion and in the humid way. In the first case, the result is a greenish or bluish coloured mass. In the second, two compounds are formed. The first, containing an excess of alumine, is in the state of an insoluble powder; the other, having an excess of the alkaline earth, remains in solution. Alumine may be united, by fusion, with the fixed alkalis, and with most of the earths.

6. Alumine, as will be afterwards shown, has a strong affinity for colouring matter.

7. Alumine has the property of shrinking considerably in bulk, when exposed to heat, and its contraction is in proportion to the intensity of the heat applied. On this property is founded the *pyrometer of Wedgwood*, which measures high degrees of heat, by the amount of the contraction of regularly shaped pieces of china clay. The pieces of clay are small cylinders, half an inch in diameter, flattened on the under surface, and baked in a low red-heat. The contraction of these pieces is measured, by putting them between two fixed rulers of brass or porcelain, twenty-four inches long, half an inch distant from each other at one end, and three tenths of an inch at the other. The rulers are divided into 240 equal parts, called degrees, which commence at the wider end; and each of which is equal to 130° of Fahrenheit. When the clay piece is fixed in its place, before exposure to heat, it is stationary at the first degree, which indicates about 1077° of Fahrenheit. After being strongly heated, in a small case which defends it from the fuel, its bulk is diminished, and it slides down, between the converging rulers, till stopped by their approach. The number on the graduated scale, opposite to the upper end of the piece, indicates the degree of heat to which it has been exposed. In the Appendix, rules may be found for reducing the degrees of Wedgwood's pyrometer to those of Fahrenheit's thermometer.*

Almost every thing that has been said respecting the base of silex is true, also, of that of alumine; for Sir H. Davy attempted the decomposition of the two earths by much the same processes. All that his results afford, is a strong presumption that alumine is a metallic oxide; but its base, *aluminium*, has not been yet obtained in such a state as to make it a fit object of investigation. Yet alloys have been formed, which give sufficient evidence of its existence; and the presence of oxygen in alumine is proved, by its changing potassium into potash when ignited with that metal.

* In the 4th edition of the American Dispensatory will be found some notice of a probable error as to the presumed range, &c. of Wedgwood's pyrometer. C.

SECTION VII.

Zircon.

I. THIS earth was discovered by Klaproth in the year 1789, in a precious stone from the island of Ceylon, called Jargon or Zircon; and has since been detected in the hyacinth. It may be obtained by the following process:

Reduce the hyacinth to fine powder, which may be done in an agate mortar, after previously igniting the stone, and plunging it into cold water, to render it brittle. Mix the powder with nine times its weight of pure potash; and project it, by a spoonful at once, into a red-hot crucible, taking care not to add fresh portions till the former ones are melted. When the whole is in fusion, increase the heat for an hour, or an hour and a half. When the crucible has cooled, break it, and detach its contents; reduce them to powder, and boil them with distilled water. Let the insoluble part subside; decant the clear liquor, and wash the sediment with water, till the washings cease to precipitate muriated barytes. On the residuum pour muriatic acid to excess, and boil it during a quarter of an hour; filter the liquor, and evaporate to dryness in a leaden vessel. Re-dissolve the dry mass; filter again, and precipitate the zircon with carbonate of soda. The carbonate of zircon is thus obtained, from which the carbonic acid may be expelled by calcination.

II. Zircon has the following properties:

1. It has the form of a fine white powder, which has somewhat the harsh feel of silex, when rubbed between the fingers. It is entirely destitute of taste and smell. Its specific gravity exceeds 4.

2. It is insoluble in water; yet it appears to have some affinity for that fluid, for it retains, when slowly dried after precipitation, one third its weight, and assumes a yellow colour and slight transparency, like that of gum Arabic.

3. It is insoluble in pure liquid alkalis; nor does it even combine with them by fusion; but it is soluble in alkaline carbonates. In the foregoing process, therefore, the carbonate of soda should not be added to excess.

4. Exposed to a strong heat, zircon fuses, assumes a light grey colour; and such hardness, on cooling, as to strike fire with steel, and to scratch glass, or even rock crystal.

5. Its action on other earths has not been fully investigated.

6. It is precipitated from its solutions in acids by triple prussiate of potash.*

III. The base of zircon, or *zirconium*, is still unknown to us, though investigated by Sir H. Davy in the same manner as the base of silex. When potassium was brought into contact with ignited zircon, potash was formed, and dark metallic particles were diffused through the alkali.

* Klaproth, ii. 214.

SECTION VIII.

Glucine.

I. THIS earth was discovered by Vauquelin, in the year 1798. He obtained it from the aqua marine or beryl, a precious stone of a green colour, and very considerable hardness, which is found crystallized in Siberia. Glucine has since been detected in the emerald of Peru, and in the gadolinite. The following process may be employed to separate it from the beryl:

Let the stone, reduced to a fine powder, be fused with three times its weight of pure potash. To the fused mass add a quantity of water, and afterwards diluted muriatic acid; which last will effect a complete solution. Evaporate the solution to dryness, redissolve the dry mass, and add carbonate of potash so long as any precipitation ensues. Dissolve the precipitate in sulphuric acid, add a little sulphate of potash; and, on evaporation, crystals of alum will be obtained. By this process the alumine is detached. The residuary liquor, which yields no more crystals, contains the glucine, and a small portion of alumine. Add a solution of carbonate of ammonia to excess; this will throw down the alumine, and the glucine will remain dissolved by the superabundant carbonate. When this solution is evaporated to dryness, and moderately heated, the alkaline carbonate is expelled, and a carbonate of glucine remains, in the proportion of 16 parts from every 100 parts of the stone.

II. Glucine has the following properties:

1. It is a fine white and soft powder, resembling alumine in its sensible properties; and, like that earth, adhering to the tongue. Its specific gravity is 2.97.
2. It has no action on blue vegetable colours.
3. It does not harden, or contract, like alumine, by heat; and is infusible.
4. It is insoluble in water, but forms with it a ductile paste.
5. It is soluble in liquid potash and soda, but not in the solution of pure ammonia. In these respects it agrees with alumine.
6. Glucine is soluble in carbonate of ammonia; a property distinguishing it from alumine.
7. It appears, like alumine, to have an affinity for colouring matter.
8. With the different acids it forms combinations, which have a sweet and rather an astringent taste. Hence its name has been derived from *γλυκὺς*, signifying sweet.
9. It is not precipitated by triple prussiate of potash.

III. We have no knowledge of the base of glucine. When obtained, its proper denomination will be *glucinum*. The general fact of its existence is proved by igniting glucine with potassium, which is thus changed into potash.

SECTION IX.

Yttria or Ittria.

I. THIS earth was discovered in 1794, by Professor Gadolin, in a stone from Ytterby in Sweden, and its title to the character of a peculiar earth rests, also, on the unquestionable authority of Klaproth and Vauquelin, both of whom have made it the subject of experiment. The following process for obtaining it, is described by Vauquelin in the 36th volume of the *Annales de Chimie*, page 150.

Fuse the pulverized stone (called Gadolinite) in the manner already described, with twice its weight of potash; wash the mass with boiling distilled water, and filter. The filtered solution, which has a beautiful green colour, yields, during evaporation, a black precipitate of oxide of manganese. When this has ceased to appear, allow the liquor to stand; decant the clear part, and saturate with nitric acid. Let the insoluble part be, also, digested with extremely dilute nitric acid, which will take up the soluble earths only, and will leave, undissolved, the silex and oxide of iron. Let the two portions be mingled together, and evaporated to dryness; then re-dissolved and filtered: by which means any remains of silex and oxide of iron are separated. To obtain the yttria from the nitric solution, it would be sufficient, if no other earth were present, to precipitate it by carbonate of ammonia; but small portions of lime, and of oxide of manganese, are still present along with it. The first is separated by a few drops of carbonate of potash; and the manganese, by the cautious addition of hydro-sulphuret of potash. The yttria is then to be precipitated by pure ammonia, washed abundantly with water, and dried. It amounts to about 35 per cent. of the stone.

II. Yttria has the following properties:

1. It is perfectly white; but it is difficult to preserve it free from a slight tinge of colour, owing to its contamination with oxide of manganese.

2. It has neither taste nor smell; and it is smooth to the touch, like alumine.

3. It is insoluble in water, and infusible except by an intense heat.

4. It is very ponderous; its specific gravity being 4.842.

5. It is not attacked by pure alkalis; and, in this respect, it differs from glucine and alumine, both of which are abundantly soluble in fixed alkalis.

6. Like glucine, it is soluble in carbonate of ammonia, but five or six times less so than that earth; or, in other words, of equal quantities of glucine and yttria, the latter requires for solution five or six times more of the carbonate of ammonia than the former.

7. It is soluble in most acids; and is precipitated by pure alkalis, by barytes, and by lime.

8. From these solutions it is also precipitated by the oxalic acid,

and by oxalate of ammonia, in a state resembling precipitated muriate of silver. Prussiate of potash throws it down in small white grains passing in a short time to pearl grey; phosphate of soda in a white gelatinous form; and infusion of galls in brown flocculi.

9. Yttria, which has been a long time exposed to the action of fire, gives out oxygenized muriatic acid, when dissolved in common muriatic acid; thus manifesting one property of a metallic oxide.*

III. The base of yttria has not yet been exhibited in a separate form; but the presence of oxygen in yttria is established by its converting potassium into potash, when ignited with that metal.

CHAPTER X.

OF ACIDS IN GENERAL.

THE term *acid* is assigned to all bodies, that possess one or more of the following properties.

1. The acids have a peculiar taste, which is expressed in common language, by the term sourness. This is very different, as to its degree, in different acids. In some it is so intensely strong, that they cannot be applied to the tongue without producing pain; and it characterizes them, even when diluted with several hundred times their weight of water. The sourness of others is such only, as to render them agreeable to the palate.

2. The acids redden blue vegetable colours; and they possess this property even when very greatly diluted. Hence blue vegetable infusions, or papers stained with them, become tests of the presence of uncombined acids. A single drop of sulphuric acid is capable of reddening a large quantity of water coloured with litmus, or with syrup of violets.

3. The acids combine chemically with alkalis, earths, and metallic oxides; and totally destroy the peculiar qualities of those bodies. Let a few ounce-measures of water be tinged blue with syrup of violets; add a few drops of solution of potash, and the colour will be changed to green; then drop in, very slowly and cautiously, sulphuric acid much diluted, and the blue colour will be restored. At this point, neither the acid nor the alkali is in excess, or, they are said to *neutralize* each other; and, on farther examination, it will be found that the other characteristic qualities of the components have ceased to be apparent in the compound.

It is not necessary, however, in order to entitle a body to rank among the acids, that it should possess all the qualities which have been enumerated. The prussic acid, for example, is neither sour to the taste, nor does it redden blue vegetable colours; but yet, from its manifesting the properties of chemical combination, enumerated under the third head, it is arranged among the acids.

* Nicholson's Journal, xviii. 77.

Other bodies, again, are excluded (though perhaps improperly) from this class, which possess, partly, the characters of acids. Thus sulphuretted hydrogen changes the blue colours of vegetables to red; and combines chemically with alkalis and earths.*

All the acids were inferred by Lavoisier, from analogy with those which had already been decomposed, to contain oxygen, which was considered, by that distinguished philosopher, as the general principle or cause of acidity. Since the brilliant discoveries of Sir H. Davy, we may, with equal justice, consider oxygen as the general principle of alkalinity. And besides, it has been lately proved with respect to the new substance *iodine*, and has been rendered highly probable with respect to *chlorine*, that those bodies afford acids by combining with hydrogen. The theory, therefore, that oxygen is essential to acidity, must be abandoned.† But it is still important to know that most of the acids contain oxygen; because it explains many of their most interesting qualities, depending on the transfer of oxygen from the acids to the bodies on which they act.

The peculiar properties of each acid are derived from the combustible base, with which the oxygen is united; and so, also, is its specific name. Thus sulphur, when oxygenated, affords sulphuric acid; carbon, carbonic acid; and so of the rest. But the same combustible base admits of being combined with different proportions of oxygen; and the compounds, thus generated, are distinguished by a very different train of qualities. Sulphur, for example, when combined with the full proportion of oxygen, with which it is capable of uniting, affords a very dense and corrosive acid,

* It appears therefore much more strictly entitled to a place amongst the acids, than the prussic above mentioned. C.

† So much for theory! "Quantum mutata!" This is perhaps the most powerful lesson against forming hypotheses (theory, falsely called, in general) that has ever yet appeared in the schools of philosophy. Thirty years have not yet elapsed, since the illustrious Lavoisier, by giving to the world his *Elements of Chemistry*, completely changed the whole aspect of the science. The nomenclature, in which he bore so conspicuous a part, and which he has so luminously explained in those elements, was not the least important of the means which led to the overthrow of the doctrines of phlogiston. The theories of acidification, and of combustion, were pronounced perfect by most of his contemporaries; and many of his opinions of inferior magnitude, were also considered as completely settled. A few revolving years have, however, shown how imperfect were the facts then known, on which to erect so imposing a superstructure. The discoveries that have since been made, through the agency of galvanism and other causes, have made this beautiful fabric totter to its fall. The nomenclature itself, from what is stated in the text, is in many respects erroneous, however correct the principles may be on which it was established; and from the multiplicity of terms, which now begin to overburden the memory, (nearly as much so as the illegitimate and barbarous names of former times,) there is great reason to believe that, ere long, an entirely new nomenclature will require to be constructed. Since, however, even in France, the doctrines of Lavoisier are no longer implicitly followed, it is to be hoped that in this country, we shall be equally open to conviction; and not hesitate to renounce what may be incorrect, even though it may cause us to retrace the steps in which we have been educated. Would not Lavoisier have done so, had he lived to the present period? My opinion of his candour, and of his love of truth, prevents a doubt in my mind upon the subject. C.

called the sulphuric; when oxygenated in a less degree, it yields a penetrating and suffocating gas called the sulphurous acid.* By these two terminations, the degrees of oxygenation are distinguished. Thus we have the phosphoric and phosphorous acids, the nitric and nitrous; the termination *ic* denoting an acid with its full proportion of oxygen. In some cases, a combustible base, which affords an acid when fully oxygenated, constitutes only an oxide when combined with a less quantity of oxygen. Carbon, for example, affords carbonous oxide and carbonic acid, but, so far as is hitherto known, no intermediate product.

The following table exhibits the compounds, which result from the oxygenation of some of the principal combustible bases.

100 parts of		united with	Result.
Carbon . .	{	. . 265 oxygen . .	carbonic acid.
		. . 132½ — . .	carbonous oxide.
Sulphur . .	{	. . 150 oxygen . .	sulphuric acid.
		. . 100 — . .	sulphurous acid.
		. . 50 — . .	oxide of sulphur?
Nitrogen	{	. . 285 oxygen . .	nitric acid.
		. . 228 — . .	nitrous acid.
		. . 114 — . .	nitric oxide.
		. . 57 — . .	nitrous oxide.
Phosphorus	{	. . 114 oxygen . .	phosphoric acid.
		. . 76 — . .	phosphorous acid.
		. . 38 — . .	oxide of phosphorus?

It is in consequence of the oxygen which they contain, that several of the acids are decomposed by inflammable substances, with the disengagement of intense heat and light; or that the acids are (as they have been well termed by Dr. Thomson) *supporters of combustion*. This property belongs most remarkably to the acids, in which oxygen is most weakly combined. Thus the nitric acid retains its oxygen so feebly, that many inflammable substances, when merely introduced into it at the ordinary temperature of the atmosphere, take fire and burn with vehemence.†

All acids in a solid or liquid state, it has been observed by Berzelius, contain water as an essential element, and do not abandon it without decomposition. Sulphuric and nitric acids, for example, cannot exist independently of water. In acids that are capable of assuming a solid form, water appears to exist in two states, as a base essential to the constitution of the acid, and as water of crystallization. Thus the citric acid in crystals contains 21 per cent.

* This word is often, I may say generally, incorrectly spelled, *sulphureous*—so *phosphoreous*, &c. This, and others ending in *ous*, ought never to have the interposed *e*, if we wish to write in conformity with the principles of the established nomenclature. C.

† And yet, although thus admitted to “retain its oxygen so feebly,” it is regarded as being undecomposed (and therefore I should say, *inactive*) in the process of procuring nitrogen from flesh! C.

of water, of which only one third can be expelled by heat without destroying the acid.

Every acid, with a few exceptions, is capable of uniting with each individual of the classes of alkalis, earths, and metallic oxides. In these compounds, the separate qualities of the component principles are in many instances no longer apparent, and hence they have been called *neutral salts*. In every salt, then, there are present two distinct ingredients. The acid, of whatever kind it may be, has been denominated, by Lavoisier, the *salifying principle*; and the body, with which the acid is combined, whether an alkali, an earth, or an oxide of any of the common metals, the *salifiable base*, or simply *the base*. The salts, formed by an individual acid with all these different bases, may be considered as a genus or class; and may be distinguished by a generic name, expressive, in part, of their composition. This generic name is taken from that of the acid. The combination of sulphuric acid, for instance, with any base, is called a *sulphat* or *sulphate*; of phosphoric acid a *phosphate*; and so of the rest. The name of the individual salt is derived from that of the base. Thus we have the *sulphat of potash*, the *sulphat of soda*, &c. But sulphur, phosphorus, and other bodies, it has already been observed, are susceptible of different degrees or stages of oxygenation; and afford, in these different stages, acids which are characterized by a peculiar train of properties. The compounds, also, which result from the union of two different acids, having the same combustible base, with alkalis and earths, are altogether different from each other. The salt, for example, which sulphuric acid affords with potash, is wholly unlike that which results from the combination of sulphurous acid with the same base. It was necessary, therefore, to distinguish the compounds of the more oxygenated from those of the less oxygenated acid; and this has been done by changing the termination from *at* or *ate* to *ite*. Thus the salts, formed with sulphurous and phosphorous acid, are called sulphites and phosphites; as sulphite of potash, phosphite of soda, &c.

An important law has been deduced, by Berzelius, respecting the combination of acids with bases, *viz.* that the quantities of different bases, required to saturate a given quantity of any acid, all contain the same quantity of oxygen. For example, 100 parts of sulphuric acid are saturated by a quantity of any base, containing 20 parts of oxygen; and 100 parts of muriatic acid by a quantity of base, which holds in combination 30.49 parts of oxygen. These proportions do not seem to be changed by varying the state of oxygenation in the acid; for sulphites absorb oxygen to become sulphates, and still remain neutral; the phosphites, when changed into phosphates, give up phosphorus and continue neutral. It would appear, therefore, that the proportion between the oxygen of the acid, and that of the base, is regulated by the proportion of the combustible ingredients of the acid and base to each other. In sulphurets, for example, the metal and sulphur are in such proportion, that when both are oxygenated, the oxide, resulting from the one, precisely saturates the acid, resulting from the other. These

facts strongly confirm the atomic theory, and cannot, indeed, be explained by any other.

Hitherto, we have considered the compounds of acids with their respective bases only in the state of neutral compounds, in which neither the acid, nor the base predominates. But we have several instances, in which a neutral compound is susceptible of uniting with an additional quantity of acid or of base, and thus of acquiring an entirely new set of properties. Potash and tartaric acid, for example, when united in the proportions which neutralize each other, compose an extremely soluble salt, which has no action on vegetable colours; but with a double proportion of acid, a salt is formed, which requires a large quantity of water for solution, has an acid taste, and instantly reddens vegetable blue colours.

To distinguish this and other similar salts, the epithet *acidulous* was first proposed; but, for the sake of brevity, it has now become customary to prefix the Latin preposition *super*. Thus we have the *super-tartrate* of potash; the *super-sulphate* of potash, &c. On the contrary, when the base is predominate, we denote the deficiency of acid by the preposition *sub*, as *sub-carbonate* of potash, *sub-borate* of soda, &c. In the instance of the compounds of oxalic acid with potash, Dr. Wollaston has employed the words *binoxalate*, and *quadroxalate*, to express the proportions in which the acid unites with the base; and this method of nomenclature he has extended to other salts, formed by the union of an acid and base in different proportions. There are several cases, however, in which it is extremely difficult to decide, whether a salt is to be classed among neutral, or among *sub* or *super* salts.*

There are a few instances of salts with compound bases; and in cases of this kind it is customary to annex to the generic name those of both the bases. Thus, for example, we have the tartrate of potash and soda, the phosphate of ammonia and magnesia, or as it is sometimes called ammoniaco-magnesian phosphate.

In no part of chemistry is the advantage of the new nomenclature more sensibly experienced, than in the class of neutral salts; for the number of these compounds is susceptible of being multiplied to an immense extent. If the knowledge of the name did not lead to that of the compound, scarcely any memory would be adequate to retain them. But by changing the arbitrary titles, formerly assigned to them, for names expressive of their composition, we are furnished with a kind of artificial memory, which renders their recollection perfectly easy. Thus for the terms *butter of antimony*, *sugar of lead*, and *Glauber's salt*, are now substituted the more appropriate epithets of *muriate of antimony*, *acetate of lead*, and *sulphate of soda*.

Of those acids, which are supporters of combustion, a few retain the same property even in combination. Nitrate of potash, it is well known, enters into active inflammation with charcoal, sulphur, and other combustible bodies. This is owing to the quantity of

* See the remarks of Berzelius, *Ann. de Chim.* vol. lxxix. p. 264, and vol. lxxxii. p. 225.

oxygen which the nitric acid contains, and which is less strongly attracted by the nitrogen than by the newly added body.

Other properties, general to the class of salts, have already been described in the section on cohesion; especially their solubility, and their crystallization. On this last subject, it is necessary to add the general law deduced by Berzelius, viz. that in all salts, the water of crystallization contains a quantity of oxygen either equal to that of the base; or a multiplication of it by 1, 2, 3, 4, &c. as far as 10; or a division by the same numbers. In sub-carbonate of soda, and muriate of ammonia, the quantity of oxygen in the water is *equal* to the oxygen in the base; in muriate of barytes, and in sulphates of ammonia and lime, the oxygen of the water is *double* that of the base; in green sulphate of iron, the oxygen of the water is *seven times* that of the oxide of iron; and, lastly, in carbonate and phosphate of soda, it is *ten times* that of the base.*

The *decrepitation* of salts when suddenly heated, or expulsion of water from them with noise, is owing probably to the water being held not chemically but mechanically; for it is observed only in salts, which contain too small a quantity of water, to allow its being considered as an essential element;† such as sulphate of potash, and muriate of soda.

The *deliquescence* of salts has been observed by Gay Lussac to bear a proportion to the temperature, at which saturated solutions of the respective salts boil. The more deliquescent the salt, the higher is the boiling point of its solution; and if not deliquescent at all, the boiling point of its solution is the same as that of water.‡

Having premised these general observations respecting the acids and their compounds, I shall proceed to the history of the different acids, and of the compounds which they yield with the several alkaline and earthy bases. Under each head, I shall first enumerate the properties of the base of the acid; and its combinations with such other combustible bodies, as may already have been introduced to the reader's notice.

CHAPTER XI.

CARBONIC ACID AND ITS BASE.—CARBONATES.—BINARY COMPOUNDS OF CARBON.

THE bodies, which form the subject of this chapter, will be described in the following order.

I. CARBON, and its various modifications.

* 80 An. de Chim. 187, note.

† This position at best is highly questionable; for since such extreme diversity appears amongst the salts in this respect, it seems too much to assert so positively, that the water in the salts above mentioned is not essential to them, at least in their perfect crystalline form. C.

‡ 82 An. de Ch. 171.

II. The compound of carbon and oxygen, in its highest stage of oxygenation, constituting CARBONIC ACID ; and, connected with it, the class of salts called CARBONATES.

III. The OXIDE OF CARBON, or CARBONOUS OXIDE, a compound containing less oxygen than exists in carbonic acid.

IV. The various combinations of carbon and hydrogen, termed CARBURETTED HYDROGEN.

SECTION I.

Carbon and Charcoal.

It had long been admitted as an established truth, chiefly on the evidence of the experiments of Guyton,* that the diamond is the only form of pure carbon ; and that charcoal is a compound of carbon and oxygen, or an oxide of carbon. The important experiments of Messrs. Allen and Pepys have suggested, however, that the diamond and charcoal, though so widely remote from each other in external characters, are, as to their chemical nature, identically the same ; and that the difference between them, in all probability, results merely from the respective states of aggregation of their particles.

Some doubts, it must be confessed, were thrown on this conclusion by an experiment of Sir H. Davy, in which an inflammable gas was obtained, by igniting charcoal, in a Toricellian vacuum, by a powerful Voltaic battery. But the hydrogen, thus evolved, may reasonably be ascribed to water, from which it is extremely difficult to free charcoal.† The absence of oxygen from charcoal was proved, by heating it with potassium, for no potash was produced ; but when potassium was heated with diamond, there was an indistinct appearance of the production of that alkali. The recent experiments of the same philosopher ‡ tend to establish, that char-

* Annales de Chimie, xxxi.

† After reflecting on the great diversity in the amount of the quantities of principles, found by the analysis of different experimenters in the same substance, some of which have been adverted to ; it would perhaps not be quite prudent, positively to deny the existence of hydrogen as essential to charcoal ; especially, as from what is said in the text, the reverse is not absolutely established ; for it is only "reasonably" to be ascribed, &c. Proof however is what is wanted, not conjecture ; and since charcoal, as we are immediately afterwards told, "*invariably contains either hydrogen or water*"—unless it can be demonstrated not to be essential, the opposite opinion must be regarded as superior in weight ; and the onus probandi, lies with those who deny such a principle in it. Neither, until analysis is much more perfect, can we with perfect confidence venture to affirm that the "Diamond is absolutely free both from water and hydrogen." If we cannot come to an absolute conclusion, with respect to the constitution of such a substance as charcoal ; how are we to expect the analysis of the Diamond, the most precious body we are acquainted with, and which, from its high price precludes much experimental research, can be so easily accomplished, as to preclude all necessity of future investigation ? C.

‡ Phil. Trans. 1814, p. 557.

coal invariably contains either hydrogen or water; for when it is burned in pure and dry oxygen gas, some moisture is always deposited. The quantity, however, is so small, that hydrogen cannot exist in charcoal as an essential ingredient, or in any definitive proportion.* The diamond appears to be absolutely free both from water and hydrogen; and it is in this respect only, and in the mechanical arrangement of its particles, that we have any evidence of its differing from charcoal.

To obtain charcoal free from contamination, pieces of oak, willow, hazle, or other woods, deprived of the bark, may be buried in sand in a crucible, which is to be exposed, covered, to the strongest heat of a wind-furnace. For purposes of accuracy, charcoal must be used when recently prepared, and before it has had time to become cold; or if it cannot be had fresh made, it must be heated again to redness under sand in a crucible.

A remarkably pure charcoal may be obtained, by passing the vapour of oil of turpentine, or of spirit of wine, through a red-hot tube. It then appears in the form of a black impalpable powder. In the experiments of Sir H. Davy, this sort of charcoal, by combustion in oxygen gas, gave a much smaller product of moisture than any other.

From 100 parts of each of the following woods, Messrs. Allen and Pepys obtained the annexed quantities of charcoal; *viz.* from fir, 18.17; lignum vitæ, 17.25; box, 20.25; beech, 15; oak, 17.40; mahogany, 15.75.

Charcoal has the following properties:

1. In its aggregated state it is black, perfectly insipid, and free from smell; insoluble in water, brittle, and easily pulverized. In close vessels, and entirely secured from contact with air, it is unchanged by any degree of heat. A gas, however, may be collected from it by distillation, which consists of hydrogen and carbon, and perhaps a little oxygen. Berthollet has found, also, in the aëriform products of its distillation, a considerable proportion of nitrogen.†

2. Charcoal has the singular property of absorbing gases without alteration. Fill a jar with common air, or any other gas, and place it over dry mercury: take a piece of charcoal, red hot from the fire, and plunge it in the mercury of the bath: when cold, let it be passed into the vessel of gas, without bringing it into contact with the atmosphere. A considerable diminution of the gas will be speedily effected.

Count Morozzo has given the following table of the quantities of different gases absorbed, in the foregoing manner, by charcoal. In each experiment, he employed a piece of that substance 1 inch long, and $\frac{3}{4}$ of an inch diameter. The receiver containing gas was 12 inches long and 1 inch diameter.

* It must be observed, that over and above this moisture, thus deposited, a portion will be retained in solution by the carbonic acid gas produced;—the quantity therefore is greater, than at first sight appears. C.

† Mémoires d'Arcueil, ii. 484.

<i>Gas absorbed.</i>	<i>Inches.</i>	<i>Gas absorbed.</i>	<i>Inches.</i>
Atmospheric	3½	Nitrous	2½
Carbonic acid	11	Hydrogen	2½
Ammonia	11	Oxygen	6½
Muriatic acid	11	Sulphurous acid	5½
Sulphuretted hydrogen	11		

This power in charcoal is probably mechanical, and depends only on the porous nature of vegetable and animal charcoal; for it does not, Sir H. Davy asserts, exist in plumbago, coke, or stone-coal.

3. From the experiments of Rouppe,* it appears, that if charcoal, which has imbibed oxygen gas, be brought into contact with hydrogen gas, water is generated.

4. Charcoal, by long exposure to the atmosphere, absorbs one twentieth of its weight, three fourths of which are water.†

The charcoal of different woods, Messrs. Allen and Pepys found to increase very differently in weight; that from fir gaining, by a week's exposure, 13 per cent.; that from *lignum vitæ*, in the same time, 9.6; from box, 14; beech, 16.3; oak, 16.5; mahogany, 18. The absorption goes on most rapidly during the first 24 hours; and by much the largest part of what is absorbed consists of water merely.

5. Charcoal resists the putrefaction of animal substances. A piece of flesh-meat, which has begun to be tainted, may have its sweetness restored by rubbing it daily with powdered charcoal; and may be preserved sweet for some time by burying it in powdered charcoal, which is to be renewed daily. Putrid water is also restored by the application of the same substance; and water may be kept unchanged at sea, by charring the inner surface of the casks which are used to contain it.‡ It produces, also, a remarkable effect in destroying the taste, odour, and colour of many vegetable and animal substances.§ Common vinegar, by being boiled on it, is rendered perfectly limpid. Rum and other varieties of ardent spirit, which are distinguished by peculiar colours and flavours, lose both by maceration with powdered charcoal.|| The colour of litmus, indigo, and other pigments, dissolved or suspended in water, is destroyed. Putrid animal fluids, also, are completely deprived of their odour. These effects are most readily produced by animal charcoal.¶

* *Annales de Chimie*, xxxii. 1.

† Clement and Desormes.

‡ Lovitz, *Annales de Chimie*, xiv.

§ 79 *Ann. de Chim.* 80.

|| Lovitz asserts that the vile smell of *bed bugs*, is destroyed, by triturating them with charcoal. C.

¶ Although this fact was known, and acted on many years past, in Europe, yet *patent rights* have been granted in this country, for distilling spirits, &c. from charcoal. See "New Experiments with Charcoal, by Mr. Lovitz—in *Crell's Chemical Journal*, vol. 2. London, (translation) 1792; and from which, all that is known in America, relating to the use of charcoal, is undoubtedly borrowed. Such patents could not stand a trial in our courts of justice; but it might be a

6. Charcoal is a very slow conductor of caloric. The experiments of Guyton have determined, that caloric is conveyed through charcoal more slowly than through sand, in the proportion of three to two. Hence powdered charcoal may be advantageously employed to surround substances which are to be kept cool in a warm atmosphere; and also to confine the caloric of heated bodies.

7. The weight of the atom of charcoal is inferred by Mr. Dalton to be 5.4, that of oxygen being 7. But if the weight of the atom of oxygen be corrected to 7.5, the atom of charcoal will then weigh 5.8. The evidence in favour of this conclusion will be stated in the following section.

SECTION II.

Combustion of Carbon.

If a small piece of charcoal be exposed red-hot to the common atmospheric air, it exhibits scarcely any signs of combustion, and soon becomes cold. But if a similar piece, heated to about 800° or 1000° Fahrenheit, or nearly to redness, be introduced into a receiver filled with oxygen gas, it continues to burn with greatly increased splendour, and with bright scintillations. If the charcoal be pure, and its proportion rightly adjusted, it is entirely consumed. When the quantity burnt is considerable, a manifest production of water takes place, and the inner surface of the glass vessel becomes covered with moisture, which disappears, however, on standing. This portion of water owes its origin to the union of oxygen with the hydrogen which, it appears from Sir H. Davy's experiments, and from the results of its distillation, all charcoal contains.

The diamond, also, which was formerly considered as an incombustible substance, may be consumed by a sufficiently intense heat, even in atmospherical air. The Florentine academicians, in the year 1694, appear first to have ascertained this fact, by exposing diamonds to the focus of a powerful burning lens. Their experiment has been repeated by subsequent chemists, with various modifications. It has been found by Sir George Mackenzie that diamonds burn, when exposed on a muffle, to the temperature of about 14° Wedgwood. In oxygen gas the diamond takes fire, when the focus of a powerful lens is thrown upon it; and continues to burn, though removed out of the focus, with a steady brilliant light, visible in the strongest sunshine.* The portion of diamond, which remains unconsumed, is not rendered black, as has been asserted, but is found to have lost its lustre, like glass acted on by fluoric acid. When the vessel has become cold, no production whatsoever of

question, whether a person thus obtaining one, for a discovery *not his own*, might not be prosecuted for damages by any one to whom he had disposed of his (assumed) rights. C.

* Davy's Phil. Trans. 1814.

moisture is visible. By effecting its combustion in this way, Guyton thought he had determined that the diamond, in an equal weight, contains more real carbon than common charcoal. His experiments, however, have not been confirmed by those of subsequent chemists. One fact, however, has been contributed on this subject by Guyton, which is of considerable value. The diamond, he first ascertained, is destroyed when thrown into red-hot and melted nitre; and this property, it will afterwards appear, has been successfully applied by Mr. Tennant to the determination of the nature of the diamond, and of the proportion of ingredients in carbonic acid.

To collect the products of the combustion of carbon, requires rather a complicated apparatus. Lavoisier burnt charcoal in a known quantity of oxygen gas, which was confined by mercury, the charcoal being set on fire by a bent iron wire heated to redness.* Messrs. Allen and Pepys collected the products of the combustion of charcoal and of the diamond, by burning them separately in a platinum tube, set horizontally in a charcoal furnace, and connected, at each extremity, with a mercurial gazometer. An idea of this arrangement will best be obtained by imagining that to each end of the tube *c*, fig. 40, the pipe *b* of a gazometer, like that shown, fig. 35, is connected. At the outset of the experiment, one of the gazometers was filled with a known quantity of the purest oxygen gas, and the other was empty. The tube was then made red-hot; and the gas, being forced alternately from one gazometer to the other, was repeatedly brought into contact with the red-hot charcoal or diamond. The volume of the gas was found to be entirely unaltered; but it had received an addition to its weight, precisely equal to what the charcoal or diamond, on weighing, was ascertained to have lost; and it was partly converted into a gas, totally different in its properties from oxygen gas, and called carbonic acid. It appears, therefore, that oxygen gas, by conversion into carbonic acid, undergoes neither expansion nor condensation. This conclusion is farther established by the recent experiments of Sir H. Davy, on the combustion of the diamond in oxygen gas.

SECTION III.

Carbonic Acid.

FROM the quantity of charcoal or diamond consumed in the experiments of Allen and Pepys, and the quantity of oxygen converted into carbonic acid, it is easy to infer the proportion of carbon and oxygen in the new compound. Reducing these to centesimal proportion, for every 28 or 29 grains of the combustible base which disappeared, 100 grains of carbonic acid (\equiv about 201 cubic inches) were generated; and it is remarkable that these proportions agree

* Elements of Chemistry, pl. iv. fig. 3.

exactly with those originally stated by Lavoisier. The same quantity of carbonic acid resulted, also, from the combustion of between 28 and 29 grains of diamond. Hence it may be inferred, that the actual quantity of carbon in equal weights of diamond and charcoal is precisely the same; and that charcoal is not, as has hitherto been supposed, an oxide of carbon. If this inference required confirmation, it is furnished by its agreement with Mr. Tennant's experiments on the combustion of the diamond, published in 1797. Two grains and a half of diamond, (this philosopher found), when consumed in a tube of gold by means of nitre, gave nine grains of carbonic acid, which in 100 parts should contain, therefore, as nearly as possible, 28 parts of diamond or carbon. The mean of a number of Messrs. Pepys and Allen's experiments give the following statement of the composition of carbonic acid:

Carbon	28.60	100.
Oxygen	71.40	250.
		100.

It is remarkable, also, that these numbers are precisely those which result from the experiments of Clement and Desormes.*

They differ, however, a little from those of Saussure, jun., who states the carbon in 100 grains of carbonic acid at between 27.04 and 27.38 grains. The results of Gay Lussac, which are conformable with the views of Berzelius, and, as nearly as possible, with those of Dr. Wollaston, are,

Carbon	27.376	100.	37.55
Oxygen	72.624	265.12	100.
		100.	365.12
			137.55

Mr. Dalton assumes the composition of carbonic acid to be, in round numbers, 28 of charcoal and 72 of oxygen; from whence he deduces the weight of the atom of charcoal to be 5.4. But if the atom of oxygen weigh 7.5, and if the proportions of Gay Lussac be correct, the atom of charcoal will weigh 5.65, and that of carbonic acid (considering it as a ternary compound of two atoms of oxygen and one of charcoal) will be 20.65.

In addition to the proofs of the constitution of carbonic acid, derived from its synthesis, we have also the evidence of its analysis, which may be effected by several processes.

1. By passing a succession of electrical discharges through a quantity of carbonic acid gas confined over mercury, I have found that the gas is separated into oxygen, and a gas called carbonous oxide, which consists of oxygen united with a larger proportion of carbon, than exists in carbonic acid. When the carbonic acid, which escapes decomposition, is washed out by a solution of potash, an electric spark inflames the residuary mixture; the oxygen and carbonous oxide again uniting, and re-composing carbonic acid.†

* Annales de Chimie, xxxix. 42.

† Philosophical Transactions, 1809, page 448.

2. When a mixture of carbonic acid and hydrogen gases is electrified, the hydrogen combines with part of the oxygen in the acid, and reduces it to the state of carbonous oxide.

3. When potassium is heated in carbonic acid gas, Sir H. Davy has found that it inflames; part of it is oxidated at the expence of the acid; and part of it unites with the charcoal which is precipitated.

4. By simply heating phosphorus in carbonic acid gas, no step is made towards the decomposition of the latter. But by applying phosphorus to some of the combinations of carbonic acid, the phosphorus is oxygenated, and carbon appears in a separate form. The original discovery of this fact is due to Mr. Tennant,* and the details of the experiment have been ably followed up by Dr. Pearson.†

To exhibit this fact, provide a tube of very thin glass about one third of an inch wide, and 18 or 20 inches long, sealed at one end. Coat it, within about an inch of the sealed extremity, with a lute of sand and clay; and when this is dry, put into it as much purified phosphorus, in small pieces, as will fill the uncoated part. Then cover the phosphorus with carbonate of lime, or carbonate of soda which has been deprived of its water of crystallization. Let the part of the tube, which contains the carbonate, be made red-hot by means of a portable furnace; and at this moment, apply heat to the part containing the phosphorus, sufficient to melt and raise it into vapour. The vapour of the phosphorus, coming into contact with the red-hot carbonate, will decompose the carbonic acid; and charcoal will be found in the residue of the process, in the form of a very light and black powder.

To procure carbonic acid, sufficiently pure for the exhibition of its properties, the combustion of charcoal is far from being the best process. The student may, therefore, have recourse to another, the rationale of which he will not, at present, understand; but which will be explained afterwards. Into a common gas bottle, put a little powdered marble or chalk, and pour on this sulphuric acid, diluted with five or six times its weight of water. A gas will be produced, which those, who have an opportunity, may receive over mercury; but a mercurial apparatus is not absolutely essential, since the gas may be collected over water, if used immediately when procured. Carbonic acid may, also, be separated by heat alone, from carbonate of lime. For this purpose, coarsely powdered chalk or marble may be put into the iron vessel *a*, fig. 85, which may be connected, by means of the conducting pipe *b*, with a gazometer. The receiving cylinder of the latter, after a sufficiently long continuance of heat to the bottle *a*, will be filled with carbonic acid gas. Its properties are the following:

Properties of Carbonic Acid.

(a) *It extinguishes flame.*—Set a vessel, filled with the gas, with

* Philosophical Transactions, 1791, page 192.

† Ibid, 1792, page 289.

its mouth upwards, and let down a lighted candle. The candle will instantly be extinguished.

A person, says Dr. Priestley, who is quite a stranger to the properties of this kind of gas, will be agreeably amused with extinguishing lighted candles, or blazing chips of wood, on its surface. For the smoke readily unites with this kind of air; so that little or none of it escapes into the atmosphere. It is remarkable, that the upper surface of this smoke, floating in the fixed air, is smooth and well defined; whereas the lower surface is exceedingly ragged, several parts hanging down to a considerable distance within the body of the carbonic acid, and sometimes in the form of balls, connected to the upper stratum by slender threads, as if they were suspended. The smoke is also apt to form itself into broad flakes, exactly like clouds. Making an agitation in this air, the surface of it (which still continues exactly defined) is thrown into the form of waves; and if, by this agitation, any of the carbonic acid be thrown over the sides of the vessel, the smoke, which is mixed with it, will fall to the ground, as if it were so much water.

(b) *It is fatal to animals.*—Put a mouse, or other small animal, into a vessel of the gas, and cover the vessel, to prevent the contact of common air. The animal will die in the course of a minute or two.

By means of this gas, butterflies, and other insects, the colours of which it is desirable to preserve, for the purpose of cabinet specimens, may be suffocated better than by the common mode of killing them with the fumes of sulphur.

(c) *This gas is heavier than common air.*—According to Sir H. Davy, 100 cubic inches, at 55° Fahrenheit, and 30 inches of the barometer, weigh 47.5 grains; and at 60°, with the same pressure, would weigh 47.11. Messrs. Allen and Pepys have lately determined that 100 cubic inches, at 60° Fahrenheit, and 30 inches barometer, weigh 47.26 grains. Its specific gravity, according to Biot and Arago, is 1.5196; and hence, if 100 cubic inches of atmospheric air weigh 30.5 grains, the same bulk of carbonic acid gas should weigh 46.34 grains. It will be a sufficiently near approximation to state the weight of 100 cubical inches to be 47 grains, at a mean of the barometer and thermometer.

To show the superior specific gravity of this gas in a general way, the following experiment will be sufficient. Let a long glass tube, proceeding from a gas bottle, containing powdered marble and dilute sulphuric acid, be twice bent at right angles; let the open end of the longer leg reach the bottom of a glass jar, perfectly dry within, and standing with its mouth uppermost. The carbonic acid will expel the common air from the jar, because it is heavier.—This superior gravity may be farther shown as follows: When the jar is perfectly filled with the gas (which may be known by a lighted candle being instantly extinguished when let down into it), take another jar, of rather smaller size, and place at the bottom of it a lighted taper, supported by a stand: then pour the contents of the first-mentioned jar into the second, as if you

were pouring in water. The candle will be instantly extinguished, as effectually as if it had been immersed in water.

It is owing to its superior gravity, that carbonic acid gas is often found at the bottom of deep wells and of mines, the upper part of which is entirely free from it. Hence the precaution, used by the sinkers of wells, of letting down a candle before they venture to descend in person.

(d) *Carbonic acid gas is absorbed by water.*—Fill partly a jar with this gas, and let it stand a few hours over water. An absorption will gradually go on, till at last none will remain. This absorption is infinitely quicker when agitation is used. Repeat the above experiment, with this difference, that the jar must be shaken strongly. A very rapid diminution will now take place. In this manner water may be charged with rather more than its own bulk of carbonic acid gas; and it acquires, when thus saturated, a very brisk and pleasant taste. This impregnation is most commodiously effected by an apparatus, sold in the glass shops, under the name of Nooth's machine.

The influence of pressure, in occasioning water to absorb a larger quantity of carbonic acid, may be illustrated by an apparatus, which I have described in the Philosophical Transactions for 1803, but which cannot be understood without the engraving that accompanies it. From a long series of experiments with this apparatus, I have deduced, as a general law, that water takes up the same volume of compressed carbonic acid gas, as of gas under ordinary pressure. And since the space occupied by any gas, is inversely as the compressing force, it follows that the quantity of gas, forced into water, is directly as the pressure. Thus, if water under common circumstances, takes up an equal bulk of carbonic acid, under the pressure of two atmospheres, it will absorb twice its bulk; under three atmospheres three times its bulk, and so on.

(e) *From water, thus impregnated, carbonic acid is again set at liberty, on boiling the water, or by exposing it under the receiver of an air-pump.*—During exhaustion, the gas will escape so rapidly, as to present the appearance of ebullition; and will be much more remarkable than the discharge of air from a jar full of common spring water, confined, at the same time, under the receiver, as a standard of comparison.

(f) *Carbonic acid is expelled from water by freezing.*—If the impregnated water be rapidly congealed, by surrounding it with a mixture of snow and salt, the frozen water has more the appearance of snow than of ice, its bulk being prodigiously increased by the immense number of air bubbles. When water, thus congealed, is liquefied again, it is found, by its taste, and other properties, to have lost nearly the whole of its carbonic acid.

(g) *Carbonic acid gas, when combined with water, reddens vegetable blue colours.*—This may be shown by dipping into water, thus impregnated, a bit of litmus paper, or by mixing, with a portion of it, about an equal bulk of the infusion of litmus. This fact establishes the title of the gas to be ranked among acids. When an infusion of litmus, which has been thus reddened, is either heated,

or exposed to the air, its blue colour is restored, in consequence of the escape of the carbonic acid. This is a marked ground of distinction from most other acids, the effect of which is permanent, even after boiling.

(h) *Carbonic acid gas precipitates lime water.*—This character of the gas is necessary to be known, because it affords a ready test of the presence of carbonic acid whenever it is suspected. Pass the gas, as it proceeds from the materials, through a portion of lime water. This, though perfectly transparent before, will instantly grow milky:—Or, mix equal measures of water saturated with carbonic acid and lime water. The same precipitation will ensue. By means of lime water, the whole of any quantity of carbonic acid, existing in a mixture of gases, cannot, however, be removed, as Saussure, jun. has shown; but recourse must be had, in order to effect its entire absorption, to a solution of caustic potash or soda.

(i) *By the application of the test, (h), it will be found, that carbonic acid is generated in several cases of combustion.*—1. Let the chimney of a small portable furnace, in which charcoal is burning, terminate, at a distance sufficiently remote to allow of its being kept cool, in the bottom of a barrel provided with a moveable top, or of a large glass vessel having two openings. A small jar of lime water being let down into the tub or vessel, and agitated, the lime water will immediately become milky. The gas will also extinguish burning bodies, and prove fatal to animals that are confined in it. Hence the danger of exposure to the fumes of charcoal, which, in several instances, have been known to be fatal. These fumes consist of a mixture of carbonic acid and nitrogen gases with a very small proportion of oxygen gas. 2. Fill the pneumatochemical trough with lime water, and burn a candle, in a jar filled with atmospheric air, over the lime water till the flame is extinguished. On agitating the jar, the lime water will become milky. The same appearances will take place, more speedily and remarkably, if oxygen gas be substituted for common air. The carbonic acid, thus formed during combustion, by its admixture with the residuary air, renders it more unfit for supporting flame, than it otherwise would be from the mere loss of oxygen. Hence, if a candle be burnt in oxygen gas, it is extinguished long before the oxygen is totally absorbed, because the admixture of carbonic acid with oxygen gas, in considerable proportion, unfits it for supporting combustion. Whenever any substance, by combustion in oxygen gas or common air over lime water, gives a precipitate, soluble with effervescence in muriatic acid, we may confidently infer that it contains carbon.

(k) *The respiration of animals is another source of carbonic acid.*—On confining an animal, in a given portion of atmospheric air, over lime water, this production of carbonic acid is evinced by a precipitation. The same effect is also produced more remarkably in oxygen gas. The production of carbonic acid, by respiration, may be proved, also, by blowing the air from the lungs, with the aid of a quill, through lime water, which will immediately grow milky.

The carbonic acid, thus added to the air, unfits it for supporting life, not merely by diminishing the proportion of oxygen gas, but apparently by exerting a positively noxious effect. Hence a given quantity of air will support an animal much longer, when the carbonic acid is removed as fast as it is formed, than when suffered to remain in a state of mixture. It has been found, that an atmosphere, consisting of oxygen gas and carbonic acid, is fatal to animals, though it should contain a larger proportion of oxygen than the air we commonly breathe.

(l) *Carbonic acid retards the putrefaction of animal substances.*—This may be proved, by suspending two equal pieces of flesh meat, the one in common air, the other in carbonic acid gas, or in a small vessel through which a stream of carbonic acid is constantly passing. The latter will be preserved untainted some time after the other has begun to putrefy.

(m) *Carbonic acid gas exerts powerful effects on living vegetables.*—These effects, however, vary according to the mode of its application.

Water, saturated with this gas, proves highly nutritive, when applied to the roots of plants. The carbonic acid is decomposed, its carbon forming a component part of the vegetable, and its oxygen being liberated in a gaseous form.

On the contrary, carbonic acid, applied as an atmosphere, by confining a living vegetable in the undiluted gas over water, is injurious to the health of the plant, especially in the shade. M. Saussure, jun. found, that a proportion of carbonic acid in common air, greater than one eighth, is always injurious to vegetation; but that in this proportion it promotes the growth of plants, and is manifestly decomposed.

Carbonic acid is susceptible of combination with alkalis, earths, and metals, and forms an order of compounds, termed *carbonates*. At present, however, we shall only attend to the results of its union with alkalis, and earths. In the compounds of carbonic acid with these bases, and especially with the alkalis, the qualities of the base still predominate. The alkaline carbonates, for example, retain the taste, though in a less degree, which characterizes their bases; and change blue vegetable colours to green. Ammonia, also, preserves in a great measure its odour and volatility. By combination with the earths, however, carbonic acid produces a more perfect neutralization of their properties.

SECTION IV.

*Carbonates.*ART. 1.—*Sub-carbonate, and Carbonate of Potash.*

(a) *Carbonic acid gas is very abundantly absorbed by a solution of pure potash.*—The simplest mode of showing this fact is the following: Fill a common phial with carbonic acid gas over water; and, when full, stop it by applying the thumb. Then invert the bottle in a solution of pure potash, contained in a cup, and rather exceeding in quantity what is sufficient to fill the bottle. The solution will rise into the bottle, and, if the gas be pure, will fill it entirely. Pour out the alkaline liquor, fill the bottle with water, and again displace it by the gas. Proceed as before, and repeat the process several times. It will be found, that the solution will condense many times its bulk of the gas; whereas water combines only with its own volume.

This experiment may be made, in a much more striking manner, over mercury, by passing into a jar, about three fourths filled with this gas, a comparatively small bulk of a solution of pure potash, which will condense the whole of the gas. If dry potash be substituted in this experiment, no change will ensue; which proves, that solution is essential to the action of alkalis on this gas.

One hundred grains of potash unite with 42.42 carbonic acid to form the sub-carbonate, which, therefore, contains per cent. according to Berard,

Potash	70.21
Acid	29.79
	<hr/>
	100.

The composition of this salt is differently stated by other writers, viz.

	Acid.	Base.
According to Dalton 100 grains consist of	51.10	68.9
————Dulong	30.70	69.30
————Dr. Wollaston	31.71	68.29

The proportions of 70 to 30 agree very nearly with the notion, that the sub-carbonate of potash is constituted of an atom of carbonic acid, weighing 20.8, and an atom of potash weighing 50; and that the weight of its atom is 70.8. The affinity of carbonic acid for potash, though apparently feeble, is in reality very strong; since it has the power of expelling, from potash, the whole of the water, which that alkali contains in the state of a hydrate.

(b) *The changes effected in the alkali may next be examined.*—It will be found, after having absorbed as much carbonic acid as it is

capable of condensing, to have lost much of its corrosive and penetrating taste, and will no longer destroy the texture of woollen cloth; but it still turns to green the blue infusion of vegetables. Before its absorption of this gas, no remarkable change ensued on mixing it with diluted sulphuric acid; but if this, or almost any other acid, be now added, a violent effervescence will ensue, arising from the escape of the gas that had been previously absorbed. If the mixture be made in a gas bottle, the gas, that is evolved, may be collected, and will be found to exhibit every character of carbonic acid.

For experimental purposes, sub-carbonate of potash may be obtained from crystals of tartar (super-tartrate of potash) calcined in a crucible; then lixivated with water; and evaporated to dryness. By this treatment, the salt yields about one third its weight of sub-carbonate. Or it may be mixed with about an eighth of purified nitrate of potash, and wrapped up in paper in the form of cones, which may be placed on an iron dish, and set on fire. The residuary mass is to be lixivated, and evaporated as before directed. Or purified nitrate of potash may be mixed with a fourth of its weight of powdered charcoal, and projected into a red-hot crucible, the contents of which are to be poured, when in fusion, into an iron dish. The sub-carbonate, thus obtained, amounts to rather less than one-half the nitre which has been employed. Even when thus prepared, it is apt to contain some impurities, consisting chiefly of a minute proportion of sulphate and muriate of potash, with a little silex, from which it is extremely difficult entirely to free it. That which is procured from burnt tartar may be made to crystallize, in which state it contains 20.60 per cent. of water.

(c) In this state of sub-saturation with carbonic acid, potash generally occurs in the arts. The potash and pearl-ash of commerce, are *sub-carbonates* of potash, of different degrees of purity. The quantity of carbonic acid, contained in these alkalis, may be learned by a very simple experiment. Put one or two hundred grains of the alkali into a Florence flask, and add a few ounce measures of water. Take also a phial filled with dilute sulphuric acid, and place this, as well as the flask, in one scale. Balance the two, by putting weights into the opposite scale, and when the equilibrium is attained, pour gradually the acid into the flask of alkali, till an effervescence no longer ensues. When this has ceased, the scale containing the weights will be found to preponderate. This shows that the alkali, by combination with an acid, loses considerably of its weight; and the exact amount of the loss may be ascertained, by adding weights to the scale containing the flask and phial, till the balance is restored.

(d) As it is sometimes of importance to know what proportion of real alkali a given weight of potash or pearl-ash contains, it may be proper to point out how this information may be acquired. I shall, therefore, in Part III. Chap. III. of this work, describe at length the apparatus and process employed for the purpose by M. Descroizilles. Another less accurate mode of determining the strength is founded on the following property of carbonate of potash.

(e) *Sub-carbonate of potash dissolves very readily in water, which, at the ordinary temperature, takes up more than its own weight.*—Hence, when an alkali, which should consist almost entirely of sub-carbonate of potash, is adulterated, as very often happens, with substances of little solubility, the fraud may be detected by trying how much of one ounce will dissolve in two or three ounce-measures of water. In this way I have detected an adulteration of one third its weight of sulphate of potash. There are certain substances of ready solubility, however, which may be used in adulterating pearl-ashes, as common salt for example; and when this is done, we must have recourse to the acid test for the means of discovery.

The strongest solution of this salt that can be obtained has the specific gravity 1.54, and contains 48.8 per cent. by weight, or eight atoms of water to one of salt.

(f) Sub-carbonate of potash, when exposed to the atmosphere, attracts so much moisture, as to pass rapidly to a liquid state.* This change is termed *deliquescence*. All the water thus absorbed is expelled again by a heat of 280°.

(g) When submitted, in a crucible, to a high temperature, it fuses; but none of its carbonic acid is expelled.

Bi-carbonate of Potash.

Carbonate of potash, in the state which has been already described, is far from being completely saturated with acid. This sufficiently appears from its strongly alkaline taste. It may be much more highly charged with carbonic acid, by exposing a solution of one part of the sub-carbonate in three of water to streams of carbonic acid gas, in a Nooth's machine, or other apparatus; or by the process to be described in art. 3, g. When a solution of alkali, after this treatment, is very slowly evaporated, it forms regular crystals. According to Dr. Wollaston,† the quantity of acid in the bi-carbonate is exactly double that in the sub-carbonate. This he proves by disengaging the carbonic acid, from each, by a stronger acid, such as the sulphuric. One part of the bi-carbonate, thus treated, is found to give twice as much carbonic acid as the sub-salt. Berthollet‡ obtained 189 grains of carbonic acid from 500 of this salt; and as nearly as possible, the same quantity from 1000 grains of the salt, reduced by calcination to sub-carbonate. Berard found, that 100 parts of potash are fully saturated by 85.86 carbonic acid.§ The following Table exhibits the composition of the bi-carbonate, as stated by him, and by Dr. Wollaston. One hundred grains contain,

	Acid.	Base.	Water.
According to Berard	42.01	48.92	9.07
Dr. Wollaston	43.9	47.1	9.0

* This solution was formerly called "Oleum Tartari per deliquium." C.

† Philosophical Transactions, 1808.

‡ Mém. d'Arcueil, ii. 470.

§ 71 Ann. de Chim. 42.

The atomic constitution, deducible from these proportions, is one atom of potash, two atoms of carbonic acid, and one atom of water.

The BI-CARBONATE OF POTASH differs from the sub-carbonate in the following particulars.

1. In the greater mildness of its taste. Though still alkaline, yet it may be applied to the tongue, or taken into the stomach, without exciting any of that burning sensation, which is occasioned by the sub-carbonate.

2. It is unchanged by exposure to the atmosphere.

3. It assumes the shape of regular crystals. The form of these crystals is a four-sided prism, with dihedral triangular summits, the facets of which correspond with the solid angles of the prism.

4. It requires, for solution, four times its weight of water at 60°; and, while dissolving, absorbs caloric. Boiling water dissolves five-sixths of its weight; but, during this solution, the salt is partly decomposed, as is manifested by the escape of carbonic acid gas. The quantity thus separated amounts, according to Berthollet, to about $\frac{1}{10}$ th the weight of the salt.

5. By calcination in a low red-heat, the portion of carbonic acid, which imparts to this salt its characteristic properties, is expelled, and the salt returns to the state of a sub-carbonate.

(k) Bi-carbonate of potash, in all its forms, is decomposed by the stronger acids; as the sulphuric, nitric, and muriatic, which unite with the alkali, and set the gas at liberty.

This may be shown by pouring, on the carbonate contained in a gas bottle, any of the acids, and collecting the gas by a proper apparatus.

ART. 2.—Carbonate of Soda.

There are two distinct compounds of carbonic acid and soda, the one containing precisely half as much carbonic acid as the other.

The first, or *sub-carbonate*, is obtained by carefully re-crystallizing the soda of commerce. The primitive crystal of this salt is an octohedron, with a rhombic base of 60° and 120°, the planes of which meet, at the summit, at 104°, and, at the base, at 76°. This crystal varies by becoming cuneiform, and also by the replacement of the solid angle of the summits by planes parallel to the base, affording the decahedral variety, which is most common. These crystals have the following properties.

1. When heated to 150° Fahrenheit, they fuse; boil violently, if the heat be raised; and leave a dry white powder. What escapes is water only; and it forms, according to Berard, 62.69 per cent. of the weight of the salt; to Kirwan, 64; Dalton, 63; and D'Arceet, 63.6. The crystals, also, lose their water by exposure to the atmosphere, or *effloresce*.

2. If the fused salt be kept boiling in a retort, Mr. Dalton finds that it deposits a hard, small-grained salt, which contains only 46 per cent. of water; the clear liquid has the specific gravity of

1.35; and, on cooling, concretes into a fragile icy mass. The first compound, Mr. Dalton estimates to consist of 1 atom of carbonate and 10 of water; the second of 1 atom of salt and 5 of water; and the third of 1 atom of salt and 15 of water.

3. Water at 60° takes up half its weight of the sub-carbonate; and boiling water dissolves rather more than its own weight. The strongest solution, that can be preserved at the temperature of the atmosphere, has the specific gravity 1.26; but even this is liable to partial crystallization.

4. If 100 grains of the salt be slowly added to a quantity of diluted sulphuric acid, more than sufficient for saturation, and of known weight, the loss of weight will show the quantity of carbonic acid contained in 100 grains. From experiments of this kind, joined with others on its loss by fusion, Berard deduces its composition to be

Acid	13.98	100	60
Base	23.33	166	100
Water	62.69		
<hr/>			
100.			

Independently of the water of crystallization, its composition has been differently stated, viz. 100 grains contain

	Acid.	Base.
According to Berard	37.50 . .	62.50
———— Dulong	40.09 . .	59.91
———— Dalton	40.40 . .	59.60
———— Klaproth	42. . .	58.
———— Kirwan	40.10 . .	59.90

Its atomic constitution is supposed by Mr. Dalton to be one atom of soda with one atom of carbonic acid.

When a solution of the sub-carbonate of soda is saturated, by passing through it a stream of carbonic acid gas, or when a solution of 100 parts of the salt are heated with one of 14 parts of sub-carbonate of ammonia, we obtain by evaporation an indistinctly crystallized salt, which is the *bi-carbonate of soda*. The taste of this salt is much milder than that of the sub-carbonate; and it requires a much larger quantity of water for solution. To bring soda to this state of saturation, 100 parts of the alkali require 125.33 of carbonic acid. The bi-carbonate is, therefore, composed, in 100 parts,

	Acid.	Base.	Water.
According to Berard, of	49.95 . .	29.85 . .	20.20
———— Rose	49. . .	37. . .	14.

And as the acid in this salt is, as nearly as possible, double that of the sub-carbonate, it must be constituted of two atoms of acid and one atom of soda. By exposure to a red heat, the whole of its

water, and half its carbonic acid, are expelled, and it is converted into the dry sub-carbonate.

ART. 3.—*Sub-carbonate and Carbonate of Ammonia.*

Ammonia, in its pure state, exists in the form of a gas, permanent over mercury only : and carbonic acid has, also, the form of an aërial fluid. But, when these two gases are mixed together over mercury in proper proportions, (*viz.* one measure of carbonic acid to two or three of alkaline gas,) they both quit the state of gas, and are entirely condensed into a white solid body.* The compound thus formed, it appears from the recent experiments of Gay Lussac, is the *sub-carbonate* of ammonia; for the two gases, he finds, cannot by simple mixture, be made to unite in the proportions necessary to neutralize each other. To effect this, it is necessary to expose a solution of sub-carbonate of ammonia in water to carbonic acid gas, in which case the affinity of the water concurs in overcoming the elasticity of the acid gas.

Those persons who are not possessed of a mercurial trough may compose the sub-carbonate of ammonia in the following manner:—Provide a globular receiver, having two open necks opposite each other. Into one of these introduce the neck of a retort, containing carbonate of lime and dilute sulphuric acid, from which a constant stream of carbonic acid will issue. The inner surface of the globe will remain perfectly unclouded. Into the opposite opening, let the mouth of a retort be introduced, containing the materials for ammoniacal gas. (Chap. vii. sect. 2.) The inner surface of the globe will now be covered with a dense crust of carbonate of ammonia.

The sub-carbonate of ammonia may also be formed, by passing into a jar three fourths filled with carbonic acid over mercury, a solution of pure ammonia, which will instantly effect an absorption of the gas. The ordinary mode of producing it for useful purposes will be described hereafter.

(*b*) Sub-carbonate of ammonia retains, in a considerable degree, the pungent smell of the pure volatile alkali. It is, also, unlike the other sub-carbonates, volatilized by a very moderate heat, and evaporates without entering previously into a liquid state. The vapour that arises may be again condensed in a solid state; affording an example of *sublimation*. This may be shown, by applying heat to the sub-carbonate of ammonia in a retort, to which a receiver is adapted. The sub-carbonate will rise, and be condensed in the receiver in the form of a white crust.

(*c*) This sub-carbonate does not contract moisture from the air, but, on the contrary, loses weight.

* Here some free caloric appears; but far inferior to what we should expect from the condensation of two permanently elastic fluids. The vapour of the gases thus set free, and condensed into a state of water, is fully sufficient to explain its production. C.

(d) Sub-carbonate of ammonia, like those of potash and soda, converts vegetable blue colours to green, as the pure alkalis do.

(e) It requires for solution rather more than twice its weight of cold water, or an equal weight of boiling water. At the latter temperature, however, it is partly decomposed, and a violent effervescence ensues.

(f) In composition it varies considerably, according to the temperature in which it has been formed. Thus, sub-carbonate of ammonia, which has been produced in a temperature of 300° Fahrenheit, contains 50 per cent. of alkali; while carbonate formed at 60° contains only 20 per cent. By Gay Lussac,* the sub-carbonate of ammonia is said to consist of

Ammonia	43.98	100	78.57
Carbonic acid . .	56.02	127.5	100.
	<hr/>	<hr/>	<hr/>
	100.	227.5	178.57.

(g) It is decomposed by pure potash and pure soda; and by the sub-carbonates of those alkalis, which attract its carbonic acid, and expel the alkali. Hence it has been recommended, by Berthollet, to employ this salt for the full saturation of potash with carbonic acid, which may be accomplished by the following process.

To a filtered solution of four pounds of pearl-ash in four quarts of water, add one pound of carbonate of ammonia, reduced to powder; and stir the mixture at intervals, till the carbonate of ammonia is entirely dissolved. Filter the liquor, and put it into a retort, which may be set in a sand-bath, and be connected with a receiver. A very gentle heat is to be applied; so as to distil off about half a pint of the liquor, which will consist of a solution of carbonate of ammonia in water. The liquor in the retort may either be allowed to cool in it, or be transferred into a flat evaporating dish of Wedgwood's ware. When cold, crystals of the carbonate of potash will probably be formed; otherwise another portion must be distilled off, and this must be repeated till the crystals appear; separate the first crystals that are formed; and, on repeating the distillation and cooling, fresh sets will appear in succession. A considerable portion of the solution, however, will refuse to crystallize. This may be boiled to dryness, and applied to the purposes of sub-carbonate of potash. The crystals of carbonate of potash may be washed with a small quantity of cold water and dried on blotting paper; or if they are required of great purity, they may be dissolved in cold water, and recrystallized, using the gentlest heat possible in evaporating the solution.

The NEUTRAL CARBONATE OR BI-CARBONATE OF AMMONIA was formed by Berthollet, by impregnating a solution of sub-carbonate with carbonic acid gas. According to his experiments, it is composed of

Ammonia	28.19	100	39.2
Carbonic acid . .	71.81	255	100.
	<hr/>	<hr/>	<hr/>
	100.	355	139.2

* Memoires d'Arcueil, ii. 214.

From the known specific gravity of those two bodies Gay Lussac has calculated that the neutral carbonate consists of exactly equal quantities by *measure* of the two gases, while the sub-carbonate is composed of two volumes of alkaline gas to one of carbonic acid gas.

ART. 4.—Carbonate of Barytes.

I. Pure barytes has a very powerful affinity for carbonic acid.

1. Let a solution of pure barytes be exposed to the atmosphere. It will soon be covered with a thin white pellicle; which, when broken, will fall to the bottom of the vessel, and be succeeded by another. This may be continued, till the whole of the barytes is separated. The effect arises from the absorption of carbonic acid, which is always diffused through the atmosphere, and which forms with barytes a substance, *viz.* carbonate of barytes, much less soluble than the pure earth.

2. Blow the air from the lungs, by means of a quill, a tobacco-pipe, or glass tube, through a solution of barytes. The solution will immediately become milky, for the same reason as before.

3. With a solution of pure barytes, mingle a little water, impregnated with carbonic acid. An immediate precipitation of carbonate of barytes will ensue.

4. Barytes has so strong an affinity for carbonic acid, as even to take it from other bodies. To a solution of a small portion of carbonate of potash, of soda, or of ammonia, add the solution of barytes. The barytes will separate the carbonic acid from the alkali, and will fall down in the state of a carbonate. By adding a sufficient quantity of a solution of barytes in hot water, the whole of the carbonic acid may thus be taken from a carbonated alkali; and the alkali will remain perfectly pure.

II.—1. Carbonate of barytes is nearly insoluble in water, which, at 60° , does not take up more than $\frac{1}{4300}$ part, or, when boiling, about $\frac{1}{2300}$. Water impregnated with carbonic acid dissolves a considerably larger proportion.

2. Carbonate of barytes is perfectly tasteless, and does not alter vegetable blue colours. It acts as a violent poison.

3. The combination of carbonic acid with barytes may either be formed artificially, as in the manner already described, and by other processes, to be detailed in the sequel, in which case it is termed, the *artificial carbonate*: or it may be procured, ready formed, from the earth, and is then called the *native carbonate*. It is not, however, a very common production of nature. The largest quantity, hitherto discovered, is in a mine, now no longer worked, at Anglezark, near Chorley, in Lancashire.

4. The native and artificial carbonates differ in the proportion of their components. The former contains, in 100 parts, 20 acid and 80 barytes. The artificial, according to Pelletier, consists of 22 acid, 62 earth, and 16 water. Strictly speaking they are both sub-carbonates; but as we are unacquainted with any other compound of barytes and carbonic acid, they may be allowed to retain the ac-

customed name of carbonate. The latest analyses of this compound by Mr. Aikin, Mr. James Thomson,* and others, fix its composition as follows :

	<i>Carb. acid.</i>	<i>Barytes.</i>
From Mr. Aikin's experiments	21.67 . . .	78.33
———— Thomson's	21.75 . . .	78.25
———— Claproth and Rose's	22.00 . . .	78.00
———— Bucholz's	21.00 . . .	79.00
———— Berzelius's†	21.60 . . .	78.40
———— Dr. Wollaston (from theory)	22.09 . . .	77.91

When 100 grains of the carbonate are dissolved in nitric acid, and precipitated by a sulphate, they afford, according to Berzelius, 118.6 or 119 grains of sulphate of barytes.

5. Carbonate of barytes is decomposed by an intense heat; its carbonic acid being expelled; and the barytes remaining pure. The artificial carbonate is most readily decomposed; but the native one is generally employed for obtaining pure barytes, because it may be had in considerable quantity. The process, which I have found to answer best, is nearly that of Pelletier. Let the native carbonate be powdered, and passed through a fine sieve. Work it up with about an equal bulk of wheaten flour into a ball, adding a sufficient quantity of water. Fill a crucible of proper size, about one-third its height, with powdered charcoal; place the ball on this; and surround and cover it with the same powder, so as to prevent its coming into contact with the sides of the crucible. Lute on a cover: and expose it, for two hours, to the most violent heat that can be raised in a wind furnace. Let the ball be removed when cold. On the addition of water, it will evolve great heat, as already described (chap. viii.), and the barytes will be dissolved. The filtered solution, on cooling, will shoot into beautiful crystals.

6. Carbonate of barytes is decomposed by the sulphuric, nitric, muriatic, and various other acids, which detach the carbonic acid, and combine with the earth.

ART. 5.—*Carbonate of Strontites.*

The relation of strontites to carbonic acid resembles, very closely, that of barytes; and all the experiments, directed to be made with the solution of the latter earth, may be repeated with that of strontites, which will exhibit similar appearances.

The carbonate of strontites requires for solution 1536 parts of boiling water. It is found native at Strontian in Argyleshire; and may, also, be prepared by artificial processes, which will be afterwards described. From this carbonate pure strontites may be prepared, by treating it in the same manner as was directed for the calcination of carbonate of barytes.

ART. 6.—*Carbonate of Lime.*

1. Lime has a strong attraction for *carbonic acid*, but not when perfectly dry.

* Nicholson's Journal, xxii. xxiii.

† 78 An. de Ch. 29.

(a) If a piece of dry quicklime be passed into a jar of carbonic acid gas over mercury, no absorption ensues. But invert a bottle, filled with carbonic acid gas, over a mixture of lime and water of the consistence of cream, and a rapid absorption will be observed, especially if the bottle be agitated.

(b) Let a jar or bottle, filled with carbonic acid, be brought over a vessel of lime water. On agitating the vessel, a rapid diminution will ensue, and the lime water will become milky.

(c) Leave a shallow vessel of lime water exposed to the air. A white crust will form on the surface, and this, if broken, will fall to the bottom, and be succeeded by another. This is owing to the absorption of carbonic acid gas from the air by the lime, which is thus rendered insoluble in water.

(d) Lime, when exposed to the atmosphere, first acquires moisture, and then carbonic acid; and, in a sufficient space of time, all the characters distinguishing it as lime disappear.

(e) Lime has an extremely strong affinity for carbonic acid, which enables it to take this acid from other substances. Thus carbonates of alkalis are decomposed by lime. Slake a given quantity of lime into a paste with water, and add half its weight of carbonate of potash or soda. Boil the mixture, for half an hour, in an iron kettle, and separate the liquid part by filtration or by subsidence. The carbonic acid combines with the lime, and the alkali is obtained in a state of solution perfectly free from carbonic acid. This is the ordinary mode of depriving the alkalis of carbonic acid.

(f) Lime, when saturated with carbonic acid, must necessarily form carbonate of lime. We are unacquainted, however, with this salt, and it is chiefly by a process of reasoning that Berthollet has shown it must consist of 100 parts of lime united to 150.6 carbonic acid; whereas in the sub-carbonate 100 parts of lime are combined with only half that quantity.* Of this, common chalk may be taken as a fair sample; and in all sub-carbonates of this earth, we find the characters of insipidity and insolubility in water. Calcareous spar, marble, stalactites, lime-stone, and chalk, are all varieties of sub-carbonate of lime. It contains per cent.

	Acid.	Base.
According to Wollaston . .	43.7 . .	56.3
———— Berzelius . .	43.6 . .	56.4

It appears to be constituted of an atom of lime united with an atom of carbonic acid.

(g) Carbonate of lime is decomposed by a strong heat. If distilled in an earthen retort, carbonic acid gas is obtained, and lime remains in the retort in a pure or caustic state. By this process it loses about 45 per cent.

The very curious and important experiments of Sir James Hall have proved, that when the escape of the carbonic acid is prevented by strong pressure, carbonate of lime is fusible in a heat of about

* Memoires d'Arcueil, ii. 478.

22° of Wedgwood's pyrometer.* And Mr. Bucholz has lately fused this substance, by the sudden application of a violent heat, without additional compression.†

(h) Carbonate of lime is decomposed by the stronger acids. Put some chalk into a gas bottle, and pour on it diluted sulphuric acid. The sulphuric acid will unite with the lime, and the carbonic acid will be set at liberty. One hundred grains of carbonate of lime, according to Pfaff, are saturated by 88 grains of sulphuric acid of the specific gravity 1854; and give 129.4 of sulphate of lime. These numbers, however, are not consistent with the known composition of carbonate and sulphate of lime, which requires that 100 grains of the carbonate should be saturated by 9.75 of oil of vitriol of the specific gravity 1850, and that there should result 136 of calcined sulphate of lime.

By a comparison of this experiment with the preceding one (g), we may learn the proportion of carbonic acid and water contained in any carbonate of lime. Let 100 grains of the carbonate be put into a Florence flask, with an ounce or two of water; place this in the scale of a balance; and in the same scale, but in a separate bottle, about half an ounce of muriatic acid. Add the muriatic acid to the carbonate as long as any effervescence is produced, and then blow out the disengaged carbonic acid, which remains in the flask, by a pair of bellows. Ascertain, by adding weights to the opposite scale, how much has been lost; suppose it to be forty grains; this shows the quantity of carbonic acid disengaged. Calcine another 100 grains in a covered crucible. It will lose still more of its weight; because, besides its carbonic acid, all the water is expelled which it may contain. Let this loss be stated at 45 grains; the former loss deducted from this (45 — 40), or 5 grains, shows the quantity of water in 100 of the carbonate.

(i) Carbonate of lime, though scarcely dissolved by pure water, is soluble in water saturated with carbonic acid. The most striking method of showing this is the following: Add to a jar, about one fourth filled with lime water, a very small quantity of water saturated with carbonic acid. An immediate milkiness will ensue, because the carbonic acid forms with the lime an insoluble carbonate. Add gradually more of the water, impregnated with carbonic acid, shaking the jar as these additions are made. At last the precipitate is re-dissolved. Hence it appears that lime, with a certain proportion of carbonic acid, is insoluble, and, with a still larger, again becomes soluble in water.

(k) The carbonate of lime, dissolved by an excess of carbonic acid (i), is again separated, when this excess is driven off. Thus boiling, which expels the superabundant acid, precipitates the carbonate. Caustic, or pure alkalis, also produce a similar effect.

ART. 7.—*Carbonate of Magnesia.*

I. Pure magnesia does not attract carbonic acid with nearly the same intensity as lime. Hence magnesia may be exposed, for a

* Nicholson's Journal, xiii. xiv.

† Ibid. xvii. 229.

long time, to the air, without any important change in its properties, or much increase of weight. The carbonate of magnesia, used in medicine, and for experimental purposes, is prepared by a process to be described in the sequel. In this state, however, it is not entirely saturated with carbonic acid, and is rather a sub-carbonate. Its composition Bucholz states to vary, as it is prepared with or without heat. If the former, it contains per cent. 42 base, 35 acid, 23 water; if prepared from cold solutions of sub-carbonate of soda and sulphate of magnesia, it consists of 33 base, 32 acid, and 35 water. Mr. Dalton makes it to be composed of 43 base, 40 acid, and 17 water, which numbers indicate that it is constituted of one atom of acid, one of earth, and one of water.

II. The saturated carbonate (as it has generally been considered) may be obtained, by passing streams of carbonic acid gas through water, in which the sub-carbonate is kept mechanically suspended. The solution yields, when evaporated, small crystals, which are transparent hexagonal prisms, terminated by hexagonal planes. These crystals have no taste, and are soluble in 48 parts of cold water; whereas the sub-carbonate requires at least ten times that quantity. The crystallized carbonate contains per cent. 30 acid, 30 earth, and 40 water, so that it is in reality constituted like the common carbonate, but with 3 atoms of water instead of one.

III. The carbonate of magnesia is decomposed by the same agents as the carbonate of lime. It yields its carbonic acid, however, in a much more moderate heat.

IV. Lime has a stronger affinity than magnesia for carbonic acid. Hence, if lime water be digested with carbonate of magnesia, the lime is precipitated in the state of an insoluble carbonate.

ART. 8.—*Carbonate of Glucine.*

Glucine appears to have a considerable affinity for carbonic acid; for, when precipitated from acids by pure alkalis, and dried in the air, it becomes effervescent. The carbonate of glucine is white, insipid, insoluble and very light. It contains about one fourth its weight of carbonic acid, which it loses by exposure to a low red-heat.

The carbonate of silex does not exist, and those of zircon, alumine, and yttria, have no peculiarly interesting properties.

SECTION V.

Gaseous Oxide of Carbon, or Carbonous Oxide.

THIS combination of carbon with oxygen contains a less proportion of oxygen than is found in carbonic acid. Its discovery was announced in Nicholson's Journal, for April 1801, by Mr. Cruickshank, and in the 38th volume of the *Annales de Chimie*, by Cle-

ment and Desormes, whose experiments are continued in the 39th volume, page 26. The Dutch chemists, however, in volume 43, object to its being considered as a distinct gas, and regard it merely as a carburet of hydrogen. But their objections do not appear sufficiently strong to prevent the acknowledgment of the gaseous oxide as a new and peculiar species.

It may be procured by any of the following processes :

1. By the distillation of the white oxide of zinc with one eighth its weight of charcoal, in an earthen or glass retort ; from the scales which fly from iron in forging, mixed with a similar proportion of charcoal ; from the oxides of lead, manganese, or, indeed, of almost every imperfect metal, when heated in contact with powdered charcoal. It may also be obtained from the substance which remains after preparing acetic acid from acetate of copper.

2. From well dried carbonate of barytes or of lime (common chalk), distilled with about one fifth of charcoal ; or with rather a larger proportion of dry iron or zinc filings, which afford it quite free from hydrogen.

3. By transmitting carbonic acid gas over charcoal ignited in a porcelain tube. The acid gas combines with an additional dose of charcoal ; loses its acid properties ; and is converted into the carbonous oxide. An ingenious apparatus, contrived by M. Baruel, and extremely useful for this and similar purposes, is described and represented by a plate, in the 11th volume of Nicholson's Journal.

The last product of the distillation is the purest, but still contains carbonic acid, which must be separated by washing the gas with lime liquor.

Its properties are as follow :

(a) It has an offensive smell.

(b) It is lighter than common air, in the proportion of 966 to 1000. One hundred cubical inches weigh 30 grains, the temperature being 55° Fahrenheit, and pressure 29.5 (Cruickshank) ; or at temperature 60° , and barometer 30° , 100 cubic inches weigh 30.19 grains. Its specific gravity from calculation, according to Gay Lussac, should be .96782.

(c) It is inflammable, and, when set fire to, as it issues from the orifice of a small pipe, burns with a blue flame. When mixed with common air, it does not explode like other inflammable gases, unless in very few proportions,* but burns silently with a lambent blue flame. It detonates, however, with oxygen gas.

(d) When a stream of this gas is burnt, in the manner described in speaking of hydrogen gas, no water is condensed on the inner surface of the glass globe, a proof that the gaseous oxide contains no hydrogen.† Berthollet, indeed, still contends, in opposition to most

* Dalton's System, p. 373.

† Assuredly this proof is at best very unsatisfactory ; for since it is admitted by all, that gases hold water in solution, the carbonic acid gas formed, will take up the small quantity produced in such experiments—for on so very small a scale, the proportion of hydrogen, must be extremely minute. C.

chemists (and among others to Gay Lussac) that hydrogen is one of the elements of this gas.

(e) It is sparingly soluble in water; is not absorbed by liquid caustic alkalis; nor does it precipitate lime water.

(f) It is extremely noxious to animals; and fatal to them if confined in it. When respired for a few minutes, it produces giddiness and fainting.*

(g) When 100 measures of carbonous oxide are fired over mercury in a detonating tube, with 45 of oxygen gas, the total 145 are diminished to 90, which consist entirely of carbonic acid. Proportions, differing a little from these, have been stated by Berthollet, viz. that 100 measures of carbonous oxide are saturated by 50 measures of oxygen, and give 100 of carbonic acid; and these last proportions are coincident, also, both with the theory and experience of Gay Lussac.

(h) It is not expanded by electric shocks, nor does it appear to undergo any change by electrization.

(i) When the carbonic oxide, mingled with an equal bulk of hydrogen gas, is passed through an ignited tube, the tube becomes lined with charcoal. In this temperature the hydrogen attracts oxygen more strongly than it is retained by the charcoal, and forms water. It was found, also, by Gay Lussac, to be decomposed by the action of potassium, which combines with the oxygen, and precipitates charcoal.

According to Mr. Cruickshank, it contains per cent. about 70 oxygen, and 30 carbon by weight; or the former is to the latter as 21 to 8.6, or as 21 to 9. Gay Lussac, however, makes it to consist of 43 charcoal and 57 oxygen; Berzelius of 44.28 charcoal and 55.72 oxygen, proportions, which agree, within a small fraction, with those of Clement and Desormes. It contains, therefore, just half the oxygen that exists in carbonic acid; and it is constituted of one atom of charcoal and one atom of oxygen, and weighs, according to Mr. Dalton, $7 + 5.4 = 12.4$, or by the corrected numbers, $7.5 + 5.8 = 13.3$.†

* See Phil. Mag. xliii. 367.

† This gas, which contains much more carbon in its composition than carbonic acid gas, and is lighter than common air, must be a very singular anomaly, if in fact it contains no hydrogen. Since the Dutch chemists nevertheless, as well as Mr. Berthollet, maintain its existence in it; this, together with its inflammability, would induce me to accede to their opinion, rather than to the other. It is also shewn above that great difference of sentiment, as to the proportions, exists between those, who contend for its being constituted of only carbon and oxygen. Shall we then admit *unsettled* assertion, as an absolute negative to the presence of hydrogen? C.

SECTION VI.

Combination of Carbon with Hydrogen, forming Carburetted Hydrogen Gas, or Hydro-Carburet.

I. OF this combination there appear, on first view, to be several distinct varieties, consisting of carbon and hydrogen, united in various proportions, and obtained by different processes.

1. When the vapour of water is brought into contact with red-hot charcoal, (by means of an apparatus similar to that represented, fig. 40), two different products are obtained. The oxygen of the water, uniting with the carbon, constitutes carbonous oxide and carbonic acid; and the hydrogen of the water dissolving, at the moment of its liberation, a portion of charcoal composes carburetted hydrogen gas.* The carbonic acid may be separated from the hydro-carburet, by agitating the gas, which has been produced, in contact with lime and water, mixed together, so as to be of the consistence of cream.

2. By stirring, with a stick, the mud that is deposited at the bottom of ditches or stagnant pools, bubbles of gas ascend to the surface, and may be collected in an inverted bottle of water, to the mouth of which a funnel, also inverted, is fixed.

3. By submitting coal to distillation, in an iron or coated glass retort, a large quantity of gas, besides a portion of tar, is produced. The latter may be received in an intermediate vessel; and the gas must be well washed with lime liquor. The first product only is to be reserved as a specimen of coal gas; for, as the distillation proceeds, its density becomes gradually less; till, at length, the gas, which is produced at the close of the operation, is only about half as heavy as that evolved at first. The quantity of gas, also, which is produced from a given weight of coal, is so variable from different kinds of this mineral, and is so much influenced by the degree of heat employed in its production, that it is scarcely possible to state any general average. From 120 pounds avoirdupois of the sort of coal called *Wigan Cannel*, about 340 cubic feet of gas may be obtained, of which half a cubic foot *per* hour is equal to a mould candle of six to the pound, burning during the same space of time.

4. Let a porcelain tube, coated with clay, be fixed horizontally in a furnace, in the manner represented, fig. 40. To one end let a retort be luted, containing an ounce or two of ether or alcohol; and, to the other, a bent tube, which terminates under the shelf of the pneumatic trough. A gas will be disengaged, on igniting the tube, and transmitting, through it, the alcohol or ether in vapour, which, when washed with lime-liquor, is the carburetted hydrogen.

5. A fifth mode of obtaining hydro-carburet, consists in distilling, in a glass retort, with a gentle heat, three measures of concentrated sulphuric acid, and one measure of alcohol. The mixture

* In Nicholson's Journal, xi. 68, I have stated my reasons for believing that this gas is not pure hydro-carburet.

assumes a black colour and thick consistence ; and bubbles of gas are disengaged, which may be collected over water. For reasons which will afterwards be stated, this gas has been named the olefiant gas.

II.—1. These different gases vary considerably, in density or specific gravity. Atmospheric air being 1000, the specific gravity of gas from *moistened charcoal*, is 480 ; from *ether* or *alcohol* 520 ; from *pit-coal* between 300 and 780, according to the period of the distillation, at which it is collected, the early products being always the heaviest. Gas from *stagnant water*, according to Mr. Dalton, is of the specific gravity 600, and hence 100 cubic inches must weigh 18.3 ; but Dr. Thomson fixes its specific gravity at 555, which would give only 16.93 grains for 100 cubic inches. The specific gravity of *olefiant gas* is stated by the Dutch chemists, its discoverers, at 909, by Dalton and Henry at 967 or 950, and by Dr. Thomson at 974. From the last number, the weight of 100 cubic inches, at 60° Fahrenheit, and 30 inches barometer, may be deduced to be 29.72 grains.

2. These gases differ as to the quantity, which water is capable of absorbing ; for of the olefiant gas it takes up $\frac{1}{8}$ th of its bulk ; of gas from stagnant water $\frac{1}{84}$; and of the others still less.

3. The varieties of carburetted hydrogen gas, all agree in being inflammable ; but they possess this property in various degrees, as is evinced by the variable brightness of the flame, which they yield when set on fire. They may be inflamed as they proceed from the orifice of a small pipe, or from between two concentric cylinders of sheet-iron or copper, placed at the distance of a small fraction of an inch from each other. On this principle, an Argand's lamp may be constructed, for burning the gases, which will issue from that space, commonly occupied by the wick.

When burned in either of these modes, there is a manifest gradation in the density and brightness of the flame. The gas from charcoal burns with a faint blue light, not suited to the purpose of illumination ; that from ether or alcohol with more brilliancy ; but still short of that with which the coal gas burns, when recently prepared ; and the first product of gas from a given quantity of coal, affords at least twice as much light, as an equal volume of the last portions. The olefiant gas surpasses them all, in the quantity of light evolved by its combustion.

If these gases be burned in a vessel of oxygen gas over lime-water, by means of a bladder and bent brass pipe (pl. iv. fig. 41), two distinct products are obtained, viz. water and carbonic acid. That water is produced, may be shown by burning a very small stream of this gas, under a long funnel-shaped tube open at both ends. The formation of carbonic acid is evinced, by the copious precipitation of the lime-water in the foregoing experiment.

The composition of each of the above gases is learned by firing it, in a detonating tube over mercury, with a known quantity of oxygen gas ; and observing the nature and quantity of the products. These products are carbonic acid and water. The former may be exactly measured ; but the water is generated in such small quan-

tity, that it can only be computed. The following table shows the results of a few experiments of this kind.

Kind of Gas.	Measures of Oxygen Gas required to saturate 100 Measures.	Measures of Carbonic Acid produced.
Pure hydrogen gas	50 to 54	—
Gas from charcoal	60	35
———— coal	190	97.5
———— stagnant water .	200	100
Olefiant gas	300	200

Now since, for the formation of each measure of carbonic acid gas, in the foregoing experiments, an equal volume of oxygen gas is required, we may learn, by deducting the number in the third column from the corresponding one in the second, what proportion of oxygen has been spent in the saturation of the hydrogen of each variety of hydro-carburet. Thus, for example, in burning the gas from stagnant water, 100 measures of oxygen have been employed in forming carbonic acid; and the remaining 100 in saturating hydrogen. But 100 measures of oxygen are sufficient to saturate 200 of hydrogen gas; and a quantity of hydrogen must therefore be contained in 100 measures of gas from stagnant water; which, expanded to its usual elasticity, would occupy 200 measures.

From these data, it is easy to deduce the composition of this variety of carburetted hydrogen; for if its specific gravity be 0.6.

100 cubic inches must weigh	grains.
The 100 cubic inches of carbonic acid produced weigh 47 } 18.3	
grains, and contain of charcoal	13.2
Hence the hydrogen, in 100 cubic inches, weighs	5.1

Or one hundred grains of gas from stagnant water are composed of

Carbon	72
Hydrogen . . .	28
	—
	100

These results are most consistent with the opinion that this gas, which may be called simply *carburetted hydrogen*, is constituted of one atom of charcoal and two atoms of hydrogen.

Olefiant gas, or *super-carburetted hydrogen*, investigated in precisely the same manner, is composed, in 100 grains,

	Carbon.	Hydrogen.
According to Dr. Thomson* of	85 . .	15
———— Saussure, jun. of	86 . .	14

* 37 Phil. Mag. 260.

It consists, therefore, according to Mr. Dalton, of one atom of carbon and one atom of hydrogen. This would make the weight of an atom of charcoal 5.66; for 85 is to 15, as 5.66 to 1; a result which coincides, as nearly as can be expected, with the weight of the atom of charcoal, already deduced from the composition of carbonic acid, viz. 5.65.

The only distinct and well characterized species of hydro-carburetted appear to me to be the olefiant gas; and the gas from stagnant water. Of these, with occasionally a portion of carbonic oxide, the other varieties appear to be mixtures. The coal gas, for example, which is now so generally used for the purpose of affording light, I have shown* to be a mixture of at least five others, the proportion of which varies at every successive stage of the distillation of coal. It has been contended, indeed, by Berthollet and others, that carbon and hydrogen are capable of uniting in a variety of proportions, not only with each other, but with oxygen. But there seems reason to believe, from a careful examination of all the best experiments on these compounds, that hydrogen and carbon unite only in *definite proportions*, and that these proportions are no other, than the two which constitute *carburetted* and *super-carburetted* hydrogen gases.

CHAPTER XII.

SULPHUR.—SULPHURIC ACID.—SULPHATES.—BINARY COMPOUNDS OF SULPHUR.

IN describing sulphur and its compounds, I shall take them in the following order:

- I. SULPHUR in its uncombined state.
- II. Sulphur united with its full proportion of oxygen, constituting SULPHURIC ACID; and the compounds of this acid with alkalis and earths, termed SULPHATES.
- III. Sulphur united with a less proportion of oxygen, composing SULPHUROUS ACID; and the compounds of this acid, called SULPHITES.
- IV. The compounds of sulphur with alkalis and earths, termed SULPHURETS.
- V. The combination of sulphur and hydrogen, named SULPHURETTED HYDROGEN; and the compounds, which it forms with alkaline and earthy bases, called HYDRO-SULPHURETS.
- VI. The compound of sulphuretted hydrogen with a still farther quantity of sulphur, composing SUPER-SULPHURETTED HYDROGEN; and its compounds with different bases called HYDROGURETTED SULPHURETS, or sometimes SULPHURETTED-HYDRO-SULPHURETS.

* Phil. Trans. 1808.

SECTION I.

SULPHUR.

I. THE sulphur, which occurs as an article of commerce, is a mineral production, and is brought to this country chiefly from Sicily. That which is produced in our own island, is generally of very inferior quality, and contains a portion of the metal, from combination with which it has been separated. It is met with under two different forms; of a compact solid, which has generally the shape of long rolls or sticks; and of a light powder called *flowers of sulphur*. In general, the latter may be considered as most pure; but the two varieties, it will presently appear, are readily convertible into each other by the modified application of heat. Its specific gravity is 1.98 or 1.99.

II. Sulphur is readily fused and volatilized. When heated to 170° of Fahrenheit, it begins to evaporate, and to produce a very disagreeable smell; at 185° or 190° it begins to melt; and at 220° is completely fluid. If the heat be rapidly increased, it loses at 350° its fluidity, and becomes firm, and of a deeper colour. It regains its fluidity, if we reduce the temperature; and this may be repeated at pleasure, in close glass vessels, if the changes of heat be not slow; otherwise it is volatilized. It sublimes at 600° .

III. If, after being melted, it be suffered to cool, it congeals in a crystalline form, but so confusedly, that we cannot define the shape of the crystals, farther than that they are slender interlaced fibres. If a large mass be kept fluid below, while it congeals at the surface, the crystallization there is much more distinct. When sulphur in complete fusion, *viz.* at 300° , is poured into water, it becomes tenacious like wax, and may be applied (as is done by Mr. Tassie) to take impressions from engraved stones, &c. These impressions are quite hard, when the sulphur has become cold. It is then of a red colour, and of the specific gravity 2.325.

IV. At the temperature of about 290° Fahrenheit, sulphur is converted into vapour; and if this operation be conducted in close vessels, the volatilized sulphur is again collected in a solid form. What remains has been called *sulphur vivum*. This affords an example of the process of *sublimation*, which differs from distillation, in affording a solid product, while the latter yields a condensed liquid. In this mode, sulphur may, in part, be purified; and its purification is completed, by boiling it repeatedly in distilled water; then in twice or thrice its weight of nitro-muriatic acid, diluted with one part of distilled water; and, finally, by washing it with distilled water, till this comes off tasteless, and incapable of changing the blue colours of vegetables.

V. When flowers of sulphur are digested in alcohol, no union takes place; but if the two bodies be brought into contact, when both are in a state of vapour, they enter into chemical union. This may be shown by an ingenious experiment of La Grange, the apparatus for performing which is represented in the first plate of his

"Manual." Into a glass alembic (see the plates to this work, fig. 2) put a little sulphur; over this suspend a small bottle filled with alcohol; and apply a receiver to the pipe of the alembic, the head being put into its place. Lute the junctures, and apply a gentle heat to the alembic. The sulphur will now be raised in vapour; and the vapour surrounding the bottle of alcohol, the latter will be volatilized, and will meet in this state the fumes of sulphur. A combination will take place between the two bodies, and sulphurized alcohol will pass into the receiver. On pouring this preparation into water, the sulphur will be precipitated.

VI. Though it had already been suspected (chiefly from the experiments of M. Berthollet, junior, described in sect. 6, art. 4, of this chapter) that sulphur contains hydrogen, yet the first unequivocal evidence of the fact was furnished by Sir H. Davy. A bent glass tube, having a platina wire hermetically sealed into its upper extremity, was filled with sulphur. The sulphur was melted by heat; and a proper connection being made with the Voltaic apparatus of 500 double plates, each six inches square and highly charged, a most intense action took place. A very brilliant light was emitted; the sulphur soon entered into ebullition; elastic matter was evolved in great quantities; and the sulphur, from being of a pure yellow, became of a dark reddish brown tint. The gas was found to be sulphuretted hydrogen, or hydrogen gas holding sulphur in solution; and its quantity, in about two hours, was more than five times the volume of the sulphur employed.

Another proof of the presence of hydrogen in sulphur is derived from the action of potassium; for these two bodies combine with great energy, and evolve sulphuretted hydrogen with intense heat and light.

Lastly, when dry sulphur is burned in dry oxygen gas, Sir H. Davy is of opinion that, besides sulphuric acid, a portion of water is also formed; but he is still doubtful whether the hydrogen in sulphur can be considered as any thing more than an accidental ingredient.* This view of the subject is embraced, also, by Berze-

* In some of the first experiments on this subject, Sir H. Davy, finding sulphuretted hydrogen evolved in more than five times the volume of the sulphur employed, concluded that it *was a constituent* of the sulphur. See Nichol. Jour. vol. 25. p. 145. "I have stated (says he) in the last Bakerian lecture, that hydrogen is produced from sulphur and phosphorus in such quantities, by Voltaic electricity, that it cannot *well be considered as an accidental ingredient* in these bodies." And in the lecture he refers to, his language is still stronger; "The existence of hydrogen in sulphur is *fully proved*, and we have no right to consider a substance, which can be produced from it in such large quantities, *merely as an accidental ingredient*." Nich. Jour. 23. p. 323. Now which are we to credit? H. Davy, Esq. in 1809, or Sir H. Davy in 1812?—For myself, the experiments detailed by Davy, in conjunction with those of Mr. Clayfield, amply satisfy me that hydrogen is an essential ingredient in sulphur. Dr. Thomson, in his excellent system of chemistry, appears to be equally satisfied. Why Sir Humphrey should thus fluctuate in opinion, and in deductions drawn from the same (and those his own) experiments, I cannot imagine; excepting that at the first named period, he evidently inclined to a modification of the phlogistic doctrines; but this, his subsequent views opposed; the acquiescence therefore, in the first opinion of the presence of hydrogen, must of consequence be given up! 1

lius,† who found, by heating sulphur with oxide of lead, that the quantity of water produced, is much too minute to indicate any definite proportion of hydrogen in sulphur.

Another ingredient of sulphur, it appeared probable from the experiments of Sir H. Davy, is oxygen. For potassium, after being made to act on sulphuretted hydrogen gas, evolved less hydrogen from water, than it ought to have done. It has since, however, been proved by Gay Lussac,‡ that when all sources of fallacy, are avoided, a given weight of potassium, which has been exposed to sulphuretted hydrogen, separates exactly the same volume of hydrogen gas from water, as an equal weight of recent metal. Potassium, therefore, acquires no oxygen from the sulphur, which is contained in sulphuretted hydrogen.‡

VII. Sulphur is inflammable, and appears susceptible of two distinct combustions, which take place at different temperatures.§ At 140° or 150° Fahrenheit, it begins sensibly to attract oxygen; and if the temperature be raised to 180° or 190°, the combination becomes pretty rapid, accompanied by a faint blue light. But the heat evolved is scarcely sensible; at least it is so weak, that the sulphur may thus be burnt out of gunpowder, and the powder be rendered useless without inflaming it. At a temperature of 300°, its combustion, though still feeble compared with that of some other bodies, is much more active, and accompanied with a redder light. When set on fire in oxygen gas, it burns with a very beautiful and brilliant light; but of a given quantity of oxygen gas, it is not possible to condense the whole by this combustion, for reasons which hereafter will be stated; the product of these combustions when examined, will be found to be sulphurous and sulphuric acid, but chiefly the former, and if water be carefully excluded, sulphurous acid only is formed. It is necessary, therefore, in order to produce sulphuric acid, to make the experiment over water.

SECTION II.

Sulphuric Acid.

THE properties of this acid must be exhibited by a portion of that usually found in the shops. They are as follows:

would perhaps, (as Sir Humphrey stands so high in the chemical world,) be worth contrasting the numerous changes which this gentleman has evinced in his scientific career, as an excellent beacon against too great indulgence in speculation and theory in the unsettled state of facts themselves. The question at present is, does sulphur contain hydrogen? Sir Humphrey has shewn it does; and all the subsequent aberrations from his first opinion, are totally inadequate to destroy the conclusions he then adopted. C.

* 79 Ann. Ch. 119.

† Ann. de Chim. vol. 73.

‡ Admitting these facts, we perceive in this case another instance of the fallacy of the opinion that oxygen is the principle of acidification. Here, hydrogen is effective in producing with sulphur, a gaseous acid of a peculiar nature, without the presence of any oxygen; the same occurs with chlorine; and with some other substances. C.

§ For an account of the oxides of sulphur, see Dr. Thomson's paper in Nicholson's Journal, vi. 101.

(a) Sulphuric acid has a thick and oily consistence; as may be seen by pouring it from one vessel into another.

(b) In a pure state, it is perfectly limpid and colourless.

(c) When mixed suddenly with water, considerable heat is produced. Four parts, by weight, of concentrated sulphuric acid, and one of water, when mixed together, each at the temperature of 50° Fahrenheit, have their temperature raised to 300° . When an ounce of water, has been suddenly mixed with three of sulphuric acid, and the mixture been suffered to cool to the temperature of the atmosphere, an additional half oz. of water raises it to 86° , a second to 96° , and a third to 104° .* This rise of temperature takes place, because the affinity or capacity of the compound of sulphuric acid and water for caloric, is less than that of the acid and water separately. A diminution of bulk also ensues; that is, one measure of acid and one of water do not occupy the space of two measures, but about $\frac{1}{75}$ th less. Owing to the heat produced by its admixture with water, the dilution, for ordinary purposes, should be conducted very gradually; and the acid should be added to† the water by small portions at once, allowing each portion to cool before a fresh addition is made. On the principle of its attraction for water is to be explained, also, the rapid increase of weight which the acid acquires when exposed to air. In one day, three parts of sulphuric acid, exposed to the atmosphere, are increased in weight one part; and one ounce, by twelve months exposure, has been found to gain an addition of $6\frac{1}{4}$.

(d) Perfectly pure sulphuric acid remains quite limpid during dilution. The sulphuric acid, however, commonly found in the shops, under the name of oil of vitriol, on admixture with water, deposits a white powder, in considerable quantity, consisting of various impurities, but chiefly of sulphate of lead.

(e) Sulphuric acid is nearly twice as heavy as water. The specific gravity of the strongest, that can be obtained, is 1.850; but even this contains 19 (according to Dr. Wollaston, 18.44) per cent. of water, which appears essential to its constitution, and can only be separated by combining the acid with a base. It has been ascertained, by Mr. Dalton, that acid, of nearly the maximum strength, has its specific gravity very little altered, by adding or subtracting small portions of water. Thus acids, containing 81 and 80 per cent. of acid, do not differ more than 1 in the third place of decimals; nor is the specific gravity proportionally changed by dilution till it falls as low as 1.78. The strength of the more concentrated acid may be better ascertained, by observing how much water is required, to bring it down to the specific gravity 1.78. The boiling point, also, Mr. Dalton has discovered, is a much better test of its strength; and he has constructed the following useful Table, in which account is taken of all these circumstances.

* Philips on the London Pharmac. p. 24.

† A very good method of diluting sulphuric acid, is to expose it in a damp place. Its attraction for water is so great, that it very speedily acquires a large proportion. C.

Mr. Dalton's Table of the Quantity of real Acid in 100 Parts of Liquid Sulphuric Acid, at the Temperature 60° Fahrenheit.

Atoms Acid Water.	Real Acid per cent. by Weight.	Real Acid per cent. by Measure.	Specific Gravity.	Boiling Point.
1 + 0	100	unknown.	unknown.	unknown.
1 + 0	81	150	1.850	620°
	80	148	1.849	605°
	79	146	1.848	590°
	78	144	1.847	575°
	77	142	1.845	560°
	76	140	1.842	545°
	75	138	1.838	530°
	74	135	1.833	515°
	73	133	1.827	501°
	72	131	1.819	487°
	71	129	1.810	473°
	70	126	1.801	460°
	69	124	1.791	447°
1 + 2	68	121	1.780	435°
	67	118	1.769	422°
	66	116	1.757	410°
	65	113	1.744	400°
	64	111	1.730	391°
	63	108	1.715	382°
	62	105	1.699	374°
	61	103	1.684	367°
	60	100	1.670	360°
1 + 3	58.6	97	1.650	350°
	50	76	1.520	290°
	40	56	1.408	260°
1 + 10	30	39	1.30+	240°
1 + 17	20	24	1.200	224
1 + 38	10	11	1.10-	218

It is sometimes of importance to the chemical artist to know the proportion, not of *real acid*, but of *acid of commerce*, in diluted sulphuric acid of different specific gravities. An approximation to the true proportion may be obtained, by increasing the numbers, indicating the real acid, one fourth. For example, acid of the specific gravity 1.200, contains, according to the above table, 20 per cent. of real acid; which, increased one fourth, gives 25 per cent. of acid of sp. gr. 1.849. A very copious Table, constructed by Mr. Parkes from actual experiment, is given in the 40th volume of the *Philosophical Magazine*. Its length only prevents me from inserting it here; and the shorter Table of Vauquelin, in the 30th volume of *Nicholson's Journal*, is rendered less fit for the English chemist, because the acid, employed in the experiments on which it is

founded, is inferior in density to the average acid sold in this country.

(f) Sulphuric acid, by a sufficient reduction of its temperature, may be frozen; and under favourable circumstances, it assumes a regular crystalline form, a considerable degree of solidity or hardness, and a density exceeding that which it possessed in a fluid state. From the experiments of Mr. Keir* it follows that there is a certain point of specific gravity (*viz.* 1780 to 1000), at which the sulphuric acid most readily congeals; and when of this degree of strength it requires even a less degree of cold than is sufficient to freeze water, its congelation taking place at 45° Fahrenheit. From the specific gravity of 1786 on the one hand to 1775 on the other, it freezes at 32° Fahrenheit. It is singular that it remains congealed at a temperature higher than that originally required for freezing it. Acid, for example, which did not become solid till its temperature was reduced to 32°, remains frozen at 45°. When of the specific gravity of 1843, or as nearly as possible of that of commerce, it was found by Mr. Macnab† to freeze at — 15° Fahrenheit; but this acid, mixed with rather more than half its weight of water required for congelation the temperature of — 36° Fahrenheit.

(g) To purify sulphuric acid, it must be distilled in a glass retort, placed in the sand-bed of a reverberatory furnace. This process is a very difficult one; and an inexperienced chemist should, therefore, not attempt it. To those, however, who have the means of repeating the process, and sufficient experience in chemical operations, the following instructions may be useful; especially as it is indispensable, in all experiments of research, to employ an acid thus purified.

The furnace, in which this process is conducted, should have a contrivance for supporting a sand-bath within it at a proper height; and an opening in the side, for transmitting the neck of the retort. (Pl. vii. fig. 62, 63.) The retort must be coated with clay and sand over its whole body, and also over that part of the neck which is exposed to the fire. It is then to be placed, the coating being previously dry, in the sand-bath, about one half filled with sulphuric acid; and a receiver must be applied but not luted on. The fire must now be lighted, and raised with extreme caution. The first portion that comes over, amounting to about one sixth, consists chiefly of water, and may be rejected. This is followed by the concentrated acid; and, at this period, there is great risk that the neck of the retort will be broken, by the contact of the condensed acid, which has a very high temperature, and which frequently cracks the glass, as effectually as the application of a red-hot iron. The fire must be regulated by the register-door of the ash-pit, so that several seconds may elapse between the fall of the drops into the receiver. The process may be continued as long as any acid is condensed. The retorts, employed for this purpose, should be most attentively annealed.

* Philosophical Transactions, lxxvii. 267.

† Ibid. lxxvi. 241.

Sulphuric acid may be less perfectly purified by diluting it with an equal weight of water, allowing the impurities to settle, decanting the clear liquor, and evaporating it to the proper degree in a glass retort.

(h) The proportion of the elements of sulphuric acid has been investigated by several chemists. Berthollet oxygenated 17.846 parts of sulphur by nitric acid, and obtained a quantity of sulphuric acid, which gave 127.515 parts of sulphate of barytes. Hence 100 parts of sulphur would have formed 230.79 parts of real sulphuric acid (= about 292 of density 1.85). Klaproth, Richter, and Bucholz obtained results nearly agreeing with each other. Berzelius, to avoid all fallacy from the hydrogen contained in sulphur, combined it, in the first place, with lead, which like other metals, always evolves much hydrogen, and then oxygenated the sulphuret. The following Table exhibits the proportions, deduced from different experiments, in 100 parts of real acid.

	Sulphur.	Oxygen.
From the experiments of Berthollet . . .	43.28	56.72
————— Klaproth . . .	42.20	57.80
————— Bucholz . . .	42.50	57.50
————— Berzelius . . .	39.92	60.08
Proportions admitted by Dr. Wollaston . . .	40 0	60.0*

If the proportions be taken at 40 sulphur and 60 oxygen, and if the acid consists, as Mr. Dalton supposes, of one atom of sulphur and three atoms of oxygen, the atom of sulphur will weigh 15; for as $(60 \div 3 =) 20$ is to 40 so is 7.5 to 15; and the weight of an atom of sulphuric acid will be 37.5. Mr. Dalton's numbers are 13 for the atom of sulphur, and 34 for that of sulphuric acid.

A coincidence has been pointed out by Berzelius, which is very remarkable, and is deemed by him sufficiently general, to be admitted as a law; *viz.* that in any combination of two oxygenated bodies with each other, the oxygen of the one is either a multiple or divisor of that of the other, by some simple number. Sulphuric acid, of 1850 density, affords an illustration of this principle; for it consists of 81 real acid and 19 water; and it will be found that the oxygen in the acid is, as nearly as possible, 48; and the oxygen in the water 16, so that, in this case, the multiple is three, for $16 \times 3 = 48$. Various other examples of the same general principle will be given, in treating of metallic oxides. In all neutral compounds of sulphuric acid with alkaline, earthy, or metallic bases, the acid contains a quantity of oxygen, which exceeds that in the base by the same multiple 3.

(i) Sulphuric acid is decomposed at the temperature of the atmosphere, by inflammable substances, and acquires a dark colour.

* Every step we proceed, evinces very clearly, how unsettled are the facts, upon which our hypotheses are founded: who would not presume, that substances so tangible as sulphur and oxygen, could readily be estimated? but if such diversity exists as to these, how are we satisfactorily to speculate on such as light, heat, or even hydrogen! C.

The addition of a little brown sugar, or a drop of olive oil, to a portion of the acid, imparts to it a brownish hue, which, in time, changes to black. Hence this acid should always be kept in bottles with glass stoppers; for a small bit of straw or cork, if dropped into a considerable quantity of sulphuric acid, changes it in the manner that has been pointed out.

(*k*) In high temperatures, sulphuric acid is still farther decomposed by combustible bodies.

1. Hydrogen gas, brought into contact with sulphuric acid, in a state approaching ignition, decomposes it, and water and sulphurous acid are formed. This, however, is a most dangerous and difficult process, which it is not advisable to repeat.

2. According to Gay Lussac, sulphuric acid is decomposed by heat alone, and is resolved into two parts by measure of sulphurous acid gas, and one of oxygen gas. This experiment is best performed by passing the acid through a red-hot tube of glass or porcelain.

3. Sulphur, by being boiled in sulphuric acid, partly deoxygenates it, and converts a portion of it into sulphurous acid which comes over in a gaseous state.

4. Into a glass retort, put such a quantity of sulphuric acid as will fill about one fourth part of it, and add a small portion of powdered charcoal. On applying the heat of a lamp, gas will be produced abundantly. Let this gas be conveyed by a tube fixed to the mouth of a retort, and bent in the proper manner, into an inverted jar of water; or, if it can be had, into an inverted jar of quicksilver in a mercurial apparatus. During this operation, the carbon attracts part of the oxygen of the sulphuric acid, and forms carbonic acid gas. But the sulphur is not entirely disoxygenated; and a compound is therefore formed of sulphur and oxygen, containing less oxygen than the sulphuric acid. This compound exists in the state of a gas, and its properties may next be examined. To avoid, however, the complication which the admixture of carbonic acid with this new product introduces into the experiment, it may be proper to prepare it in a mode less objectionable, but the *rationale* of which cannot at present be explained. This consists in dissolving two parts, by weight, of quicksilver in one of sulphuric acid, and boiling the mass to dryness, in the bottom of a broken Florence flask. The dried mass is next to be distilled in a strong sand-heat; a glass globe being interposed between the retort and the receiving mercurial trough, to condense any sulphuric acid that may escape decomposition. (See pl. iii. fig. 31.) The gas thus obtained is termed, conformably to the principles of the new nomenclature, *sulphurous acid*.

SECTION III.

Sulphurous Acid Gas.

SULPHUROUS acid may be formed, also, 1st, by burning sulphur at a low temperature in common air, under a glass bell; and if slips of linen cloth, dipped in a solution of potash, be exposed to the vapour, the alkali forms a combination with the sulphurous acid, which may afterwards be washed off and evaporated. The dry salt, distilled with liquid tartaric acid, gives sulphurous acid gas.

2dly. It is formed, exclusively, when sulphur is burned in dry oxygen gas. The gas, when restored to its original temperature, is found to be contracted $\frac{1}{12}$ th or $\frac{1}{15}$ th of its bulk; but this is probably owing to the hydrogen contained in sulphur, for there is every reason to believe that oxygen gas, by becoming sulphurous acid, is not at all changed in volume.

3dly. It is produced, by heating red oxide of mercury with one fourth of its weight of sulphur, in the proportion of about a cubic inch for every five grains of the oxide.

Its properties are the following:

(a) It has a pungent and suffocating smell, exactly resembling that which arises from burning sulphur.

(b) It is more than twice as heavy as atmospherical air. One hundred cubic inches are stated by Mr. Kirwan to weigh 70.215 grains, which would make its specific gravity 2.265. By Sir H. Davy, the same volume is said to weigh 68 grains, which would give the specific gravity of 2.23. According to a calculation of Gay Lussac, founded on the proportion of its elements, its specific gravity should be 2.30314.

(c) Monge and Clouet assert, that if the gas be exposed at the same time, to a temperature of 31° Fahrenheit, and to great pressure, it assumes a fluid state.

(d) It extinguishes burning bodies; and kills animals, when respired.

(e) It has the property of whitening or bleaching silk, and of giving it lustre.

(f) Of sulphurous acid, water absorbs 33 times its bulk, or one eleventh of its weight, caloric is evolved, and the solution at 68° has the specific gravity 1.0513. Mr. Dalton states the quantity absorbed to be only 22 times the bulk of the water. From the solution, when recently prepared, the gas may be separated by heat, but not by congelation.

(g) The watery solution does not redden infusion of litmus, as acids in general do, but totally destroys its colour. Hence its use in bleaching several vegetable and animal products. It restores the colour of syrup of violets, which has been reddened by other acids.*

* Nicholson's Journal, xvii. 303.

(h) Sulphuric acid, saturated with this gas, which may be effected by passing the gas through the acid, acquires a strong smell, a yellowish brown colour, smokes when exposed to the air, and has the property of assuming a solid form, by a moderate reduction of its temperature. When distilled, the first product, which is a compound of the two acids, assumes a solid form. It has been called *glacial sulphuric acid*. It has recently, however, been asserted by Vogel,* that the presence of sulphurous acid is not the cause of the glacial quality of oil of vitriol; and that, when converted to this state, by boiling in contact with sulphur, it contains no sulphurous acid. The nature of the change he has not yet fully explained.

(i) Sulphurous acid is again converted to the state of sulphuric, by restoring oxygen to it.

1. A mixture of oxygen and sulphurous acid gases, both perfectly dry, and standing over mercury, is not diminished by remaining in contact with each other during some months; but if a small quantity of water be added, the mixture begins to diminish, and sulphuric acid is formed. The same gases in a state of mixture, by the action of electricity, or by being driven through a red-hot porcelain tube, afford sulphuric acid. The proportions required for mutual saturation are two measures of sulphurous acid and one of oxygen gas.

2. To a portion of water saturated with sulphurous acid gas, add a little oxide of manganese, a substance that contains much oxygen, loosely combined. The pungent smell of the water, and the other characteristics of sulphurous acid will soon disappear.

3. Sulphurous acid gas is condensed into sulphuric acid by admixture with nitrous gas, and also by oxy-muriatic acid gas; but not unless the gases are in contact with water.

(i) When the temperature of sulphurous acid gas is greatly reduced, by surrounding it with a mixture of snow and muriate of lime, it is changed into a liquid.

(k) If sulphurous acid gas and fresh muriate of tin are brought into contact over mercury, the volume of the gas is speedily diminished, sulphur is deposited, and the promuriate becomes a permuriate of tin. (Accum.)

Both these acids are susceptible of combination with alkalis.

(l) It is decomposed, when submitted to the heat of ignition, in contact with certain combustible bodies. Thus, when a mixture of sulphurous acid and hydrogen gases are driven through a red-hot porcelain tube, the oxygen of the acid combines with the hydrogen, and forms water, and sulphur is obtained in a separate form. The sulphurous acid is decomposed, also, when transmitted over red-hot charcoal; and, as appears from Gay Lussac's experiment, by potassium.

From the testimony of the same chemist we learn that 100 parts of sulphur, to become sulphurous acid, unite with 95 oxygen. The following Table shows the numbers derived from different authorities. Sulphurous acid contains per cent.

* 84 Ann. de Chim. 283.

	Sulphur.	Oxygen.
According to Gay Lussac . . .	51.30 . . .	48.70
———— Berzelius . . .	50.03 . . .	49.97
———— Thomson . . .	53.0 . . .	47.0

The determination of Berzelius, of equal weights of its ingredients, agrees best with the specific gravity of the gas; for if 100 cubic inches weigh 68, and 100 cubic inches of oxygen 34, the remaining 34 must consist of sulphur.

Its atomic constitution, according to Mr. Dalton, is 1 atom of sulphur + 2 atoms of oxygen; and the weight of its atom will, therefore, be 30. The combination of 1 atom of sulphur with 1 atom of oxygen remains to be discovered; and it will probably appear in the state of an oxide.

SECTION IV.

Combination of Sulphuric Acid with Alkalis.

ART. 1.—*Sulphate of Potash.*

THIS salt may be formed by saturating the carbonate of potash with sulphuric acid, and crystallizing the solution. Its properties are the following:

(a) It crystallizes in small six-sided prisms, terminated by six-sided pyramids with triangular faces. Its specific gravity, according to Hassenfratz, is 2.0473.

(b) It has a bitter taste.

(c) It decrepitates when thrown on a red-hot iron, or on red-hot coals, and is volatilized by a strong heat, first running into fusion. By a low red-heat it loses very little of its weight, not more than one and a half or two per cent. Indeed it does not essentially contain any water.

(d) Water, at 60° of Fahrenheit, takes up only one sixteenth of its weight; but boiling water dissolves one fifth, or by continuing the application of heat even one fourth.

(e) The composition of this salt is determined by the quantity of sulphate of barytes, which its solution affords with any barytic salt. From 100 parts of the ignited salt, dissolved in water, Dr. Marcet obtained 132 of sulphate of barytes, Berzelius 134.68, and Mr. R. Phillips, 136.7. Hence the composition of the salt (reckoning the acid in sulphate of barytes at 33.5 per cent.) is,

	Acid.	Base.
According to Dr. Marcet	44.22	55.78
———— Mr. Phillips	45.79	54.21
———— Bucholz	46.21	53.79
———— Dalton	44.70	55.30
———— Berard	42.76	57.24
———— Berzelius	45.0	55.0

If the weight of the atom of potash be 50, and that of sulphuric acid 37.5, the determination of Berard would be nearest the truth; but the proportions which would best suit the weights assigned by Mr. Dalton (42 for potash and 34 for sulphuric acid), are those approaching to 45 acid and 55 base. For though some doubt may exist as to the precise weights of the atoms of potash and sulphuric acid, it can scarcely be questioned that this salt is composed of one atom of potash united with one atom of acid. Mr. Dalton's numbers make the weight of the atom 76, and the corrected ones would increase it to 87.5.

(f) Sulphate of potash is decomposed, in high temperatures, by charcoal. Mix any quantity of the salt with one fourth of its weight of charcoal finely powdered, and expose the mixture, in a crucible, to a strong heat. The carbon will unite with the oxygen of the sulphuric acid, and will escape in the state of a gas. What remains is a compound, hereafter to be described, of sulphur and potash.

*Super-sulphate of Potash.**

When to a saturated solution of sulphate of potash in boiling water, we add an excess of sulphuric acid, the first crystals, which are formed, contain a considerable excess of sulphuric acid, not less in the whole, according to Berthollet,† than 55.8 per cent. By continuing to evaporate the solution, we obtain successive quantities of crystals, which hold less and less acid in combination. Thus the second set, according to the same chemist, contain only 49.5 per cent. of acid; and he was therefore of opinion, that sulphuric acid and potash are capable of uniting in all proportions. It is much more agreeable, however, to analogy to believe, that in this, as in all other energetic combinations, the proportions are limited. The super-sulphate, it is probable, consists of one atom of base with two atoms of acid, or of 55 base + 90 acid; and its composition may be contrasted with that of the sulphate as follows:

	Super Sulphate		Sulphate	
Potash	38	100	55	100
Sulphuric acid	62	164	45	82
	<hr/>	<hr/>	<hr/>	<hr/>
	100	264	100	182

This salt has an intensely sour taste and a powerful action on blue vegetable colours. One part is soluble in two of water at 60°, and in less than an equal weight at 212°. It is insoluble in alcohol.

ART. 2.—*Sulphate of Soda.*

(a) This salt forms regular octahedral crystals, of a prismatic or cuneiform figure; the two terminating pyramids of which are truncated near their basis.

* This is the sal enixum of old authors. It is employed for cleaning metallic plates for various purposes. C.

† Memoires d'Arcueil, ii. 480.

(b) It has a more bitter taste than the preceding sulphate, and melts more easily in the mouth.

(c) It swells upon a heated iron, in consequence of the loss of its water of crystallization, and a white powder is left, amounting to only about 36 parts from 100 of the original salt, or 43.2 according to Bucholz.

(d) By exposure to the atmosphere, it effloresces, and loses weight, and with so much quickness, that it is difficult to ascertain precisely its water of crystallization. Berzelius states it at 56 per cent.

(e) It is very soluble in water, three parts of which, at 60° of temperature, dissolve one of the salt; and boiling water dissolves its own weight.

(f) Its composition is inferred from the quantity of sulphate of barytes, obtained by decomposing the solution of a known weight of this salt by any barytic salt. Bucholz, from 1000 grains of the crystallized salt (= 432 deprived of water) obtained 698 of sulphate of barytes; and Berzelius, from 5 parts of the dry salt, precipitated 8.16 of sulphate of barytes. His experiment, to have corresponded with that of Bucholz, should have given 8.12. Assuming the acid in sulphate of barytes to be 33.5 per cent., 100 parts of dry sulphate of soda (giving 161.3 of the barytic sulphate) must consist of

Base	46	. . . .	100
Acid	54	. . . .	117.5
<hr/>			
	100		

Mr. Dalton's numbers are 54.8 acid + 45.2 base; Dr. Wollaston's 56 + 44; and those of Berzelius 55.76 + 44.24. But whichever of these numbers may be adopted, it will be found not inconsistent with the opinion, that the salt is composed of one atom of base + one atom of acid.

The crystallized sulphate consists, calculating from the data furnished by Berzelius, of

Soda	19.36
Acid	24.64
Water	56.
<hr/>	
	100.

ART. 3.—*Sulphate of Ammonia.*

(a) The sulphate of ammonia forms long flattened prisms with six sides, terminated by six-sided pyramids.

(b) It slightly attracts moisture from the air.

(c) It has a cool bitter taste.

(d) Two parts of water, at 60°, take up one of the salt, and boiling water dissolves its own weight. During solution, it produces cold; and also when mingled with powdered ice, or with snow.

(e) The sublimed salt has an excess of acid; a portion of the base being expelled by the application of heat.

(f) It contains, per cent., according to Berzelius,

Ammonia	22.6
Sulphuric acid	53.1
Water	24.3

100.

(g) It liquefies, by a gentle heat, and is volatilized. If a stronger heat be applied, it is decomposed.*

(h) The pure fixed alkalis, potash, and soda, seize the sulphuric acid, and set at liberty the alkali. Hence a strong smell of ammonia arises on the admixture of pure soda or potash with this salt.

ART 4.—*Sulphate of Barytes.*

Barytes has a powerful affinity for sulphuric acid; and the combination of these two bodies may be effected with great facility.

(a) To a solution of pure barytes, add sulphuric acid. A white precipitate will appear, which is the sulphate of barytes.

(b) The same compound is formed, by adding sulphuric acid to carbonate of barytes, or to a solution of muriate or nitrate of barytes.

(c) The sulphate of barytes is one of the most insoluble substances, requiring for its solution 43,000 times its weight of water.

(d) Barytes has a stronger affinity than any other body for sulphuric acid.

(e) Owing to these properties the solution of pure barytes, and of the nitrate and muriate of barytes, are very sensible tests of sulphuric acid, and of all its combinations. Let a single drop of sulphuric acid fall into a wine quart of pure distilled water. On adding a few drops of one of the foregoing solutions of barytes, a precipitation will ensue.

(f) Sulphate of barytes is decomposed by carbonate of potash. Boil the powdered sulphate with a solution of twice or three times its weight of carbonate of potash. The carbonic acid will pass to the barytes, and the sulphuric to the potash.

(g) By this process, carbonate of barytes may be procured, for the purpose of preparing the pure earth, and its various salts, when the native carbonate cannot be had in sufficient abundance. The sulphate is found, in considerable quantities, accompanying lead ore, in Derbyshire and other parts of England, where it is known by the names of cawk, ponderous spar, &c. When applied to the purpose of obtaining the carbonate of barytes, it is to be finely powdered, mixed with three or four times its weight of sub-carbonate of potash, and boiled with a proper quantity of water for a considerable time, in an iron kettle, stirring it, and breaking down the hard lumps, into which it is apt to run, by an iron pestle. It

* See Mr. Hatchett's paper in Philosophical Transactions, 1796, or Davy's Researches.

is then to be washed with boiling water, as long as this acquires any taste. On the addition of dilute muriatic acid, a violent effervescence will ensue, and a considerable portion of the earth, probably along with some metals, will be dissolved. To the saturated solution, add a small portion of pure ammonia. This will throw down any metals that may be present; and the barytes may afterwards be precipitated in the state of a carbonate, by a solution of carbonate of potash. Let the precipitated earth be well washed with distilled water; and, if the pure barytes is to be obtained from it, let it be treated as directed, chap. x.

(h) Sulphate of barytes is also decomposed when ignited with powdered charcoal, which abstracts the oxygen of the sulphuric acid, and leaves a combination of sulphur and barytes. From this, the barytes may be removed by muriatic acid, as already directed, and the muriatic solution be decomposed by carbonate of potash.*

(i) The sulphate of barytes, when decomposed by charcoal, affords one variety of solar phosphorus. This phosphorus has been called, from the place where the sulphate is found from which it was first prepared, the Bolognian phosphorus. The native sulphate, powdered after being ignited, and finely sifted, is to be formed into a paste with mucilage of gum arabic, and divided into cylinders or pieces of one fourth of an inch in thickness. These, after being dried in a moderate heat, are to be exposed to the temperature of a wind furnace, placed in the midst of the charcoal. When the fuel is half consumed, it must be replenished, and suffered to burn out. The pieces will be found, retaining their original shapes, among the ashes, from which they may be separated by the blast of a pair of bellows. They must be preserved in a well-stopped phial.

This phosphorus, after being exposed a few minutes to the sun's rays, shines in the dark sufficiently to render visible the dial of a watch. This property is lost by repeated use, in consequence of the oxygenation of the sulphur; but may be restored by a second calcination.

(k) Sulphate of barytes, when artificially formed and calcined, contains in 100 parts,

	Base.	Acid.
According to Klaproth	66.55	33.45
————— Mr. A. Aikin† . . .	66.04	33.96
————— Mr. J. Thomson‡ . . .	66.96	33.04
————— Berthollet§	66.50	33.50
————— Berzelius|| . . . .	65.69	34.81

* Thenard, in his "Traité de Chimie Élémentaire," 2, 557, recommends the decomposition of sulphat of barytes, to form the muriat, to be effected by calcining a mixture of sulphat of barytes and muriat of lime, equal parts of each in powder. These are exposed in a covered Hessian crucible to the heat of a reverberatory furnace for one hour. The mass is thrown into boiling water stirred for some time; the liquor is then suffered to stand, and when settled is decanted or filtered, evaporated, and crystallized. C.

† Nicholson's Journal, xxii. 301.

‡ Nicholson's Journal, xxiii. 174.

§ Mémoires d'Arcueil, ii.

|| 79 Annales de Chimie, 138.

The determination of Berthollet, being nearly a mean of three, may be considered as sufficiently accurate. Dr. Wollaston assumes 66 parts of base and 34 of acid, as expressing most correctly its composition. The native sulphate, according to Klaproth, is composed of one third acid and two thirds base.* Its atomic constitution is one atom of base and one of acid.†

ART. 5.—*Sulphate of Strontites.*

I. This salt resembles, very nearly, the sulphate of barytes. It may be formed in a similar manner, by pouring the solution of pure strontites into diluted sulphuric acid, or into the solution of an alkaline sulphate; for it has a stronger affinity than any of the alkalis for sulphuric acid. It is soluble in 3840 parts of boiling water.

II. The sulphate of strontites is also found native in considerable quantities; chiefly at Aust Passage, and at other places in the neighbourhood of Bristol. As the native carbonate is now becoming scarce, this compound may be advantageously employed for procuring artificial carbonate of strontites. The process is precisely similar to that already described for decomposing the sulphate of barytes. (Art. 4. g.)

According to a considerable majority of the chemists who have analyzed it, it consists of

Acid	42	. . .	100
Strontites . . .	58	. . .	138
	<hr/>		<hr/>
	100		238

The accuracy of these numbers is admitted by Dr. Wollaston. But Vauquelin has stated, that it is composed of 46 acid and 54 base.

ART. 6.—*Sulphate of Lime.*

I. The sulphate of lime is formed, by adding to the carbonate a sufficient quantity of sulphuric acid; and by gently calcining the residue, to expel the redundancy of the latter acid. It is also found native, in great abundance, under the names of gypsum, plaster of Paris, &c.

II. It has the following properties:

1. It is insipid and free from smell.
2. It is difficultly soluble, requiring 500 times its weight of cold water, or 450 of hot water,
3. It is fusible by a moderate heat. When sulphate of lime, which has been dried at 160° Fahrenheit, is exposed to a low red-

* Contributions, i. 377.

† Both the carbonat and sulphat of barytes artificially prepared, make beautiful pigments, useful both as water and oil colours. C.

heat, it loses 22 (according to Berzelius, and Bucholz 21) per cent. of its weight, consisting entirely of water. After calcination, it absorbs water rapidly, and forms a good cement.

4. It is decomposed by carbonates of alkali, a double exchange of principles ensuing. Hence the milkiness which ensues on adding carbonate of potash to many spring waters; the carbonate of lime, which is generated, being less soluble than the sulphate. Hence, also, hard waters, which always contain sulphate of lime in solution, curdle soap, the alkali of which is detached by the sulphuric acid, and the oil is set at liberty.

5. It is decomposed by ignition with charcoal, which separates the oxygen of the sulphuric acid, and leaves a combination of lime with sulphur.

By dissolving 100 grains of calcined sulphate of lime in boiling distilled water, and adding muriate of barytes, I obtained a precipitate, which, when well washed, dried, and calcined in a low red-heat, weighed 175.9. Hence 100 parts of calcined sulphate of lime must contain very nearly

	Acid.	Base.
According to the above experiment . . .	59 .	41
———— Thomson and Berzelius . . .	58 .	42
———— Klaproth	57.63	42.37
———— Dalton	58.60	41.40

It consists, therefore, of an atom of lime united with an atom of acid.

ART. 7.—*Sulphate of Magnesia.*

I. When highly concentrated sulphuric acid is suddenly added to fresh prepared and pure magnesia, very great heat and vapour are excited, and are accompanied frequently with an extrication of light. This appearance was first observed by Westrumb.

II. If the carbonate of magnesia be added to diluted sulphuric acid, the carbonic acid is expelled, and a solution of sulphate of magnesia is formed, which crystallizes on cooling. Crystals of sulphate of magnesia may also be procured in the shops, under the name of Epsom salt.

III. These crystals have the following properties:

1. They have the form of small quadrangular prisms, surmounted by quadrangular pyramids with dihedral summits.* They undergo no change by exposure to the atmosphere.

2. At the temperature of 60°, this salt is soluble in an equal weight of cold water, and in three fourths its weight of boiling water, which thus receives an addition of one fourth of its bulk.

3. When exposed to a low red-heat, it undergoes the watery fusion, but is not volatilized. It loses, however, about one half its weight, which is water of crystallization, and, according to Berzelius, a very minute portion of acid.

* These crystals formed by spontaneous evaporation, may sometimes be obtained two inches in length, and more than half an inch in breadth. C.

4. One hundred grains of sulphate of magnesia, deprived, by calcination in a low red-heat of its water of crystallization, afforded me 200 grains of sulphate of barytes when precipitated by the muriate of the latter earth. Hence 100 grains of dry sulphate of magnesia are composed of 67 acid and 33 magnesia, and the crystallized salt, supposing it to contain half its weight of water, will consist in 100 parts of

50 water,
33.5 sulphuric acid,
16.5 magnesia.

Berzelius, from 100 grains of desiccated sulphate of magnesia, obtained 194.3 of sulphate of barytes. Hence the dry salt consists of 65.1 acid and 34.9 earth, and its atomic constitution is one atom of earth + one atom of acid.

5. Its solution is precipitated by carbonates of potash and of soda; but not by carbonate of ammonia, unless heat is applied. The carbonate of magnesia of the shops is prepared by mixing together concentrated and hot solutions of carbonate of potash and sulphate of magnesia. The sulphate of potash, thus formed, is removed by copious washing with water, and the carbonate of magnesia is then dried. The proportions employed are filtered solutions of four parts of the crystallized sulphate, and three of the sub-carbonate. One hundred parts of the desiccated sulphate give about seventy-one of sub-carbonate of magnesia, or about 31.6 of the pure earth.

6. When a dilute solution of carbonate of soda is mixed with a dilute solution of sulphate of magnesia, and the sub-carbonate which is formed, if any, is separated by filtration, crystals of carbonate of magnesia, after some time, shoot in the liquid, containing a larger proportion of water, but no more carbonic acid than the common carbonate, see chap. x. sect. 4. When solution of pure ammonia is added to that of sulphate of magnesia, part of the earth is precipitated. The rest remains in solution, and, by evaporation, a triple salt is formed, consisting of sulphuric acid, magnesia, and ammonia, and called *ammoniaco-magnesian sulphate*.

ART. 8.—*Sulphate of Alumine.*

The properties of this salt may be exhibited by those of the common alum of commerce; though, as will afterwards appear, alum is not merely a combination of this earth with sulphuric acid; but is a triple salt, composed either of sulphuric acid, alumine, and potash; or of sulphuric acid, alumine, and ammonia. It has the following characters.

(a) It has a sweetish astringent taste. Its specific gravity is 1.71.

(b) It dissolves in water, five parts of which, at 60°, take up one of the salt, but hot water dissolves about three fourths of its weight.

(c) This solution reddens vegetable blue colours; which proves the acid to be in excess.

(d) When mixed with a solution of carbonate of potash, an effervescence is produced by the uncombined acid, which also prevents the first portions of alkali, that are added to a solution of sulphate of alumine, from occasioning any precipitate.

(e) On a farther addition of alkali, the alumine is precipitated.

(f) Sulphate of alumine, when heated, swells up, loses its regular form, and becomes a dry spongy mass; but, according to Vauquelin,* the whole of its acid cannot thus be expelled.

(g) The combination of sulphuric acid with alumine is incapable of crystallizing without an admixture of sulphate of potash, which forms a constituent of all the alum of commerce. According to Vauquelin, 100 parts consist of 49 dry sulphate of alumine, 7 sulphate of potash, and 44 water. Or 100 grains are composed of

Acid . .	30.52 . .	33 . .	34.23
Alumine .	10.50 . .	12 . .	10.86
Potash .	10.40 . .	9 . .	9.81
Water .	48.58 . .	47 . .	46.
	<hr/>	<hr/>	<hr/>
	100.00 †	100 ‡	99.90 §

The acid in Vauquelin's estimate, is evidently rated too low; for alum, when precipitated by muriate of barytes, gives, as nearly as possible, an equal weight of sulphate of barytes, 100 grains of which contain 33.5 of sulphuric acid, the quantity, therefore, present in 100 parts of alum. According to Berzelius, alum is composed of

Sulphate of alumine	36.85
potash	18.15
Water	45.
	<hr/>
	100.

The oxygen of the potash being represented by 1, Berzelius finds that the oxygen of the alumine will be as 3; that of the sulphuric acid as 12; and that of the water as 24. The salt consists, according to Mr. Dalton, of one atom of sulphate of potash, four atoms of sulphate of alumine, and 30 atoms of water. The alumine, he contends, does not exist in the state of super-sulphate, but of a saturated sulphate, a salt composed of

Alumine	29.934
Acid	70.066
	<hr/>
	100.

* Annales de Chimie, xxxvii. 91.

† Vauquelin.

‡ Dalton.

§ Berzelius. In this there is a deficiency of 0.1 per cent.

A neutral sulphate was obtained by Berzelius, by the following process. He decomposed alum by ammonia; washed the precipitate, and redissolved it in sulphuric acid. To the liquor, after evaporation, he added alcohol, which threw down a sulphate nearly neutral, and rendered perfectly so, by being washed with further portions of alcohol.

(h) Alum is decomposed by charcoal, which combines with the oxygen of the sulphuric acid, and leaves the sulphur attached to the alumine. A combination of alumine, sulphur, and charcoal, forms the *pyrophorus of Homberg*. To prepare this, equal parts of powdered alum and brown sugar are melted over the fire, and are kept stirring till reduced to dryness. The mixture, when cold, is to be finely powdered, and introduced into a common phial, coated with clay, to which a glass tube, open at each end, is to be luted, to allow the escape of the gases that are produced. The phial must then be set in the fire, surrounded by sand, in a crucible. Gas will issue from the open end of the tube, and may be inflamed by a lighted paper. When this ceases to escape, the crucible may be removed from the fire, and a little moist clay pressed down upon the open end of the tube, to prevent the access of air to the contents of the phial. When cold, the tube may be removed, and a cork substituted in its place. The principal difficulty in the process, is to stop it precisely at the period when the pyrophorus is formed; for if the heat be continued longer, the preparation will be spoiled.

The pyrophorus thus formed is a black and light powder, which instantly takes fire when poured out of the bottle into the air, and inflames suddenly in oxygen gas. Sulphate of potash appears to be essential to its production, and hence the sulphuret of potash is a necessary ingredient. From the recent discoveries of Mr. Davy, it appears not improbable that this pyrophorus may contain sulphuret of potassium. The principal part of the phenomena, however, are owing to the combustion of an extremely light and finely divided charcoal.*

ART. 9.—*Sulphate of Glucine.*

Glucine combines readily with sulphuric acid, both in its pure and carbonated state. The resulting salt is extremely soluble; in-somuch that, when evaporated, it assumes the form of a syrup, without crystallizing. Its taste is sweet, and rather astringent. It is decomposed entirely in a high temperature, the earth being left

* The whole process of forming pyrophorus, is well adapted to reduce the potash in the mixture to the state of potassium. The phenomenon of combustion in a damp atmosphere appears to depend altogether on the evolution of potassureted hydrogen gas, which is spontaneously fired by exposure to the oxygen of the atmosphere. The residue of the combustion, if mixed with a small quantity of sulphuret of potash, or a solution of potash, and again heated as before, will re-constitute an excellent pyrophorus. This is worth attention, for it saves a very tedious and troublesome preliminary process. C.

in a state of purity. It is also destroyed by ignition with charcoal. It does not yield its earthy ingredient to any of the acids; but is decomposed by all the alkalis and earths, alumine excepted.

ART. 10.—*Sulphate of Zircon.*

To effect the combination of zircon with any acid, this earth should be fresh precipitated; for, after being dried, it enters with difficulty into union.

The salt, resulting from the union of sulphuric acid with zircon, is white, insoluble, and without taste. It is decomposed by a high temperature, which expels the acid, and leaves the zircon pure. It is not changed by other acids, but yields its sulphuric acid to the alkalis, and to most of the earths.

ART. 11.—*Sulphate of Yttria.*

Sulphuric acid readily dissolves yttria, and caloric is evolved during the process. As the solution goes on, the sulphate crystallizes in small brilliant grains, which have a sweetish taste, but less marked than that of the sulphate of glucine. Their colour is a light amethyst red. They require 30 parts of water, of the temperature of 60° , for solution, and give up their acid when exposed to a high temperature. They are decomposed by oxalic acid, prussiate of potash, infusion of galls, and phosphate of soda.

SECTION V.

Sulphites.

I. THE combination of sulphurous acid with alkaline and earthy bases, may be effected by passing the gas, as it proceeds from the materials, (sect. 2, *h*,) through the base, dissolved or diffused in water. An intermediate vessel may be placed, as represented, fig. 30 and 31, to condense any sulphuric acid that may pass over; and the solution of the alkali or earth may be contained in a bottle with two necks. Pure potash, soda, or ammonia, are readily kept in solution: but barytes or strontites must be dissolved in boiling water; and the bottle containing them must be surrounded with hot water, while the gas is transmitted through the solution. The solution, when saturated with gas, may be evaporated; and this is best done in an alembic, covered with its capital, because the salts of this class are changed by the action of the atmosphere.

II. The sulphites have no peculiarly interesting properties, that can entitle them to minute and specific description, in a work devoted solely to the students of chemical science. I shall enumerate, therefore, only the principal ones; and refer, for farther information, to the 2d and 24th volumes of the *Annales de Chimie*, and

to Dr. Thomson's memoir in Nicholson's Journal, vi. 94. Their general qualities are the following :

1. They have a disagreeable taste and smell, resembling the fumes of burning sulphur.

2. When heated, they emit sulphurous acid and water, and then sulphur, which, on the application of an inflamed substance, takes fire, and burns violently.

3. Exposed to the atmosphere, in a state of solution, or moistened with water, they absorb oxygen, and are slowly converted into sulphates, without undergoing any change in their state of neutralization.

4. When added to nitric acid, red fumes arise, and the salts become sulphates. Oxymuriatic acid produces the same effect. Concentrated sulphuric acid expels sulphurous acid gas, which may be collected over mercury.

5. When sulphuretted hydrogen gas is passed through a solution of the sulphites, they combine with an additional quantity of sulphur, and form *sulphuretted sulphites*. Or when sulphur is boiled with the sulphites in solution, sulphur is taken up, and sulphurous acid escapes.*

6. When perfectly pure, sulphites are not precipitated by a solution of pure barytes or strontites, or by any of the salts with base of either of those earths. If a precipitation ensue, it indicates the presence of a portion of sulphate.

SULPHITE OF POTASH crystallizes in the form of lengthened rhomboidal plates, or of needles, which have sometimes a slight yellowish tinge. It has a pungent and sulphurous taste, and is soluble in an equal weight of cold, or in less than an equal weight of boiling water. At the temperature of 300° Fahrenheit, it loses only about 2 per cent.; but when more strongly heated, the salt is decomposed, and sustains a loss of about 22 per cent., of which 15 are sulphurous acid, 5 sulphur, and 2 water. When thrown into a red-hot crucible, a blue flame arises from it, and its weight is diminished in the proportion which has just been stated. When this solution is exposed to the air, the salt slowly attracts oxygen, and is converted into sulphate of potash. This change goes on more rapidly in oxygen gas; or when it is mixed with any substance holding oxygen in loose combination, as nitric or oxymuriatic acid. It contains, in 100 parts, from Dr. Thomson's experiments,

43.5 acid
54.5 potash
2 water
<hr/>
100

SULPHITE OF SODA forms compressed tetrahedral prisms with dihedral summits. It requires for solution less than its own weight of boiling water, or four times its weight of cold water. It efflo-

* Gay Lussac, 85 Ann. de Chim. 199.

resces in the air, but much less perfectly than the sulphate of soda. It is composed, according to Dr. Thomson, of

31 acid
18 soda
51 water

100

SULPHITE OF AMMONIA crystallizes in hexahedral prisms terminated by pyramids with the same number of sides, or in rhomboidal prisms with trihedral summits. It is soluble in an equal weight of cold water, or in less than an equal weight of boiling water. It deliquesces in the atmosphere, and absorbing oxygen is changed into sulphate of ammonia, which becomes dry.

SULPHITE OF BARYTES, like the salt formed by uniting the same base with sulphuric acid, is almost insoluble. When united with an excess of sulphurous acid, however, (which may be done by dissolving the white powder, that is first formed, in liquid sulphurous acid,) it forms a crystallizable salt, still of sparing solubility, consisting of

Base 69.74
Acid 28.84
Water 1.42

100.

The solution of this salt may be advantageously used to purify the solution of any sulphite from sulphuric acid, which it precipitates in the state of an insoluble sulphate of barytes.

SULPHITE OF LIME is also insoluble, but may be crystallized by being first dissolved in liquid sulphurous acid. In this state it requires 800 parts of water for solution.

SULPHITE OF MAGNESIA differs from the sulphate of this earth in being vastly less soluble in water, of which it requires 20 parts at the common temperature. Hot water takes up a farther portion, which is deposited on cooling.

SULPHITE OF ALUMINE is not crystallizable, but has the form of a white soft powder, insoluble in water, but soluble in an excess of acid. It consists, according to Dr. Thomson, of

32 acid
44 alumine
24 water

100

SECTION VI.

Binary Compounds of Sulphur.—1st, With Alkalis.—2d, With Hydrogen.

ART. 1.—*Sulphurets.*

I. THE combination of sulphur, with the fixed alkalis and earths, may be formed by fusing together, in a covered crucible, equal parts of sulphur and the respective alkali or earth with which it is to be combined. The compound is to be poured, when in a state of fusion, into an iron dish, or upon a smooth stone; and preserved in a well closed bottle. The compounds have, for the most part, a reddish brown or liver colour; and hence were formerly called *hepars* or *livers* of sulphur. They may be formed, also, by fusing the alkaline or earthy sulphates with powdered charcoal; but in this case, the sulphuret generally contains a portion of carbonic acid, and also of charcoal.

Sulphuret of lime, when intended for the purpose of *Canton's phosphorus*, is best prepared, by placing, in a crucible, alternate strata of calcined and pounded oyster-shells and sulphur; exposing them to a moderate heat; and then confining them in a bottle with a ground stopper. Or, according to the original directions of Canton, three parts of oyster-shells, calcined for about an hour and pulverised, are to be mixed with one of sulphur, and rammed tightly into a crucible, which is to be kept red-hot for about an hour. The compound, when cold, has the properties already assigned to the Bolognian phosphorus.

II. Sulphurets have the following properties:

(a) In a moist state they emit an offensive smell, and have a disagreeable taste.

(b) They change to green the colour of violets, in the same manner as uncombined alkalis.

(c) They blacken the skin, silk, and other animal substances.

(d) They are decomposed by all acids. Into a Nooth's machine put a weak solution of sulphuret of alkali, and pass through it streams of carbonic acid gas. In the course of a few days, the sulphur will be precipitated, and a carbonate of alkali will be obtained. This decomposition ensues, instantly, on adding, to a solution of sulphuret of potash, any of the stronger acids, as the sulphuric, nitric, or muriatic; and we obtain a compound of the alkali with the respective acid employed.

(e) The liquid sulphurets absorb oxygen gas. This may be shown by the experiments already described (chap. v.) If the change thus effected be examined, it will be found that the oxygen has combined with the sulphur, and formed sulphurous acid, which, uniting with the alkali, has composed the sulphite of potash.

(f) If dilute muriatic be poured on the solution of sulphuret of potash or soda, a violent effervescence will ensue, and a very offensive gas be disengaged. This gas may be collected over water. It is termed sulphuretted hydrogen gas.

ART. 2.—*Sulphuretted Hydrogen Gas.*

This gas may be procured :

1. By the action of diluted sulphuric acid on sulphuret of iron, prepared in the following manner. A bar of iron is to be heated to a white or welding heat in a smith's forge, and, in this state, is to be rubbed with a roll of sulphur. The metal and sulphur unite, and form a liquid compound, which falls down in drops. These soon congeal ; and the compound must be preserved in a well closed phial.

2. The sulphuret, prepared by melting iron filings with sulphur in a crucible, does not answer the purpose equally well, because the gas, which it affords, is mixed with a good deal of hydrogen gas. So, also, is the sulphuretted hydrogen produced by heating sulphur in hydrogen gas.

3. The sulphuret of potash, if prepared by boiling flowers of sulphur with liquid potash, quite free from carbonic acid, gives pure sulphuretted hydrogen, when acted upon by diluted sulphuric or muriatic acid.*

II. Its properties are the following :

(a) Its smell is extremely offensive, resembling that of putrefying eggs.

(b) It is inflammable, and burns either silently or with an explosion, according as it is previously mixed, or not, with oxygen gas or atmospheric air. During this combustion, water results from the union of the hydrogen with the oxygen, and sulphuric and sulphurous acids from that of the oxygen and sulphur. Two measures require three of oxygen gas, one measure of which saturates the hydrogen, and two the sulphur.

When three parts of sulphuretted hydrogen are mingled with two of nitrous gas, the mixture, on being inflamed, burns with a yellowish green flame.

(c) It tarnishes silver, mercury, and other polished metals, and instantly blackens white paint.

(d) It is absorbed by water, which takes up its own bulk, or, according to Gay Lussac, three times its bulk of the gas ; but in order to obtain so considerable an absorption, the gas, submitted to experiment, should be perfectly pure. Water thus saturated acquires the peculiar smell of the gas. It is this gas which gives to the Harrogate, and some other natural waters, their disagreeable odour. Liquid muriatic acid absorbs at least three times its volume ; and sulphuric acid, diluted with an equal weight of water, once and a half its volume.

(e) Water, saturated with this gas, reddens the infusion of violets, in this respect producing the effect of an acid. From this and other properties, some of the German chemists have proposed for it the name of *hydrothionic acid*.

* Thenard recommends its preparation, by treating, with the aid of heat, sulphuret of antimony with muriatic acid. The sulphuret reduced to powder is put into an appropriate vessel with 5 or 6 times its weight of concentrated acid. The gas is collected over water or mercury. C.

(*f*) Water impregnated with sulphuretted hydrogen, when exposed to the atmosphere, becomes covered with a pellicle of sulphur. Sulphur is even deposited when the water is kept in well-closed bottles.

(*g*) On the addition of a few drops of nitric or nitrous acid to the watery solution, sulphur is instantly precipitated. In this case the oxygen of the acid combines with the hydrogen of the gas, and the sulphur is separated.

(*h*) This gas, as will afterwards appear, is decomposed by mixture with oxy-muriatic acid gas; and sulphur is precipitated.

(*i*) It is decomposed also when kept in a state of mixture with atmospheric air, the oxygen of which combines with the hydrogen, and forms water, while the sulphur is precipitated.

(*k*) A succession of electric explosions throws down sulphur from it, and the volume of the gas remains unaltered.

(*l*) When six measures of sulphuretted hydrogen gas and five measures of sulphurous acid gas are mingled together, the hydrogen of the former unites with the oxygen of the latter, and the sulphur of both is precipitated. But five measures of sulphurous acid contain twice the oxygen necessary for saturating six measures of sulphuretted hydrogen. Hence it is probable, that the sulphur is separated in the state of an oxide.

(*m*) It is decomposed when passed over ignited charcoal, and is converted into carburetted hydrogen gas.

(*n*) Sulphuretted hydrogen, both in the state of a gas and of watery impregnation, precipitates all metallic solutions, excepting those of iron, nickel, cobalt, manganese, titanium, and molybdena.

(*o*) It is copiously absorbed by alkalis, and by all the earths, excepting alumine and zircon. These alkaline and earthy combinations are termed hydro-sulphurets.

(*p*) When potassium or sodium is made to act on sulphuretted hydrogen gas, a brilliant combustion takes place; a quantity of hydrogen gas is evolved, precisely equivalent to that which the metal would have separated from water; the metal loses its lustre, and becomes greyish, or amber coloured, or reddish; and by the action of diluted muriatic acid, the whole of the sulphuretted hydrogen is recovered. This experiment proves, that sulphuretted hydrogen, and consequently sulphur, contain no oxygen; for, in that case, the potassium would not, after being acted on by the gas, evolve the original quantity of sulphuretted hydrogen. All that appears to take place is, the combination of the metal with sulphur, and the formation of a sulphuret of potassium or sodium, which disengages from water exactly as much hydrogen, as would have been evolved by the metal in its separate state. The results of Sir H. Davy, which are somewhat different, are satisfactorily explained by Gay Lussac and Thenard.*

(*q*) The specific gravity of sulphuretted hydrogen gas has been variously stated. Mr. Kirwan found 100 cubic inches, at 60° Fahrenheit, and 30 inches barometer, to weigh 34.286 grains, which

* Recherches, i. 202.

makes its specific gravity 1.124. Sir H. Davy states the weight of the same quantity at 36.5 grains, and its specific gravity, therefore, at 1.180. Gay Lussac and Thenard determined its specific gravity to be 1.1912; and 100 cubic inches should, therefore, weigh 36.33 grains.

(r) Admitting the accuracy of Sir H. Davy's statement of its specific gravity, and also that 100 cubic inches of the gas contain exactly the same volume of hydrogen (= 2.27 grains,) then 36.5 grains of sulphuretted hydrogen will contain 2.27 grains of hydrogen; and 100 grains will consist of

Sulphur	93.8
Hydrogen . . .	6.2
	<hr/>
	100.

From these data, which agree very nearly with those of Berzelius,* the weight of the atom of sulphur may be stated at 15; for as 6.2 to 93.8 so is 1 to 15 very nearly. The weight of this atom, therefore, turns out to be the same, whether investigated by its combinations with oxygen or with hydrogen.

ART. 3.—*Hydro-Sulphurets.*

In its union with alkaline and earthy bases, sulphuretted hydrogen seems to perform, in a great measure, the functions of an acid; and presents, therefore, an important exception to the doctrine of acidification; for, in this instance, a body, which contains no oxygen, possesses some of the most important characters of an acid, viz. the property of changing vegetable blues to red, and of uniting with alkalis.

I. The hydro-sulphurets may be formed, by transmitting sulphuretted hydrogen gas, as it issues from the materials that afford it, through a solution of the alkaline or earthy base. Or the base, when insoluble, must be kept suspended in water by mechanical agitation.

II. The hydro-sulphurets have several qualities common to the whole genus.

1. They are all soluble in water, and the recent solution is colourless. By exposure to the air, however, it first becomes green, or greenish yellow, and deposits sulphur on the sides of the vessel. The glass bottle, containing the solution, becomes black on its inner surface, in consequence of the combination of sulphur with the oxide of lead contained in the glass.

2. The solution of hydro-sulphuret of magnesia is decomposed by heat; that of lime nearly so; but those of potash and soda, though rendered much more alkaline by heat, still contain a large proportion of sulphuretted hydrogen.

3. After long exposure to the atmosphere, the solution entirely loses its colour, and again becomes perfectly limpid. When ex-

* 31 Ann. de Chim. 26.

aminated, it is found to consist of a combination of sulphuric acid with the peculiar base of the hydro-sulphuret. This is owing to the absorption of oxygen, which all hydro-sulphurets take from the atmosphere; the formation of a sulphite; and the conversion of this, by farther oxygenation, into a sulphate. Hence, when confined in contact with a limited quantity of atmospherical air, hydro-sulphurets effect a diminution of volume; and may be employed to ascertain its proportion of oxygen. They entirely absorb pure oxygen gas.

4. When a hydro-sulphuret, fully charged with gas, is heated with sulphur, a strong effervescence ensues; much of the sulphur is dissolved; and sulphuretted hydrogen escapes. If the hydro-sulphuret is not fully saturated, sulphur is still dissolved, but without any escape of sulphuretted hydrogen.

5. When an acid is poured on any of the hydro-sulphurets, the sulphuretted hydrogen gas is disengaged, and no sulphur is deposited. This non-precipitation of sulphur distinguishes hydro-sulphurets, both from sulphurets and hydroguretted sulphurets. The acid employed should be one which strongly retains its oxygen, such as the sulphuric or muriatic; otherwise it will be decomposed. A hydro-sulphuret, which has been a few days exposed to the air, yields, by this treatment, sulphurous acid gas, along with sulphuretted hydrogen.

6. The solutions of hydro-sulphurets precipitate all metallic solutions. They also precipitate alumine and zircon from their solutions, but no other earths.

7. The hydro-sulphurets are, for the most part, susceptible of a regularly crystallized form.

HYDRO-SULPHURET OF POTASH forms large transparent crystals, not unlike in size those of sulphate of soda, but having the shape of four-sided prisms, acuminated with four planes; or of six-sided prisms, acuminated by six planes. It is deliquescent, and affords a thick syrupy liquor, which gives a green colour to the skin. It dissolves readily in water and alcohol, producing cold. When dilute acids are added to the solution, a brisk effervescence is excited, but no sulphur is deposited.

HYDRO-SULPHURET OF SODA is a compound, which derives some importance from its being produced along with carbonate of soda, in several processes for decomposing the sulphate of soda.* It is transparent at first, colourless, and crystallized in four-sided prisms acuminated by four planes. It has an acrid and alkaline taste, which soon becomes very bitter. Its solution is colourless, but tinges the skin or paper green. It effervesces briskly with acids, and no sulphur is deposited, unless the nitric or oxymuriatic acids are added, which oxidate the hydrogen, and throw down sulphur.

Vauquelin has proposed to distinguish these two sulphurets, which so closely resemble each other, by the following test. The hydro-sulphuret of potash, when added to a solution of sulphate of

* *Annales de Chimie*, lxiv. 59.

alumine, occasions a crystallization of alum; but that of soda has no such action.

HYDRO-SULPHURET OF AMMONIA may be formed by the direct mixture of sulphuretted hydrogen and ammoniacal gases in a dry vessel, cooled externally by ice. It is deposited in needle-shaped crystals. But, for all practical uses, it is better prepared, by putting a solution of pure ammonia into the middle vessel of a Nooth's machine, and passing through it streams of sulphuretted hydrogen gas, till the liquid acquires a yellowish colour. In this state it constitutes the hepatized ammonia, so strongly recommended by Dr. Rollo as a remedy of diabetes.

HYDRO-SULPHURETS OF BARYTES AND STRONTITES are crystallized salts, having a white silky lustre, and readily soluble in water.*

HYDRO-SULPHURET OF LIME, formed by transmitting sulphuretted hydrogen through water, in which lime is kept mechanically suspended, composes a crystallizable salt, soluble in water; and having the general properties of hydro-sulphurets.

ART 4.—*Super-Sulphuretted Hydrogen, and Hydroguretted Sulphurets.*

Super-sulphuretted hydrogen is obtained, when hydro-sulphuret of potash is poured, by little and little, into muriatic acid. A very small portion only of gas escapes; and while the greater part of the sulphur separates, one portion of it combines with the sulphuretted hydrogen; assumes the appearance of an oil; and is deposited at the bottom of the vessel. Or, dissolve sulphur in a boiling solution of pure potash; and into a phial containing about one third its capacity of muriatic acid, of the specific gravity 1.07, pour about an equal bulk of the liquid hepar. Cork the phial, and shake it; the hydroguretted sulphur gradually settles to the bottom in the form of a brown, viscid, semifluid mass. Its properties are the following:

1. If gently heated, sulphuretted hydrogen gas exhales from it; the super-sulphuret loses its fluidity; and a residue is left, consisting merely of sulphur.

2. It combines with alkalis and earths; and forms with them a class of substances called hydroguretted sulphurets.

3. It is constituted, according to Mr. Dalton, of two atoms of sulphur, weighing 30, with one atom of hydrogen, and consists, therefore, per cent. of

Sulphur	96.75
Hydrogen	3.25
	<hr/>
	100.

There are, therefore, three distinct combinations of sulphur and its compounds with alkalis and earths. The first consist, simply, of

* See Annales de Chimie, lxii. 181.

sulphur, united with an alkaline or earthy base, and are properly called *sulphurets*. The second are composed of sulphuretted hydrogen, united with a base, and are called *hydro-sulphurets*. The third contain super-sulphuretted hydrogen, attached to a base, and constitute *hydroguretted sulphurets*.

The sulphurets can exist, as such, only in a dry state; for the moment they begin to dissolve in water, a decomposition of that fluid commences; sulphuretted hydrogen is formed; and this, uniting with an additional proportion of sulphur, composes super-sulphuretted hydrogen. This last, uniting with the base, forms an hydroguretted sulphuret. The sulphurets, therefore, are partly changed, by solution, into hydroguretted-sulphurets. The solution, however, still contains so large a proportion of sulphur, that we may consider it as composed, in part, of liquid sulphuret. Hence the affusion of an acid throws down a large quantity of sulphur. A distinguishing character, also, of solutions of this kind, is that sulphur is precipitated by passing through them sulphuretted hydrogen gas.

According to Proust, if red oxide of mercury be added to solutions of the kind which have just been described, the sulphuretted hydrogen is removed, and what remains is a pure liquid sulphuret, from which acids precipitate sulphur only, without any effervescence.

II. The hydroguretted sulphurets are also formed by boiling, along with a sufficient quantity of water, the alkaline, or earthy base, with flowers of sulphur. Thus a solution of pure potash, pure soda, or of barytes or strontites, may be changed into an hydroguretted sulphuret. To prepare this compound, with a base of lime, the powdered earth, mixed with sulphur, may be boiled with a proper quantity of water, and the solution filtered or cleared by subsidence. One hundred grains of lime dissolve about 45 of sulphur, and afford a liquid of 1.020 specific gravity.

The hydroguretted sulphuret of ammonia (which base cannot, in strictness, owing to its liquid form, compose a true sulphuret) may be prepared as follows: Mix together, in a mortar, three parts of hydrat of lime, one part of muriate of ammonia, and one of flowers of sulphur. Introduce the mixture into a retort, and apply a receiver. Begin the distillation with a gentle heat. The first liquor, that comes over (long known under the name of *Boyle's Fuming Liquor*), has a light yellow tinge, and emits fumes; the second has a deeper colour, and is not fuming. When the latter begins to appear, the fire may be raised.

Another method of forming, by a very simple process, the hydroguretted sulphurets, consists in digesting, in a gentle heat, a hydro-sulphuret with powdered sulphur, an additional portion of which is thus dissolved, while part of the sulphuretted hydrogen escapes.

Hydroguretted sulphurets have the following properties:

1. They have a deep greenish-yellow colour; an acrid and intensely bitter taste; and an excessively offensive smell.
2. They deposit sulphur when kept in close vessels; become

much more transparent and lighter coloured; and less offensive to the smell.

3. They rapidly absorb oxygen from the atmosphere, and from oxygen gas. Hence their employment in eudiometry.*

4. On the addition of dilute sulphuric, or muriatic, or of certain other acids, they are decomposed. Sulphuretted hydrogen gas is evolved, and sulphur is precipitated.

HYDROGURETTED SULPHURETS OF POTASH AND OF SODA differ very little from each other. They may be formed by boiling solutions of pure potash or soda with flowers of sulphur. When very concentrated, they have a deep reddish brown colour, a nauseous taste, a disagreeable odour, and a soapy feel, tinging the cuticle black. When exposed to the air, a thin pellicle of sulphur forms upon their solutions, which, by sufficiently long exposure, are changed into sulphates. When an acid is suddenly added, sulphur is thrown down, which becomes, when washed with sufficient water and dried, almost white, and constitutes what has been called precipitated sulphur, milk of sulphur, or magistery of sulphur.

HYDROGURETTED SULPHURET OF AMMONIA may be formed by the process already described, or by digesting hydro-sulphuret of ammonia with sulphur, a portion of which is dissolved.

HYDROGURETTED SULPHURET OF BARYTES is obtained by boiling crystals of pure barytes with one fourth their weight of sulphur and sufficient water. Two compounds are formed, *viz.* an hydroguretted sulphuret, which has a red colour, and remains in solution; and colourless crystals, which are supposed to be a hydro-sulphuret of barytes. Strontites forms similar compounds.

HYDROGURETTED SULPHURET OF LIME is formed by boiling hydrate of lime with a third its weight of sulphur and ten times its weight of water. The compound has a deep orange colour, and is of importance from its application to eudiometrical purposes.

Sulphuret of Carbon, or Alcohol of Sulphur.

There has been much controversy respecting the nature of this compound; and several contradictory statements have been given of its composition. It was discovered by Lampadius in 1796, and was considered by him as consisting of sulphur and hydrogen. Clement and Desormes were led, by their researches, to deny the presence of the latter element; and to conclude that it is a compound of sulphur and charcoal. This inference was afterwards controverted by Vauquelin and by Berthollet, jun.; but it has been proved correct, by the recent and able investigations of Drs. Berzelius and Marcet.† -

To prepare this substance, a coated earthen tube, of about one inch and a half in diameter, partly filled with small pieces of charcoal, may be disposed in a furnace as represented fig. 40, *c c*, one end being placed higher than the other. To this end may be adapted a glass tube, open at both ends, containing small bits of sulphur; and, to the other end, by means of an adapter, is to be fixed a

* See chap. v. sect. 4.

† Phil. Trans. 1813.

curved tube, passed into water contained in a two-necked bottle. The part of the tube, containing the charcoal, may then be made red-hot ; and, when this happens, the bits of sulphur are to be pushed forwards, one by one, by means of a wire, carefully excluding air. As soon as the sulphur comes into contact with the charcoal, bubbles of gas will be produced in great abundance, and a vapour will appear, which will condense, under the water in the bottle, into a liquid, of which, in the course of a day, about half a pint may be procured. This liquid may be purified by redistilling it at a very gentle heat, not exceeding 100° or 110° Fahrenheit ; and some dry muriate of lime may be put into the retort, in order to obtain the fluid perfectly free from water. The liquid which comes over is quite pure, and some sulphur remains in the retort.

The alcohol of sulphur has the following properties :

1. It is eminently transparent, and perfectly colourless. Sometimes, immediately after distillation, the oily liquid appears a little opake and milky ; but the next day it is found to have become completely limpid. It has an acrid, pungent, and somewhat aromatic taste ; its smell is nauseous and fetid, though differing from that of sulphuretted hydrogen.

2. Its specific gravity is 1.272 ; its refractive power, as ascertained by Dr. Wollaston, is 1.645. Its expansive force (at 30 inches barometer, and $53\frac{1}{2}^{\circ}$ Fahrenheit) is equal to the pressure of 7.36 inches of mercury ; so that air, to which it is admitted, will dilate about one fourth of its volume. It boils briskly under the common atmospheric pressure, at a temperature of 105° or 110° Fahrenheit. It does not congeal, at a temperature as low as 60° , below 0 of Fahrenheit.

3. It is highly inflammable, and takes fire at a temperature scarcely exceeding that at which mercury boils. Its flame is bluish, and it emits copious fumes of sulphurous acid. If a long glass tube, open at both ends, be held over the flame, care being taken to keep the tube quite cool, no moisture whatever is deposited on its inner surface, a sufficient proof of the absence of hydrogen.

4. The oily liquid readily dissolves in alcohol and ether, though not in all proportions, and these solutions are decomposed by the addition of water. It readily incorporates with fixed and volatile oils, and rapidly dissolves camphor. It is not soluble in water.

5. In its liquid state, it suffers no change on being heated with potassium ; but potassium, when heated in its vapour, becomes ignited, and emits a reddish flame. The residue, when washed with water, affords sulphuret of potash and charcoal.

6. It does not tarnish mercury or its amalgams, nor silver, unless it contain more sulphur than is essential to its constitution.

7. The alkalis dissolve it entirely, but very slowly. Of the acids, none exert any sensible action on it, but the nitromuriatic and liquid oxymuriatic acids, which occasion its decomposition.

By an ingenious and well conducted series of experiments, Drs. Berzelius and Marcet determined, that the alcohol of sulphur con-

tains no hydrogen; but that it is a true SULPHURET OF CARBON, composed of

Sulphur . . .	84.83 . . .	or . . .	100.
Carbon . . .	15.17		17.89
	<hr/>		<hr/>
	100.		117.89

The above-mentioned numbers establish the proportion of the elements of this compound to be two atoms of sulphur to one of carbon.

The sulphuret of carbon was found by Berzelius to be capable of uniting with alkaline and earthy bases, and of forming compounds which may be called *Carbo-Sulphurets*. But their properties, and the proportion of their elements, require further investigation.

In a subsequent memoir in the same volume of the Philosophical Transactions, Dr. Marcet describes the extraordinary power of alcohol of sulphur, in producing cold. The bulb of a thermometer being covered with fine lint, and moistened with a few drops of the liquor, the mercury sinks rapidly from 60° to 0 , and under the exhausted receiver of an air pump, from $+70^{\circ}$, to 70° or even 80° below 0 , so that by this process mercury may readily be frozen.

CHAPTER XIII.

COMBINATION OF NITROGEN WITH OXYGEN, CONSTITUTING NITRIC ACID,—NITROUS GAS,—NITROUS OXIDE,—AND COMPOUNDS OF NITRIC ACID WITH ALKALIS.

WHEN nitrogen and oxygen gases are mingled together, in whatsoever proportions they are employed, no combination ensues. The result is a simple mixture* of the two gases, which do not, like inelastic fluids, separate on standing, but remain diffused through each other for an indefinite length of time. This is the case with the air of our atmosphere; and it is fortunate that such a provision of nature exists, since the atmosphere contains the elements of several combinations which, if actually formed, would be fatal to animal and vegetable life. When, however, either one or both of these elements, in any mixture of the two, is in a condensed

* However different the union of oxygen and nitrogen gases may be when combined together in form of atmospheric air, compared to the same in their junction, as nitric acid, &c.—there can, I think, be little doubt of the union being chemical and not mechanical. Their condensation produces a change of specific gravity; of itself sufficient to disprove a merely mechanical effect; independently of which, the chemical properties of the two bodies, are themselves so much modified, that it is improper to conclude the effect to be otherwise than chemical; neither can they be separated by mere mechanical means, and the proportions are not incompatible with those of the other compounds. C.

state, or deprived of part of that caloric which keeps the particles of all gases at a distance from each other, they unite and form compounds, distinguished by very striking properties. According to the proportions in which the oxygen and nitrogen exist in these compounds, their qualities undergo a remarkable variation, so that from two elementary bodies, variously united, we have several compounds, totally unlike each other in external qualities, as well as in their chemical relations.

Before describing the compounds of oxygen and nitrogen in detail, it will contribute to perspicuity to take a general view of the whole. Some of them exist essentially in an aëriform state, and are capable of uniting with water and other liquids in only small proportion. Others, again, combine with water to such an extent, that the liquid form is the only one, under which they occur to our observation. When entirely deprived of water, however, they are all gaseous bodies.

In a series of the compounds of nitrogen, founded on their proportion of oxygen, they occupy (excluding atmospherical air from the number*) the following order, the last containing the largest proportion of oxygen—nitrous oxide—nitric oxide or nitrous gas—nitrous acid or nitrous vapour—and nitric acid. The two first are sparingly soluble in water; but the two last unite with it largely, and form liquid compounds of decidedly acid taste and quality.

The following Table exhibits the composition of three of these bodies, the calculation being founded on the experiments of Sir H. Davy, published in his "Researches." Oxygen gas is assumed to weigh 33.8 grains, and nitrogen, 29.5 for 100 cubical inches.

	Proportion of Elements by Weight.		Proportion by Measure.	
	Nitrogen.	Oxygen.	Nitr. gas.	Oxy. gas.
Nitrous oxide .	63.30	36.70	100.	50.65
— gas .	44.05	55.95	100.	110.
Nitric acid .	29.50	70.50	100.	208.60

From a comparison of the third and fourth columns of the foregoing Table, it is obvious, that in nitrous oxide, the nitrogen is, in volumes, very nearly double the oxygen; that in nitrous gas, the

* Upon the presumption that atmospherical air is strictly a chemical compound of oxygen and nitrogen; in conformity with the nomenclature, the names of the various bodies constituted of these two substances in different proportions, should be

Protoxyd of nitrogen	or Atmospherical air.
Dentoxyd of do.	Nitrous oxyd.
Tritoxyd of do.	Nitric oxyd (or nitrous gas.)
Nitrous acid.	
Nitric acid.	
Oxy nitric acid (if such exists.)	

The difficulty of the subject is however apparent, by what Dr. Henry says in the last paragraph of this chapter. C.

two elements exist in almost equal volumes; and that in nitric acid, the oxygen is a little more than twice the volume of the nitrogen. These coincidences, and others of the same kind, are the foundation of the theory advanced by Gay Lussac; viz. *that compounds, whose elements are gaseous, are constituted either of equal volumes of those elements; or, that if one of the elements exceeds the other, the excess is by some simple multiple of its volume.* That the proportions of nitrogen and oxygen by measure do not, in the foregoing instances, exactly conform to this law, Gay Lussac imputes to unavoidable inaccuracies, attendant on all delicate processes for determining the constitution of gaseous bodies. In one instance, this was proved experimentally; for M. Berard, by the combustion of potassium in 100 measures of nitrous gas, obtained exactly 50 measures of nitrogen. Hence, if the table were corrected to coincide with the views of Gay Lussac, it would stand as follows:

	Measures of		100 Grains contain	
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
Nitrous oxide consists of	100	50	63.58	36.42
— gas	100	100	46.60	53.40
Nitric acid	100	200	30.40	69.60

To these compounds, Gay Lussac has added a fourth, which he calls *nitrous acid vapour*, consisting of three volumes of nitrous gas, and one volume of oxygen gas. These are equivalent to $1\frac{1}{2}$ volumes of nitrogen and $2\frac{1}{2}$ volumes of oxygen; or 100 parts by weight of nitrous acid vapour consist of

Nitrogen	34.49	100.	52.5
Oxygen	65.51	190.	100.
	<hr/>	<hr/>	<hr/>
	100.	290.	152.5

The existence, however, of this compound, is not coincident with the law of definite proportions; for the oxygen, assigned to it, is not a multiplication of that in nitrous oxide, by any entire number, as will appear from the following Table. The numbers express the proportional weights, as inferred from the volumes of Gay Lussac.

	In Weight.	
	Nitrogen.	Oxygen.
Nitrous oxide is composed of . . .	100	57
— gas ————— . . .	100	114
— acid vapour ————— . . .	100	190
Nitric acid ————— . . .	100	228

In nitrous gas, the oxygen is a multiple by 2 of that in nitrous oxide; and, in nitric acid, by 4; but the law fails with respect to nitrous acid vapour. The constitution of nitric acid also does not agree with that deduced (as will appear in the next section) by Dr. Wol-

laston and Sir H. Davy, according to whom nitric acid is composed of 100 nitrogen and 285 oxygen by weight, the last number being a multiplication of 57, (the oxygen in nitrous oxide) by 5.

In all these compounds, the elements are in a state of condensation, except in nitrous gas, in which the nitrogen and oxygen, according to Gay Lussac, are precisely in the same state of density, as in nitrogen and oxygen gases. With respect to the other compounds, the contraction, he apprehends, is exactly equal to the bulk of the oxygen gas. For example, as 100 measures of nitrogen gas and 50 measures of oxygen gas form 100 of nitrous oxide, the condensation is 50 measures. On the same principle 100 measures of nitrogen gas and 200 of oxygen gas constitute 100 of nitric acid gas.

Mr. Dalton, in his "New System of Chemical Philosophy," has given the following Table of the Compounds of nitrogen and oxygen, which differs essentially from that of Gay Lussac.

	Weight of an Atom.	Atoms of Nitr ⁿ . Ox ⁿ	100 by Weight contain Nitr ⁿ Ox ⁿ .	100 by Measure contain Nitr ⁿ . Ox ⁿ .
Nitrous gas	12.1	1+1	42.1+57.9	48. +56.6
Nitrous oxide	17.2	2+1	59.3+40.7	99.1+58.3
Nitric acid	19.1	1+2	26.7+73.3	30. +70.
Oxynitric do.	26.1	1+3	19.5+80.5	22.1+77.9
Nitrous acid	31.2	2+3	32.7+67.3	36.2+63.8

The proportions, by weight and volume, of the ingredients of the nitrous compounds, calculated from the fourth column of the foregoing Table, and reduced to a common standard, are as follow :

	In Weight.		In Volume.	
	Nitrogen.	Oxygen.	Nitrogen.	Oxygen.
Nitrous oxide . . .	100.	68.6	100.	60
— gas . . .	100.	138.	100.	120
— acid . . .	100.	206.	100.	182
Nitric acid . . .	100.	274.5	100.	240
Oxynitric acid . . .	100.	413.	100.	360

From an examination of the numbers in the last Table, it will appear that the oxygen, in nitrous gas, is very nearly, both in weight and volume, a multiple of that in nitrous oxide by 2; in nitrous acid by 3; in nitric acid by 4; and in oxynitric acid by 6. The last-mentioned compound, however, Mr. Dalton has never obtained in a separate form; and its existence may be considered as not sufficiently established.

On the whole, it appears, that the compounds of nitrogen and oxygen require further investigation, to reconcile the discordant statements of philosophers, on a subject, respecting which certainly appears to be by no means unattainable.

SECTION I.

Nitric Acid.

I. THE direct combination of nitrogen and oxygen, affording a decisive synthetic proof of the nature of this acid, may be effected by passing electric sparks through a mixture of nitrogen and oxygen gases. The experiment is an extremely laborious one, and requires, for its performance, a powerful electrical machine; but those who are disposed to repeat it, may proceed as follows:

Let the tube, fig. 84, *c*, be filled with, and inverted in mercury. Pass into it a portion of atmospherical air, or an artificial mixture of nitrogen and oxygen gases, in the proportion of one of the former to two of the latter. Let an iron wire, lengthened out with one of platina, be introduced within the tube, so that the latter metal only may be in contact with the mixed gases; and let the end of this wire be distant about one fourth of an inch from the extremity of the upper conducting one. When the apparatus is thus disposed, pass a series of electric sparks or shocks through the gases for several hours. The mixture will be diminished in bulk; will redden litmus-paper when enclosed in it; and will exhibit distinctly the smell of nitrous acid. If the experiment be repeated, with the addition of a few drops of solution of potash, in contact with the gases, we shall obtain a combination of nitric acid with potash.

This interesting experiment on the generation of nitric acid we owe to Mr. Cavendish, who discovered the fact in the year 1785.* The proportions, which he found to be necessary for mutual saturation, were five parts of oxygen gas and three of common air, or seven parts of oxygen gas to three of nitrogen gas. No evolution either of light or heat attends this combination, which is very slowly and gradually effected.

Another synthetic proof of the production of nitric acid will be stated under the article *nitrous gas*. It is furnished by the generation of nitrous gas, and ultimately of nitric acid, when ammonia is brought into contact with the black oxide of manganese.

For all purposes of utility or experiment, however, nitric acid is prepared in a different manner, *viz.* by the decomposition of nitrate of potash, in a way which will be described in the section on that salt.

II. The analysis of the nitric acid may be obtained by driving its vapour through a red-hot porcelain tube, (fig. 40, *c c*), and receiving the generated gases, which prove to be a mixture of nitrous acid, oxygen, and nitrogen gases.

III. The nitric acid has the following properties:

(*a*) It is heavier than water, in the proportion of 1.5 or upwards to 1. Proust obtained it as high as 1.62; and the specific gravity

* Philosophical Transactions, lxxv.

of real nitric acid, which cannot, however, be obtained, may be calculated at 1.75.

In its heaviest form, it still contains a portion of water, which is essential to its existence in a liquid state, and without which its elements would separate from each other. In acid of the sp. gr. 1.50, it amounts, calculating from the data furnished by Dr. Wollaston, to 25.11 grains in 100 grains of acid.

Pure nitric acid may be considered as a gaseous body, of the specific gravity, compared with common air, of 2440 : one hundred cubic inches at 55° Fahrenheit and under 30 inches pressure, weigh, according to Sir H. Davy, 76 grains ; or corrected to the temperature of 60° Fahrenheit, they weigh 75.21 grains. The liquid acid (termed by Davy *hydro nitric acid**) consists of this gas condensed by water, of which it contains various proportions. We have not, however, at present, documents sufficient for the construction of an accurate Table of the quantities of *real nitric acid* in acids of different densities. According to Sir H. Davy, the strongest acid (sp. gr. 1.55) contains 14.4 parts of water in 100 ; and acid of sp. gr. 1.42 contains 25.2 of water in 100.† The Table published by Mr. Dalton‡ that philosopher has since found reason to believe to be inaccurate ; but on the following results, which he has been so good as to communicate to me, he thinks full reliance may be placed.

Table of the quantity of real Acid in Nitric Acid of different densities.

Parts of Acid.	Parts of Water.	Acid per ct. by weight.	Acid per ct. by measure.	Specific Gravity.	
45	+	8	84.9	137.5 ?	1.62 ?
45	+	16	73.8	114.4 ?	1.55 ?
45	+	24	65.2	96.4	1.48 +
45	+	32	58.4	84.	1.44
45	+	40	53.	74.7	1.41
45	+	48	48.4	67.2	1.39
45	+	56	44.5	60.5	1.36
45	+	64	41.3	55.3	1.34
45	+	180	20.	22.8	1.142

* This term (*hydro*) has become a favourite adjunct by many late writers to the class of acids ; distinguishing thereby the *real* solid (if I may so say) acid, from that which is united with *water* : in other words, that part alone which is effective in saturating the alkalies or other bases. The term, high as is the authority by whom it is employed, is in my opinion altogether inadmissible ; at least, until we alter the meaning of the *same term* as applied to other bodies. Thus we have *hydro-sulphuret* of potash, soda, &c. ; but the term *hydro*, here, implies the union of *hydrogen*, not of water ; and we have already too much confusion creeping into the science, by the extensive coinage of *new names*, (and those not always confirmed by experience,) to tolerate the *same term* as applied to distinct substances. C.

† Elements, p. 265.

‡ New System, p. 355.

(b) Pure gaseous nitric acid, according to the experiments of Sir H. Davy, published in the year 1800, is composed in 100 grains, of $29\frac{1}{2}$ azote, and $70\frac{1}{2}$ oxygen. This approximation differs but little from the proportions deducible from the synthetic experiments of Cavendish, viz. 27.8 nitrogen to 72.2 oxygen. The latter results of Sir H. Davy have led him, however, to believe, that 4 in volume of nitrous gas and 2 of oxygen gas, when condensed in water, absorb 1 in volume of oxygen, to become nitric acid. Now, estimating the oxygen gas, existing in nitrous gas, at one half its volume, and taking the specific gravities of oxygen and nitrogen gases at the numbers already given, 100 parts by weight of nitric acid will consist of

Oxygen	74.13	286.
Nitrogen	25.87	100.
	<hr/>	<hr/>
	100.	386.

In investigating what number should be used as the equivalent of nitric acid, Dr. Wollaston was led to inquire into the composition of that acid; and, from his own experiments and those of Richter, he infers the oxygen, which nitric acid contains, to be by weight to the nitrogen, as 50 to 17.54. Hence nitric acid, as it exists in nitre, will be composed, by weight, of

Oxygen	74.03	100.	285.
Nitrogen	25.97	35.	100.
	<hr/>	<hr/>	<hr/>
	100.	135.	385.

By an easy calculation, it will be found that the nitrogen, in 100 grains of nitric acid thus constituted, is equal in volume to 88 cubic inches, and the oxygen to 219. But as 88 to 219, so is 100 to 249; and on this view of the nitric acid, it is composed of 1 volume of nitrogen and $2\frac{1}{2}$ of oxygen, which agrees with the result of Sir H. Davy. These proportions are favourable to the opinion, that nitric acid consists of two atoms of oxygen to one of nitrogen; for as 75 to 25, so is 15 (twice 7.5) to 5, the number already deduced from the analysis of ammonia, as representing the weight of the atom of nitrogen. It must be acknowledged, that there is some uncertainty respecting the weight of the atom of that element. Dr. Wollaston deduces its equivalent (oxygen being 10) to be 17.54; and hence the atom of nitrogen will bear to that of oxygen the proportion of 13.15 to 7.5; and nitric acid, according to this view, will consist of 5 atoms of oxygen = 37.5, and 1 atom of nitrogen = 13.15; and its atom will weigh 50.20. Farther investigation must determine, which of these views is most conformable to truth.

(c) Hydro-nitric acid is perfectly limpid and colourless, and emits white fumes, when exposed to the air.

(d) It gives a yellow stain to the skin.

(e) It boils at 248° Fahrenheit, and may be distilled over, with-

out any essential change. This, however, is true only of acid of the specific gravity 1.42; for an acid, weaker than this, is strengthened by being boiled; while an acid, stronger than 1.42, becomes weaker by boiling. All the varieties of nitric acid, therefore, are brought, by sufficient boiling, to the specific gravity 1.42.

(f) Hydro-nitric acid may be frozen by the application of a sufficiently low temperature. Like sulphuric acid, there is a certain point of density, at which it most readily congeals. Mr. Cavendish has described this, not by its specific gravity, but by the quantity of marble which it is capable of dissolving. When it takes up $\frac{418}{1000}$ ths of its weight, in which case its specific gravity is 1.3, the acid freezes at 2° below 0 Fahrenheit. When considerably stronger and capable of dissolving $\frac{561}{1000}$ ths, it required cooling to -41.6 ; and when so much diluted as to take up only $\frac{276}{1000}$ ths, it did not congeal till cooled to -40.3 .*

(g) Strong hydro-nitric acid absorbs moisture from the atmosphere; in consequence of which it increases in weight, and diminishes in specific gravity.

(h) When two parts of the acid are suddenly diluted with one of water, an elevation of temperature is produced to about 112° Fahrenheit. When more water is added to this diluted acid, its temperature is reduced. Snow or ice added to the cold dilute acid is instantly liquefied, and an intense degree of cold is produced.

(i) It becomes coloured by exposure to the sun's light, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of the acidifying principle to the nitrogen is diminished.

By exposing it to the sun's rays in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured.

(k) This acid retains its oxygen with but little force.—Hence it is decomposed by all combustible bodies, which are oxygenized by it, with more or less rapidity, in proportion to their affinity for oxygen.†

1. When brought into contact with hydrogen gas at a high temperature, by transmitting them through an ignited porcelain tube, a violent detonation ensues. This experiment, therefore, requires great caution. 2. Poured on perfectly dry and powdered charcoal, it excites the combustion of the charcoal, which becomes red-hot, and emits an immense quantity of fumes. 3. It also inflames essential oils (as those of turpentine and cloves), when suddenly poured on them. In these experiments, the acid should be poured out of a bottle, tied to the end of a long stick; otherwise the operator's face and eyes may be severely injured. 4. Nitric acid is decom-

* Philosophical Transactions, 1788.

† With these facts continually before us, we are satisfied to credit each succeeding writer, that nitric acid is not decomposed in the process by which nitrogen is procured from flesh by distillation! C.

posed, by boiling it in contact with sulphur, which attracts the oxygen, and forms sulphuric acid.

(l) The hydro-nitric acid is also decomposed by metals; as iron, tin, zinc, copper, &c., and with different phenomena, according to the affinity of each metal for oxygen. This may be seen, by pouring some strong nitric acid on iron filings, or powdered tin. The acid must be of greater density than 1.48, otherwise it will not produce the effect. Violent heat, attended with red fumes, will be produced, and the metals will be oxydized.

(m) If the action of metals on nitric acid be more moderately conducted, a new product is obtained in a gaseous state. Dilute some nitric acid of commerce with six or eight parts of water, and dissolve, in this, some turnings of copper, or a portion of quick-silver, applying a gentle heat. This must be done in a gas bottle, and the product, received over water, is nitrous gas, or nitric oxide. Mr. Dalton recommends acid, of density 1.2 or 1.3 to be poured on filings of copper, without any other heat than that, which the action of the acid and metal on each other occasions.

SECTION II.

Nitrous Gas, or Nitric Oxide.

THE properties of this gas, procured in the manner described at the close of the last section, are the following :

(a) It is permanent over water; but it is absorbed in the proportion of about one volume to 18 or 20 water, when agitated with water which has been recently boiled, and has become cold. This solution, according to La Grange,* is converted, by long keeping, into nitrate of ammonia, in consequence of the decomposition of the water.

Nitrous gas is rather heavier than common air, 100 cubic inches at 55°, barometer 30°, were stated by Sir H. Davy in 1800 to weigh 34.26, or at 60° Fahrenheit 33.80 grains. He now, however, gives the weight of 100 cubic inches at 32 grains, and hence its specific gravity is 1050.

(b) When well washed with water, it is not acid. It will be found not to redden the colour of litmus. This may be shown by introducing a piece of paper, tinged with that substance, into a jar of nitrous gas, standing inverted over water. To accomplish this, the paper should be fastened to the end of a glass rod or a piece of stick. The colour will remain unchanged.

(c) It extinguishes flame, and is fatal to animals. Homberg's pyrophorus, however, is inflamed by it, and charcoal and phosphorus, introduced into it when in a state of actual combustion, continue to burn vehemently.

(d) Mingled with hydrogen gas, it imparts a green colour to its flame. It does not, however, explode with hydrogen in any pro-

* Vol. i. page 131.

portion, nor with any of the varieties of carburetted hydrogen. But, when mixed with ammonia, an electric spark produces a detonation, as I have shown in the Philosophical Transactions for 1809. The proportions required for mutual saturation are about 120 measures of nitrous gas to 100 of ammonia.

(e) When mixed with oxygen gas, red fumes arise; heat is evolved; a diminution takes place; and if the two gases be in proper proportion, and perfectly pure, they disappear entirely. Nitrous acid, at the same time, is regenerated. Ten measures of oxygen, Mr. Dalton asserts, may be made to condense any quantity of nitrous gas, between 13 and 36 measures, according as the mixture is conducted.

(f) The same appearances ensue, less remarkably, with atmospheric air; and the diminution is proportionate to the quantity of oxygen gas which it contains. On this property, of its condensing oxygen, but no other gas, is founded the application of nitrous gas to the purpose of *eudiometry*, or of ascertaining the purity of air. The sources of error, in its employment in this mode, have hitherto been considered such, as to forbid our relying implicitly on the results which it may afford. Learning, however, from Mr. Dalton, that he constantly employs nitrous gas in determining the purity of air, and with perfect satisfaction as to the accuracy of his results, I have obtained from him the following communication. It may be necessary to premise, that for applying nitrous gas to this purpose, two tubes will be found convenient, shaped like fig. 24; each from three to four tenths of an inch in diameter; eight or nine inches long, exclusive of the funnel-shaped part; and accurately graduated into minute aliquot parts. What these parts are, is of no consequence. Hundredth parts of a cubical inch give rather too large divisions of the scale; but if each of these be divided into two, the scale will be sufficiently small. If the tube employed be not long enough to comprise 100 of these parts, the experiment may be made on 50 parts only of atmospherical air; and the results, multiplied by 2, will give the proportion in 100 parts.

“To use nitrous gas accurately in eudiometry, it is only requisite to take both gases in a dilute state, namely, containing four or five times their bulk of azotic gas (which atmospheric air naturally does), or of any other gas not acted upon by nitrous or oxygen gases. In this case, if an excess of one gas be used, the other is, in a few minutes, entirely taken up, and in a constant proportion; whatsoever may be the form of the vessel, or the manner of mixing the gases. The proportion is 1 of oxygen to 1.7 of nitrous, so that 10-27ths of the diminution over water are oxygen, and 17-27ths nitrous gas. It is proper, as soon as the greater part of the diminution has ensued, to transfer the mixture through water into a graduated vessel, without using any agitation.

“If pure nitrous gas be admitted to pure oxygen gas in a narrow eudiometer tube, so that the oxygen gas is uppermost, the two unite very nearly in the same uniform proportion as above. If, on the other hand, the nitrous be the upper gas, a much less quantity of it disappears, viz. 1.24 nitrous to one oxygen. If undiluted nitrous gas

be admitted to pure oxygen gas in a wide vessel over water, the whole effect takes place immediately; and one measure of oxygen will condense 3.4 nitrous gas.

"To render this rule more intelligible, an example may be necessary. Let 100 measures of common air be admitted to 100 measures of a mixture of nitrous gas, with an equal volume of azotic or hydrogen gas. After standing a few minutes in the eudiometer, there will be found 144 measures. The loss 56 being divided by the common divisor, 2.7, gives 21 nearly for the oxygen gas present in 100 measures of common air."

To these directions I may add, that when atmospherical air is the subject of experiment, it is scarcely necessary to dilute the nitrous gas, with any other gas, previously to its use. If a number of experiments be made, it will be proper, in all cases, to let the gases remain together a definite time (say ten minutes) before noting the diminution; and it is needless to transfer them into another vessel. If the mixed gas, under examination, contain much more oxygen, than is present in atmospherical air, then it is proper to dilute the nitrous gas with an equal bulk of hydrogen gas; and, in this case, the narrower the tube, in which the experiment is made, the more accurate will be the result.

Subsequent experience has convinced me that the method, proposed by Mr. Dalton, though sufficiently correct, when applied to a mixture of the same, or nearly the same, standard as the atmosphere, cannot be relied on when the proportion of oxygen is either considerably greater or less. In the former case, the process gives too great a diminution, sometimes indeed to such an extent as to indicate more oxygen gas than the whole amount of what was submitted to experiment. When the air, on which we are operating, is of an inferior standard to the atmosphere, we do not learn its full proportion of oxygen. Notwithstanding these objections, however, the method has considerable value, since it may be applied to determine the proportion of oxygen in some mixed gases, to which other eudiometrical tests are not applicable: for example, to mixtures of hydro-carburet and oxygen gases.

The application of nitrous gas to eudiometrical purposes, it has lately been contended by Gay Lussac, is susceptible of perfect accuracy, provided certain precautions be observed which he has pointed out, and which were suggested by his theoretical views of the constitution of these gases. A narrow tube he finds to be unfit for an eudiometer, his object being to form nitrous acid gas, which is but slowly absorbed by water. Instead therefore of a tube, we must take a wide vessel, such as a small tumbler glass; and to 100 parts of atmospheric air, previously measured, we must add at once 100 measures of nitrous gas. A red fume will appear, which will soon be absorbed without agitation, and in half a minute, or a minute at most, the absorption will be complete. Pass the residuum into a graduated tube, and it will be found, almost invariably, that 84 measures have disappeared. Dividing this number by 4, we have 21 for the quantity of oxygen condensed.

By a series of experiments on mixtures of oxygen and nitrogen gases in various proportions, Gay Lussac found that this eudiometrical process may be depended upon, whether the oxygen exceed or fall short considerably of the proportion contained in atmospheric air.

(g) The generation of an acid, by the admixture of nitrous gas with common air or oxygen gas, may be shown by the following experiment. Paste a slip of litmus-paper within a glass jar, near the bottom; and into the jar, filled with and inverted in water, admit as much nitrous gas, previously well washed, as will displace the water below the level of the paper. The colour of the litmus will remain unchanged; but, on adding atmospheric air or oxygen gas, it will be immediately reddened.

(h) That the peculiar acid, thus produced, is the nitric, will appear from the following experiment. Into a jar, filled with and inverted in mercury, pass a small quantity of a solution of pure potash; and, afterward, measures of oxygen and nitrous gases, separately, and in proper proportion. On removing the solution from the jar, exposing it for some time to the atmosphere, and afterward evaporating it, crystals of nitrate of potash will be formed, a salt which is ascertained to be formed of potash and nitric acid.

(i) Nitrous gas is absorbed by hydro-nitric acid, which, by this absorption, is considerably changed in its properties.—Transmit the gas, as it issues from the materials that afford it, through colourless nitric acid. The acid will undergo successive changes of colour, till at last it will become orange-coloured and fuming. In this state it is called nitrous acid, because it contains a less proportion of oxygen than the colourless nitric acid.

According to Dr. Priestley, 100 parts of nitric acid, of the specific gravity of 14 to 10, absorb, in two days, 90 parts by weight of nitrous gas.* When about seven parts of gas have been absorbed, the acid acquires an orange colour; when 18 have been absorbed, it becomes green; and the whole quantity, which it is capable of condensing, changes it into a liquor, which emits an immense quantity of red fumes. The gas, thus absorbed, is mostly separated again on dilution with water.

(k) The nitrous gas, thus absorbed, is expelled again by a gentle heat. This may be shown by gently heating the acid coloured in Experiment i, till it again becomes limpid. In this experiment light should be excluded.

(l) Nitrous gas is decomposed by exposure to bodies that attract oxygen. Thus, iron filings decompose it, and become oxidized, affording a proof of the presence of oxygen in this gas.

* Priestley on Air, 2d edition, i. 383. In the experiment alluded to, one-fifth of an ounce-measure of nitric acid absorbed 130 ounce-measures of nitrous gas; or more than 60 per cent. by weight. There is reason, however, to suspect some inaccuracy in the experiment; for, according to Sir H. Davy, 100 parts of nitric acid, after having absorbed all the nitrous gas which it is capable of condensing, hold only nine or between nine and ten parts in combination, and Mr. Dalton could not condense more than 20 times its bulk, or a little more than 2 per cent. by weight of nitrous gas, into acid of the specific gravity 1.3.

During this process, water, ammonia, and nitrous oxide, in the proportion of 1 volume from 2 of nitrous gas, are generated. Sulphuret of potash, &c. have a similar effect. Mixed with sulphurous acid, nitrous gas is decomposed, and this acid is changed into the sulphuric, but not unless water is present.*

Bodies that have a still more powerful affinity for oxygen decompose nitrous gas into its *ultimate* elements. Charcoal ignited in 100 measures, gives 50 measures of nitrogen gas, and 50 of carbonic acid. Arsenic, zinc, or potassium, when heated in it, evolve half its volume of nitrogen. Nitrous gas should consist, therefore, of 1 volume of oxygen \times 1 volume of nitrogen, neither of which elements is in a state of condensation. This, however, would lead to a determination of the weight of the atom of nitrogen, very different from that already deduced from the composition of ammonia and of nitric acid. For if nitrous gas be constituted, as Mr. Dalton supposes, of an atom of each of its elements, and if these exist in it in equal volumes, the atom of oxygen will be to that of nitrogen as 33.8 to 29.5 (the proportions by weight in nitrous gas, according to this view of its composition) or as 7.5 to upwards of 6.5, which last number would denote the weight of the atom of nitrogen. There is, therefore, either a defect in this part of the theory, or in the experiments on which it is founded; for the weight of the atom of nitrogen, investigated from its other compounds, appears to be nearly 5.

(m) Nitrous gas is absorbed by the green sulphate and muriate of iron,† which do not absorb nitrogen gas. To ascertain, therefore, how much nitrogen gas a given quantity of nitrous gas contains, let it be agitated in a graduated tube with one of these solutions. This information is necessary, previously to deducing, from its effects on atmospheric air, the proportion of oxygen gas.

From the important use which is now made by some chemists of this solution of nitrous gas in eudiometry, it may be proper to describe the mode of its preparation.

Dissolve as much of the green sulphate of iron in water as the water will take up, or dissolve iron filings in sulphuric acid, diluted with five or six parts of water, leaving an excess of the iron, in order to ensure the perfect saturation of the acid. Fill a wide-mouthed bottle with this solution, invert it in a cupful of the same, and into the inverted bottle receive the nitrous gas, as it is generated by the proper materials, shaking the inverted bottle frequently. The colour of this solution will change to black, and the production of gas and the agitation are to be continued, till the absorption can be carried no farther. The impregnated solution should be preserved in a number of small bottles, not holding more than an ounce each. The most commodious method of applying this solution, is by means of Dr. Hope's eudiometer, already described. (Chap. v. sect. 4.)

(n) A very interesting experiment, affording a synthetic proof

* Nicholson's Journal, xvii. 43.

† For an account of these salts, see chap. xviii. sect. 6.

of the constitution of nitrous gas, was made by the Rev. Dr. Milner, of Cambridge.* Into an earthen tube, about 20 inches long and three fourths of an inch wide, open at both ends, put as much coarsely powdered manganese as is sufficient nearly to fill it. Let this be placed, horizontally, in a furnace, having two openings opposite to each other (fig. 40). To one end of the earthen tube adapt a retort, containing a strong solution in water of pure ammonia, and to the other a bent glass tube, which may terminate in a two-necked empty bottle. To the other neck of the bottle, lute a glass tube, bent so as to convey any gas that may be produced, under the shelf of the pneumatic trough. Let a fire be kindled in the furnace; and, when the manganese may be supposed to be red-hot, drive over it the vapour of the ammonia. The alkali will be decomposed; its hydrogen, uniting with part of the oxygen which is combined with the manganese, will form water; while its nitrogen, uniting with another portion of the oxygen, will constitute nitrous gas. The gas, thus generated, may be collected by the usual apparatus.

(o) Another fact, showing the mutual relation of ammonia and of the compounds of nitrogen, was discovered some years ago by Mr. Wm. Higgins.† Moisten some powdered tin (which is sold under this name by the druggists) with strong nitric acid; and, when the red fumes have ceased to arise, add some quick-lime or solution of pure potash. A strong smell of ammonia will be immediately produced.

In this experiment, the tin, at the same instant, attracts the oxygen both of the nitric acid and of the water. Hydrogen and nitrogen are consequently set at liberty; and before they have assumed the gaseous state, these two bases combine, and constitute ammonia. The ammonia, thus generated, unites with a portion of undecomposed nitric acid; and is disengaged from this combination by potash or lime, which render it evident to the smell.

SECTION III.

Gaseous Oxide of Nitrogen.—Nitrous Oxide of Davy.

I. THIS compound, also consisting of oxygen and nitrogen, but in different proportions from those of nitrous gas, may be obtained by several processes.

(a) By exposing common nitrous gas for a few days to iron filings; or to various other bodies strongly attracting oxygen, this gas is changed into the nitrous oxide.

Some nicety and experience are required to suspend the decom-

* Philosophical Transactions, 1789.

† See his Comparative View of the Phlogistic and Antiphlogistic Theories, 2d edition, page 300, note.

position before it has gone too far; in which case nitrogen gas is obtained. The sulphite of potash, being incapable of decomposing nitrous oxide, is best adapted to the conversion of nitrous gas into that elastic fluid. The process, in all cases, may be suspended, when about two thirds the original bulk of the gas are left.

(b) By dissolving zinc, or tin, in nitric acid, diluted with five or six times its weight of water. Zinc, during this solution, disengages nitrous oxide till the acid begins to exhibit a brownish colour, when the process must be suspended, as nitrous gas is then formed. But by neither of these processes is the gas obtained sufficiently pure for exhibiting its qualities. To procure it in a state of purity, the following process is the best adapted.

(c) To nitric acid, diluted with five or six parts of water, add carbonate of ammonia, till the acid is saturated. Then evaporate the solution by a gentle heat; and, to supply the waste of alkali, add, occasionally, a little more of the carbonate. The salt obtained, after the solution has cooled, is next to be put in a glass retort, and distilled with a sand-heat, not exceeding 440° Fahrenheit.* The heat of an Argand's lamp is more than sufficient, and requires cautious regulation. The salt will presently liquefy, and must be kept gently simmering, avoiding violent ebullition. The gas may be collected over water, and allowed to stand a few hours before it is used, during which time it will deposit a white cloud, and will become more perfectly transparent.

A gazometer is best adapted for its reception; because all danger is then avoided of an absorption of the water of the trough into the retort; and because the gas is brought into contact with a much smaller surface of water, which has the property of absorbing a considerable proportion of the gas. On this account, water, which has been once used to confine the gas, may be kept for the same purpose.

The changes that take place, during the conversion of nitrate of ammonia into nitrous oxide, are the following: Nitric acid is composed of oxygen and nitrous gas; ammonia, of hydrogen and nitrogen. In a high temperature, the nitrous gas combines with an additional dose of nitrogen, and forms nitrous oxide; while the oxygen of the decomposed nitric acid unites with the hydrogen of the ammonia, and forms water.

The gas, thus obtained, was termed, by the Society of Dutch chemists, gaseous oxide of azote; but for the sake of brevity, and as more conformable to the nomenclature of other compounds of nitrogen, I shall use, with Sir H. Davy, the name of nitrous oxide.†

In order to ascertain whether nitrous oxide be adulterated with

* From the observations of Mr. Sadler (Nicholson's Journal, xv. 286,) it appears that the purity of the nitrate of ammonia is of considerable importance; and that its adulteration with muriate diminishes the quantity, and impairs the quality of the gas.

† For a full account of this gas, consult Sir H. Davy's Researches, Chemical and Philosophical. London. Johnson, 1800.

either common air or oxygen gas, we may mix equal measures of the gas under examination, and of nitrous gas. If any diminution ensue, the presence of one of these may be suspected; and the amount will show which of them is contained in it. Nitrous gas, however, is a much more common contamination; for it is generated, along with nitrous oxide, whenever the temperature of the salt is raised too high. Its presence may be detected, either by a diminution on the admixture of oxygen gas; or by an absorption being effected, on agitating the gas with a solution of green sulphate of iron, which has no action on pure nitrous oxide.

II. Nitrous oxide gas has the following properties:

(a) It is considerably heavier than common air. At about 55° Fahrenheit, and 30 inches pressure, 100 cubic inches weigh 50.20 grains, or under the same pressure, and at 60° Fahrenheit 49.68. (Davy.) More recently, Sir H. Davy has stated 100 cubic inches to weigh between 48 and 49 grains, and hence its specific gravity is very nearly 1.6.

(b) A candle burns in it with a brilliant flame and crackling noise. Before its extinction, the white inner flame becomes surrounded with an exterior blue one.

(c) Phosphorus, introduced into it in a state of inflammation, burns with increased splendour.

Phosphorus, however, may be melted and sublimed in this gas, without alteration. It may even be touched with red-hot iron wire, without being inflamed; but when a wire, intensely heated, or made white-hot, is applied, the phosphorus burns, or rather detonates with prodigious violence.

(d) Sulphur, introduced into nitrous oxide when burning with a feeble blue flame, is instantly extinguished; but when in a state of an active inflammation, it burns with a vivid and beautiful rose-coloured flame.

(e) Red-hot charcoal burns in it more brilliantly than in the atmosphere. When the experiment is made in a proper apparatus, the results of its combustion are found to be one measure of nitrogen gas and half a measure of carbonic acid (equivalent to half a measure of oxygen) from each measure of nitrous oxide. It must, therefore, consist of 59 parts by weight of nitrogen, 33.8 oxygen,* or it must contain by weight

Oxygen	36.43	100	57.
Nitrogen	63.57	174	100.
	<hr/>	<hr/>	<hr/>
	100.	274.	157.

But on the supposition that nitrous oxide is constituted of two atoms of nitrogen and one of oxygen, this would make the weight of the atom of nitrogen = 6.7; for as 33.8 to 59, so is 7.5 to 13.4,

* 200 cubic inches of nitrogen gas weigh 59 grains, and 100 of oxygen weigh 33.8.

which last number divided by 2 gives 6.7. Either, therefore, this part of the theory, or the analysis of nitrous oxide, is defective in accuracy; and it will be important to reconcile this, which is one of the few anomalies of the atomic theory, to its general principles, by multiplied and accurate experiments.

(f) Iron wire burns in this gas with much the same appearance as in oxygen gas, but for a shorter period.

(g) Nitrous oxide is rapidly absorbed by water that has been previously boiled, about one thirtieth the original bulk of the gas remaining uncondensed. A quantity of gas, equal to considerably more than nine-tenths the bulk of the water, may be thus made to disappear. This property furnishes a good test of the purity of nitrous oxide; for the pure gas is almost entirely absorbed by boiled water, which has cooled without the access of air. The gas employed should exceed the water three or four times in bulk, in order to obtain a saturated solution.

(h) Water, that has been saturated with this gas, gives it out again, unchanged, when heated.

(i) The impregnated water does not change blue vegetable colours.

(k) It has a distinctly sweet taste, and a faint, but agreeable, odour.

(l) Nitrous oxide is not diminished by admixture with either oxygen or nitrous gas.

(m) A mixture of this gas with hydrogen gas detonates loudly, on applying a lighted taper, or passing an electric spark.

When the proportion of hydrogen is nearly equal to that of nitrous oxide, or as 39 to 40, nitrogen gas only remains after the explosion; but when the proportion of hydrogen is smaller, nitric acid is also generated. In general terms, it may be stated that one measure requires one measure of hydrogen gas, and leaves after combustion one measure of nitrogen. Nitrous oxide forms, also (as I have shown, *Philosophical Transactions*, 1809, page 444), a combustible mixture with ammoniacal gas, 100 measures of the latter requiring for saturation 130 measures of nitrous oxide.

" (n) Nitrous oxide is not absorbed by alkalis; but if it be brought into contact with them, when in a nascent state, or before it has assumed the form of a gas, it then enters into combination with alkaline bases. Thus, when a mixture of sulphite of potash and pure potash is exposed to nitrous gas, the gas is disoxygenized by the sulphite, and changed into nitrous oxide, which unites with the alkali. We obtain, therefore, a mixture of sulphate of potash with a compound of nitrous oxide and alkali, the former of which may be separated by priority of crystallization. The latter is composed of about three parts of alkali, and one of nitrous oxide. It is soluble in water; has a caustic taste, of peculiar pungency; and converts vegetable blues to green. Powdered charcoal, mingled with it, and inflamed, burns with bright scintillations. The nitrous oxide is expelled from fixed alkalis by all acids, even by the carbonic.

(o) Animals, when wholly confined in this gas, die speedily.

(p) One of the most extraordinary properties of this gas is ex-

hibited by its action on the human body, when received into the lungs. When thus employed, it does not prove fatal, because, when received into the lungs, it is mixed and diluted with the atmospherical air present in that organ. To administer the gas, it may be introduced into an oiled silk bag or clean bladder, furnished with a stop-cock, and may be breathed repeatedly from the bag and back again, as long as it will last. The sensations that are produced vary greatly in persons of different constitutions; but, in general, they are highly pleasurable, and resemble those attendant on the pleasant period of intoxication. Great exhilaration, an irresistible propensity to laughter, a rapid flow of vivid ideas, and an unusual fitness for muscular exertion, are the ordinary feelings it produces. These pleasant sensations, it must be added, are not succeeded, like those accompanying the grosser elevation from fermented liquors, by any subsequent depression of nervous energy.

SECTION IV.

Nitrous Acid.

It has been a subject of controversy, whether an acid, entitled to this denomination, and holding the same relation to the nitric, which the sulphurous bears to the sulphuric, has really existence. That the acid, obtained from nitre, has different states of oxygenation, and contains a less quantity of oxygen in proportion to the depth of its colour, is generally admitted. But it has been contended that we are to consider all these varieties as nitric acid, holding in combination variable proportions of nitrous gas; and the principal argument in favour of this theory is, that the substance occasioning the colour may be separated by the mere application of heat. Sir H. Davy has given the following table, showing the proportion of nitrous gas in nitrous acid of different colours.

	Sp. Gr.	100 parts by weight contain		
		Real Acid.	Nit. Gas.	Water.
Pale yellow . . .	1.502	90.5	1.2	8.3
Bright ditto . . .	1.50	88.94	2.96	8.1
Dark orange . . .	1.480	86.84	5.56	7.6
Light olive . . .	1.479	86.	6.45	7.55
Dark olive . . .	1.478	85.4	7.1	7.50
Bright green . . .	1.476	84.8	7.76	7.44
Blue green . . .	1.475	84.6	8.	7.40

Mere dilution with water is sufficient to vary these colours. Thus the dark orange-coloured acid, by dilution, passes through the shades of blue, olive, and bright green. Nitric acid, also, by absorbing nitrous gas, has its specific gravity diminished. Colourless acid, for example, when rendered of pale yellow, becomes lighter in the proportion of 1.51 to 1.502.

It has been argued by Gay Lussac,* that the nitrous acid is as much a distinct and peculiar a compound, as any other of the combinations of nitrogen and oxygen. It is formed, he observes, whenever we mix oxygen and nitrous gases in such proportion, that the nitrous gas predominates, viz. about one measure of the former to four of the latter. It is of no consequence which is first added; for the result is invariably a condensable red vapour, containing by measure one of oxygen gas, and three of nitrous gas; or by weight,

Nitrogen	.	.	.	34.49
Oxygen	.	.	.	65.51
				<hr/>
				100.

The proportions of the elements of nitrous acid gas, as stated by Sir H. Davy, are somewhat different from these. When (he observes) two measures of nitrous gas and one of oxygen = 1 volume of nitrogen and 2 of oxygen, both freed from moisture, are mixed together in a vessel previously exhausted of air, they are condensed into half their volume, and form a deep orange-coloured elastic fluid, which may be called nitrous acid gas. It has the following properties:

A taper burns in it with considerable brilliancy. Sulphur inflamed does not burn in it; but phosphorus burns vividly. Charcoal continues to burn in it with a dull red light. Water absorbs it, and gains a tint of green. It reddens litmus paper, has a sour taste, a strong smell, and turns animal substances yellow. One hundred cubic inches, calculating from the condensation of its elements, must weigh 65.3 grains, at mean temperature and pressure, and it must contain in 100 grains,

Nitrogen	.	.	30.32	.	100
Oxygen	.	.	69.68	.	230
				<hr/>	
					100.

In this compound, therefore, the oxygen combined with one hundred grains of nitrogen, will be as nearly as possible, a multiplication by four of the oxygen in nitrous oxide (57); and it will complete the series of the compounds of nitrogen, the rest of which have been enumerated in the first section of this chapter.

To form liquid nitrous acid, nothing more is necessary than to saturate water with this vapour. The water becomes first green, then blue, and finally an orange colour more or less deep. The latter may be brought to the state of green or blue by adding more or less water. Hence the colour depends merely on the circumstance of density.

Admitting the correctness of these views, it will follow that when nitrous gas is transmitted through nitric acid, the latter is partly

* Memoires d'Arcueil, ii.

de-oxygenated; and the nitrous gas, acquiring oxygen, becomes nitrous acid. Hence the ordinary acid of nitre is a compound of nitric and nitrous acids, and not of nitric acid and nitrous gas;* and its colour will be deep in proportion to the quantity of nitrous acid which it holds in combination. Its properties, Berzelius remarks,† differ, also, from those of nitric acid; for while the latter boils at 236° , nitrous acid of the same density boils at 160° . The purely acid part he considers to be composed of 36.9 nitrogen + 63.1 oxygen. With bases, it forms a class of salts, which, he asserts, differ entirely from those containing nitric acid.

SECTION V.

Nitrates.

ART. 1.—*Nitrate of Potash.*

I. A DIRECT synthetic proof of the composition of this salt may be obtained by saturating nitric acid with potash, either pure or in a carbonated state. The solution, on evaporation, yields crystals of nitrate of potash, or nitre.

For the purposes of experiment, however, the nitrate of potash, which may be met with in the shops, and which is an abundant product of nature, may be employed on account of its greater cheapness. The nitre, which is met with as an article of commerce, is brought to this country, chiefly from the East Indies. When it arrives it is a very impure salt, containing, besides other substances, a considerable proportion of muriate of soda. In this state it is called rough nitre. For the purposes of chemistry, it requires to be purified by solution in water and re-crystallization; and it then obtains the name of refined nitre or refined saltpetre.

II. This salt has the following properties:

(a) It crystallizes in prismatic octahedrons, generally constituting six-sided prisms, terminated by two-sided summits. It contains, according to Berzelius, no water of crystallization. Thenard has determined that it consists of

59.5 potash
50.5 nitric acid.

But as potash itself, in the driest form under which we can procure it, still contains water, Berthollet has given the following proportions as those of nitrate of potash.

51.38 potash
48.62 acid

100.

* Dalton's New System, p. 366.

† 83 Ann. de Ch. 10.

These proportions are nearly reversed by Berard, who makes it consist of 48.64 base and 51.36 acid;* and the proportions, deduced by Dr. Wollaston, are 46.67 base to 53.33 acid.

(b) For solution, it requires seven times its weight of water at 60° of Fahrenheit; and boiling water takes up its own weight.

These are the proportions assigned by Bergman; but La Grange asserts, that, at the ordinary temperature, nitrate of potash requires only three or four times its weight of water for solution; and half its weight of boiling water.†

(c) By the application of a moderate heat it fuses, and being cast in moulds, forms what is called *Sal Prunelle*. After fusion, Sir H. Davy found that it still yielded water, when distilled with boracic acid.

(d) If a red-heat be applied, nitrate of potash is decomposed in consequence of the destruction of its acid. By distilling it in an earthen retort, or in a gun barrel, oxygen gas may be obtained in great abundance, one pound of nitre yielding about 12,000 cubic inches, of sufficient purity for common experiments, but not for purposes of accuracy.

(e) Nitrate of potash, that has been made red-hot, seems to contain an acid less oxygenated than the common nitric acid, and having a weaker affinity for alkalis. For if acetic acid be poured on nitre that has been thus treated, the nitrous acid is expelled in red fumes, whereas common nitre is not at all affected by acetic acid.

(f) Nitrate of potash is rapidly decomposed by charcoal in a high temperature. This may be shown, by mixing two parts of powdered nitre with one of powdered charcoal, and setting fire to the mixture in an iron vessel under a chimney. The products of this combustion, which may be collected by a proper apparatus, are carbonic acid and nitrogen gases. Part of the carbonic acid also remains attached to the residuary alkali, and may be obtained from it on adding a stronger acid.

This residue was termed, by the old chemists, *clyssus* of nitre.

(g) Nitrate of potash is also decomposed by sulphur, and with different results, according to the temperature and proportions employed.

1. Mix powdered nitre and sulphur, and throw the mixture, by a little at a time, into a red-hot crucible. The sulphur will unite with the oxygen of the nitric acid, and form sulphuric acid; which, combining with the potash, will afford sulphate of potash. The production of the latter salt will be proved by dissolving the mass remaining in the crucible and crystallizing it, when a salt will be obtained, exhibiting the characters described, chap. xii. sect. 4.

2. Mix a portion of sulphur with one sixth or one eighth its weight of nitrate of potash; put the mixture into a tin cup, and raise it, by a proper stand (fig. 25), a few inches above the surface of water, contained in a flat shallow dish. Set fire to the mixture, and cover it with a bell-shaped receiver. In this case, also, sulphuric acid will be formed; but it will not combine, as before, with

* 71 Ann. de Chim. 69.

† Manuel, 1st edition, i. 243.

the alkali of the nitre, which alkali is present in sufficient quantity to absorb only a part of the acid produced. The greater part of the acid will be condensed on the inner surface of the glass bell, and by the water, which will thus become intensely acid. The operation may be repeated three or four times, using the same portion of water. When the water is partly expelled, by evaporation in a glass dish, concentrated sulphuric acid remains, which has been formed by the union of the oxygen of the nitre, and that of the atmospherical air, with the sulphur submitted to experiment. By a process of this kind, conducted on a large scale, and in extensive leaden chambers, the sulphuric acid of commerce is prepared. The dilute acid, resulting from the union of the condensed vapour of the burning materials, with the stratum of water at the bottom of the chamber, is first boiled down in part in shallow leaden vessels, and is then transferred into glass retorts, where it is farther concentrated by the continued application of heat.

In a memoir of Clement and Desormes, published in Nicholson's Journal, xvii. 41, it is proved, that the nitre does not furnish above one tenth part of the oxygen, required for the conversion of sulphur into sulphuric acid, and that the rest of the oxygen is derived from the atmospherical air of the chamber. Sulphurous acid, they suppose, is in the first instance formed by the combustion of the sulphur; and, at the same moment, nitrous gas is evolved from the de-oxygenation of the nitric acid contained in the saltpetre. This nitrous gas, uniting with the atmospheric oxygen, composes *nitrous acid gas*, which, when water is present, has the property of converting sulphurous into sulphuric acid, and of returning, at the same time, to the state of nitrous gas. The same process is repeated, and thus the same portion of nitrous gas acts repeatedly as an intermedium between the sulphur, previously changed into sulphurous acid, and the atmospheric oxygen.

(h) A mixture of three parts of powdered nitre, two of carbonate of potash, or common salt of tartar, and one part of sulphur, all accurately mixed together, forms the *fulminating powder*, which explodes with a loud noise, when laid on an iron heated below redness.*

(i) A mixture of five parts of powdered nitre, one part of sulphur, and one of powdered charcoal, composes *gun-powder*. The materials are first very finely powdered separately, then mixed up together, and beaten with a wooden pestle, a sufficient quantity of water being added to prevent an explosion. The mixture is afterward granulated, by passing through sieves, and dried very cautiously.†

* These ingredients must be very dry, and mixed together in a warm mortar, to ensure a successful product. It requires to be kept from all moisture, which injures its detonation.

† On the preparation of gunpowder, and the theory of its detonation, consult Nicholson's Journal, xxiii. 279.(*)

(*) The paper here adverted to, consisting of scarcely one page, appears to me to afford a very imperfect idea of the theory of the detonation of gun-powder. It is a series of assumptions, many of which require proof; and at all events goes to oppose the doctrines of caloric, which assert the connection of that agent with

Process for preparing Nitric Acid.

Nitrate of potash is decomposed by sulphuric acid, which combines with the potash, and expels the nitric acid. Put into a glass retort, which may be either tubulated or not, four parts of nitrate of potash, reduced to a coarse powder, and pour upon it three parts of concentrated sulphuric acid. Apply a tubulated receiver, of large capacity, between which, and the retort, an adapter may be interposed; these junctures being luted with a mixture of pipe-clay, sifted sand, and cut tow or flax. To the tubulure of the receiver, a glass tube may be fixed by means of the fat lute, and may terminate in another large receiver, containing a small quantity of water. If the operator wishes to collect the gaseous products also, this second receiver should be provided with a tubulure, to which a bent pipe may be luted, terminating under one of the inverted funnels in the shelf of the pneumatic trough. Apply heat to the retort, through the intervention of a sand-bath. The first product that passes into the receiver, is generally of a red colour, and of a smoking quality. These appearances gradually diminish; and if the materials used were clean, the acid will come over pale, and even colourless. Afterwards it gradually re-assumes a red colour, and smoking property; which appearances go on increasing till the end of the operation; and the whole product, mingled together, has either a yellow or an orange colour, according to the temperature employed.

The proportions recommended in the new London Pharmacopœia for the preparation of nitric acid, are two pounds of nitrate of potash, deprived by heat of its water of crystallization, and two pounds of sulphuric acid. These are directed to be mixed in a glass retort, and distilled in a sand-bath, until a red vapour arises. The acid in the receiver is to be mixed with an ounce of nitrate of potash, and again distilled in a similar manner. After the second distillation its specific gravity is 1.500; and one fluid ounce, Mr. Phillips finds, decomposes 476 grains of marble. But he objects to the proportion of sulphuric acid, in the process of the College, as unnecessarily large. If, however, it be required to decompose the whole of any portion of nitre, it is necessary to use as much sulphuric acid, as will form, with the alkali of the nitre, *super-sulphate* of potash, viz. 97 parts of acid, of density 1.85, to 100 parts of nitre.

The nitric acid, which first passes over, has the greatest specific gravity. In an experiment of Dr. Perceval of Dublin, the product was taken in three portions; the first of which had the specific gravity of 1.494, the second of 1.485, and the third of 1.442.†

the different states of cohesion in bodies. Thus, although we know that a vast amount of caloric is extricated, or excited, from some source, yet the gases produced, after full expansion, are said to occupy 14000 times the space they did before, as water! But what ought to be the fact, if the above opinions of caloric were correct? Should not the gases thus expanding absorb caloric, and thereby induce the negative sensation of cold? C.

† Transactions of the Irish Academy, iv. 37.

In the large way, and for purposes of the arts, it is usual to substitute earthen or cast-iron retorts, made extremely thick, for those of glass. An earthen head is adapted, and this is connected with a range of proper condensers. The strength of the acid is varied also, by putting more or less water into the receiver. What is called double aqua fortis varies in its specific gravity from 1.3 to 1.4.

Nitric acid, obtained by this process, is never perfectly pure. It contains, generally, both sulphuric and muriatic acids; the former of which is indicated by a white precipitate, on adding a solution of nitrate of barytes to a little of the acid, diluted with 8 or 10 parts of water; and the latter, by a milkiness produced by nitrate of silver. The sulphuric acid may be separated, either by a second distillation from a portion of very pure nitre, equal in weight to one eighth of that originally employed, or by adding nitrate of barytes; allowing the precipitate to settle; decanting the clear liquid, and distilling it. Muriatic acid is separated by the addition of nitrate of silver. An immediate milkiness ensues, and fresh additions must be made of nitrate of silver, as long as it occasions this appearance. Then allow the precipitate to subside; decant the clear liquid, and re-distil it; leaving one eighth or one tenth in the retort. The product will be pure nitric acid. Nitrate of lead may be substituted for nitrate of silver.† The nitric acid may also be obtained free from muriatic acid, if a perfectly pure nitrate of potash be employed for distillation. This purification is effected by repeated solutions of the nitre, in boiling distilled water, and re-crystallizations.

Nitric acid obtained in this manner is deficient also in another respect; for it is not perfectly oxygenated, but holds in solution a considerable quantity of nitrous acid. To expel the latter, put the acid into a retort, to which a receiver is applied, the two vessels not being luted, but joined merely by paper. Apply a very gentle heat for several hours to the retort, changing the receiver as soon as it becomes filled with red vapours. The nitrous gas will thus be expelled, and the acid will remain in the retort in a state of purity, and as limpid and colourless as water. It must be kept in a bottle secluded from the light.

One hundred parts of nitrate of potash, according to La Grange, yield by this process 43 of acid, or according to my experience, above 50; but, if the process of the College be followed, 100 of fused nitre afford about 66½ of acid. Even this, however, is not the whole of what was contained in the salt; for a part is decomposed by the temperature necessary to the operation. Accordingly, a large quantity of oxygen gas is disengaged during the distillation, and may be collected by an obvious addition to the apparatus.

In the retort, there remains a compound of potash with more sulphuric acid than is essential to its saturation, or a super-sulphate of potash. On submitting this to a pretty strong heat, the

† See Nicholson's Journal, xi. 134.

excess of sulphuric acid is expelled; and the residue, dissolved and evaporated, affords crystallized sulphate of potash.

ART. 2.—*Nitrate of Soda.*

I. This salt may be formed, by saturating carbonate of soda with nitric acid; or by distilling common salt with three fourths its weight of nitric acid. When the former process is adopted, the solution must be evaporated, till a pellicle appears on its surface, and then allowed to cool. Crystals will be produced, having the shape of rhomboids, or rhomboidal prisms.

II. These crystals have a taste like that of saltpetre, but more intense. They are soluble in three parts of water at 60°, and in less than an equal weight of boiling water. They attract moisture from the atmosphere. In other respects, in the means by which their decomposition is effected and its results, they agree with the nitrate of potash. The only use of nitrate of soda is, perhaps, that which has been suggested by Proust, who has found it to be more economical in the making of fire-works than nitrate of potash.* It consists, according to Dalton, of

$$\begin{array}{r} 57.6 \text{ acid} \\ 42.4 \text{ base} \\ \hline 100. \end{array}$$

ART. 3.—*Nitrate of Ammonia.*

I. The most simple mode of preparing this salt is by adding carbonate of ammonia to dilute nitric acid, till saturation has taken place. If the liquor be evaporated, by a heat between 70° and 100°, to a certain extent, it shoots, on cooling, into crystals, having the shape of six-sided prisms, terminated by long six-sided pyramids. Evaporated at the temperature of 212°, it yields, on cooling, thin fibrous crystals; and when the evaporation is carried so far, that the salt immediately concretes on a glass rod by cooling, it then forms a compact and shapeless mass.

II. The solubility of this salt varies, according to the temperature in which it has been formed. When in crystals, it requires twice its weight of water, for solution, or half its weight of boiling water. It deliquesces, in all its forms, when exposed to the atmosphere.

III. The most important property of this salt is the one which has been already described, *viz.* of yielding, when decomposed by heat, the nitrous oxide. One pound of the compact kind gives, by careful decomposition, nearly five cubic feet of gas, or rather more than 34 doses; so that the expense, estimating the salt at 5s. 10d. the pound, is about 2d. for each dose.

IV. In a temperature of 600° this salt explodes, and is entirely decomposed. Hence it was formerly called *nitrum flammans*.

* Nicholson's Journal, xv. 262.

V. Its composition varies according to the mode of its preparation, and is stated by Sir H. Davy as follows:

Prismatic.	Fibrous.	Compact.
69.5	72.5	74.5 acid
18.4	19.3	19.8 ammonia
12.1	8.2	5.7 water
<hr/> 100.	<hr/> 100.	<hr/> 100.

The prismatic variety is stated by Berzelius,* who investigated very carefully the results of its decomposition, to consist of

67.625 acid
21.143 base
11.232 water
<hr/> 100.

ART. 4.—*Nitrate of Barytes.*

Nitrate of barytes may be prepared, by dissolving either the artificial or native carbonate in nitric acid, diluted with eight or ten parts of water. If the artificial carbonate be employed, it should be previously well washed with distilled water, till the washings cease to precipitate nitrate of silver.† A solution of nitrate of barytes, mixed with one of silver, should continue perfectly transparent. On evaporation, it yields regular octahedrons, often adhering to each other in the form of stars; and sometimes it is obtained in small brilliant plates. It requires for solution 12 times its weight of water at 60°, and three or four parts of boiling water. It is not altered by exposure to the air. In a red-heat, its acid is decomposed, and the earth remains pure. This furnishes another method of procuring pure barytes; but the heat must not be carried too far, otherwise the barytes is apt to vitresfy with the crucible. The residue, on the addition of water, dissolves with great heat and noise, and the solution, on cooling, yields crystals of pure barytes.

Nitrate of barytes is composed, in 100 parts, according to Clement and Desormes, of 60 base, and 40 acid and water. Mr. James Thomson states its composition to be

59.3 barytes
40.7 acid and water.

This scarcely differs from the determination of Berzelius, viz. 58.46 base + 41.54 acid, and no water.

* 80 Ann. de Ch. 182.

† For particulars relative to the process of forming the Nitrat of Barytes from the carbonat, the reader may consult with advantage an Essay on Barytes by Mr. Parke in his Chem. Essays, vol. 2. 224. C.

ART. 5.—*Nitrate of Strontites.*

This salt may be obtained in the same manner as the nitrate of barytes, with which it agrees in most properties. The solubility of its crystals, however, differs considerably; for they are dissolved by their own weight of water at 60° , or by little more than half their weight of boiling water. When applied to the wick of a candle, or added to boiling alcohol, they communicate to the flame a deep blood-red colour. They are decomposed by a high temperature, and afford pure strontitic earth. Exclusive of water, the salt consists, according to Richter, of 51.4 acid + 48.6 base.

ART. 6.—*Nitrate of Lime.*

This salt is found abundantly in the cement of old buildings, which have been long inhabited. To prepare it artificially, nitric acid, diluted with five or six parts of water, may be saturated with carbonate of lime. When this solution is boiled down to the consistence of syrup, and exposed, in a cool place, long prismatic crystals are formed, resembling, in their disposition, bundles of needles diverging from a common centre. These crystals are readily soluble in water, of which, at 60° , they require two parts, and boiling water dissolves an equal weight. They deliquiate speedily, when exposed to the air; and are decomposed at the temperature of ignition. Exclusive of water, Mr. Dalton states this salt to consist of

61.3 acid
38.7 base

100.

When a solution of nitrate of lime is evaporated to dryness in an earthen vessel, then fused for five or ten minutes in a crucible, and poured, while in fusion, into an iron pot previously heated, the congealed mass forms *Baldwin's phosphorus*. It must be broken into pieces, and preserved in a well-stopped phial. These pieces, after having been exposed to the sun for a few hours, emit in the dark a beautiful white light, affording one variety of solar phosphorus.

ART. 7.—*Nitrate of Magnesia.*

This compound may be prepared, by dissolving carbonate of magnesia in diluted nitric acid. The solution, when evaporated, yields crystals in the shape of prisms, with four oblique faces truncated at their summits. Most commonly, however, it forms a shapeless mass, consisting of an immense number of small needle-shaped crystals, crossing each other irregularly. These crystals deliquiate in the air, and are soluble in half their weight of water. When exposed to the heat of ignition, they fuse; a few bubbles of oxygen gas first escape; and the nitric acid then passes undecomposed. The salt contains, exclusive of water, according to Dalton, 69 acid + 31 base.

ART. 8.—*Nitrate of Alumine.*

This salt is but little known. It may be formed by the solution of fresh precipitated alumine, which has been well washed with distilled water, but not dried, in diluted nitric acid, with the assistance of heat. The solution, which has always an excess of acid, after evaporation, crystallizes in thin ductile plates. The crystals are extremely soluble; and, on the application of a high temperature, abandon their acid. They are decomposed by most alkalis and earths. Pure potash, added in excess, re-dissolves the precipitate.

ART. 9.—*Nitrate of Glucine.*

The nitrate of glucine is a sweet tasted salt, which cannot be brought to crystallize. When evaporated to dryness, it rapidly absorbs moisture from the atmosphere. It is soluble in alcohol. A high temperature decomposes it, without effecting its previous fusion.

ART. 10.—*Nitrate of Zircon.*

The nitric acid dissolves, but cannot be saturated with, fresh precipitated zircon. The solution has always an excess of acid. When evaporated, it forms a yellowish transparent mass, extremely tenacious and viscid, and difficultly dried. It has a styptic astringent taste, and leaves on the tongue a thick substance, in consequence of its partial decomposition by the saliva. This dry nitrate is extremely soluble. The solution is decomposed by sulphuric acid, and by carbonate of ammonia, which throw down a precipitate soluble in an excess of the acid, or of the carbonate. Tincture of galls forms a white precipitate, which is soluble in an excess of the tincture.

ART. 11.—*Nitrate of Yttria*

May be prepared by dissolving yttria in nitric acid. The solution has a sweetish astringent taste; and, in most properties, resembles nitrate of glucine. It can scarcely be obtained in crystals; and if too great a heat be applied during evaporation, the salt becomes soft, assumes the appearance of honey, and concretes, on cooling, into a hard stony mass. Exposed to the air, it attracts moisture, and is resolved into a liquid.

SECTION VI.

Nitrites.

THE easiest mode of obtaining nitrites, is to deprive the acid, contained in the nitrates, of part of its oxygen, by exposure for a short time to the temperature of ignition. This method, it must be obvious, cannot be used with those nitrates that abandon their acid on the application of heat, or which, like nitrate of ammonia, are more completely decomposed.

The nitrites may also be composed by the direct combination of alkaline and earthy bases with nitrous acid, formed in the mode proposed by Gay Lussac, and already described under the article *nitrous acid*.

Nitrate of potash, after ignition in a crucible, becomes a nitrite of that alkali. It emits, when powdered, a smell of nitrous gas. When diluted nitric acid, or even acetic acid, is poured upon it, vapours of nitrous acid are disengaged; and hence it appears, that the affinity of this acid for its base is weakened by partial dis-oxygenation; for no such effect arises on adding these acids to the nitrate. The solution of the salt in water changes the syrup of violets to green. Its other properties are little known.

CHAPTER XIV.

MURIATIC ACID—OXYMURIATIC ACID OR CHLORINE—AND THEIR COMPOUNDS.

THERE are few subjects, respecting which the opinions of chemists have undergone such frequent changes, as concerning the nature of the muriatic and oxymuriatic acids. The view originally taken by Scheele, the illustrious discoverer of the latter body, was, that the muriatic acid is a compound of a certain base and phlogiston; and that it becomes oxymuriatic, or as he termed it *dephlogisticated* muriatic acid, when deprived of that supposed principle of inflammability.* It was afterwards found, however, that all bodies, which are capable of producing this change in muriatic acid, contain oxygen, and that their proportion of oxygen is diminished by the process. It appeared, therefore, an obvious conclusion, that muriatic acid becomes oxymuriatic acid, by the transfer of oxygen from the oxide to the acid. Sir H. Davy was led, by his earlier experiments, to modify, in some degree, this view of the nature of muriatic and oxymuriatic acids; and to consider the former as a compound of a certain basis with water, and the latter as

* On Manganese, sect. xxiii. xxiv.

a compound of the basis with oxygen. This modification was rendered necessary by the fact, that when a metallic oxide is heated in muriatic acid gas, oxymuriatic acid is formed, and water appears in a separate state. But, at a subsequent period, that philosopher was induced, by the experiments of Gay Lussac and Thenard, as well as by his own, to form a different theory on the subject. Oxymuriatic acid, he considered as a simple or undecomposed substance; and muriatic acid, as a compound of oxymuriatic acid with hydrogen. To convert the muriatic into the oxymuriatic acid, we have only, according to this view, to abstract hydrogen from the former; and this, it is supposed, is all that is effected by the action of those oxides, which are adapted to the purpose. Again, to convert oxymuriatic into muriatic acid, we have only to supply it with hydrogen; and the simple mixture of one measure of each of those gases, by exposure for a short time to the sun's rays, affords two measures of muriatic acid gas.

The oxymuriatic acid or *chlorine* (as Sir H. Davy proposes to call it, in order to avoid all connection of its name with hypothetical views) is supposed, also, to unite at once with the metals, without requiring, like the sulphuric or nitric acid, that the metals should be in the state of oxides. In proof of this theory, it appears to be sufficiently established, that no oxygen can be obtained, either alone, or in combination with combustible bodies added for the purpose, from the compounds of chlorine and metals. The analyses, however, of the metallic muriates, as they were formerly considered, remain unimpeached by this change of theory. All that is necessary, to transmute in idea a muriate into a compound of chlorine, is to deduct the oxygen from the oxide; and, adding it to the muriatic acid, to consider the sum as chlorine. For example, muriate of soda, deprived of all water, consists

On the old theory, of muriatic acid	.	.	46
Soda composed of	{	Oxygen	13.5
	{	Sodium	40.5
			54
			<hr/>
			100
			<hr/>
On the new theory it consists of			
Sodium	.	.	40.5
Chlorine, 46 + 13.5 =	.	.	59.5
			<hr/>
			100.

It is remarkable that there is hardly any fact, connected with the chemical history of the muriatic and oxymuriatic acids, that does not admit of being equally well explained upon either hypothesis. I have, therefore, notwithstanding the increase of probability derived, by the doctrine of chlorine, from the striking analogy of that body with the newly discovered substance iodine, thought it unnecessary to make so essential a change in the arrangement of this work, as would be produced by removing the oxymuriatic acid to

the class of simple substances. On the whole, the probabilities certainly appear to me much in favour of the new, or rather the revived opinion. But there are still objections to its implicit adoption, which this is not the proper occasion to state. I shall only observe, that not the least important of these objections is, the instantaneous conversion, which the theory of chlorine supposes, of the metallic combinations of that body into muriates, when they are dissolved in water, the oxygen of which is imagined to pass, in a moment, to the metal, while the hydrogen is attracted by the chlorine. In the present state of the enquiry, indeed, we stand in need of some fact, which shall admit of explanation only on one of the opposed theories.*

* Such is the uncertainty still existing, as to the nature of muriatic and oxymuriatic acids, (although with Dr. Henry I am disposed to consider the probabilities being "much in favour of the new, or rather the revived opinion,") that, until some fact shall appear, admitting of explanation *only* on one of the opposed theories, I think speculation had better be suspended. It has already involved us in such a labyrinth of new terms, that the memory is oppressed, and research is impeded by them.

Dr. H. has very properly amended the term *new*, applied above, to that of *revived*; it is certain that to Scheele the opinion is due, of the simple nature of oxymuriatic acid, if such should finally be the one received. Sir H. Davy who advocates the opinion of its simplicity, did not at first give the credit to Scheele, nor until Thenard and Gay Lussac claimed *their* prior right to it by 18 months. He, surely could never have meant to claim it as his own! Neither could the other gentlemen have intended such an insult to their readers, as to suppose they had forgotten all the important discoveries of the illustrious Swedish chemist!

The following brief statement of the reasons for considering the oxymuriatic acid gas a simple body, from Thenard and Gay Lussac's *Recherches Chimico-Physiques*, vol. 2, 159, may be properly admitted in this place. C.

1. Oxygenated muriatic acid gas, exposed *alone* to the action of the greatest heat, or to the rays of the sun, undergoes no alteration; but exposed *at the same time*, to the action of water, it disappears, and muriatic acid gas is obtained and oxygen gas.

2. Hydrogen gas combines, in an equal volume, with oxygenated muriatic acid gas, and forms muriatic acid gas, without any water being deposited. This is effected, slowly in the dark, but instantly, and with detonation in the sun.

3. Charcoal, if *pure*, has no action at *any temperature*, upon oxygenated muriatic acid gas; but if it contains hydrogen, muriatic acid gas is formed; and if it contains water, it produces besides, gaseous oxyd of carbon.

4. Phosphorus absorbs oxygenated muriatic acid gas, and forms a peculiar fluid.

5. This fluid is easily obtained by treating the muriats of mercury with phosphorus: and then the mercury is reduced without disengaging any muriatic acid.

6. Sulphur absorbs this gas, as phosphorus does; and like that body, forms a peculiar fluid, discovered by Thomson.

7. The metallic sulphurets act upon this gas exactly as sulphur does.

8. All the metals are capable of combining with oxygenated muriatic acid gas, and of forming metallic muriats. Some of them, as those of zinc, iron, &c. act with force on muriatic acid gas, and from this action, muriats result, similar to the above, and a quantity of hydrogen gas, equal to half the quantity of muriatic acid gas absorbed.

SECTION I.

Muriatic Acid.

I. THE muriatic acid, in its purest form, exists in the state of a gas, which is permanent over mercury only. For exhibiting its properties, therefore, a mercurial apparatus is absolutely necessary.

9. None of these muriats are decomposed by pure charcoal, nor by boracic acid, or acid phosphat of lime, vitrified.

10. On the contrary, all these are decomposed by the above three substances, by the aid of water, or by hydrogenated charcoal alone, and consequently by vegetable and animal substances. With water and charcoal, we obtain, muriatic acid gas and gaseous oxyd of charcoal, and the metal is reduced. Water and phosphoric or boracic acids, give muriatic acid gas, and a phosphat or borat. With hydrogenated charcoal, or with hydrogen gas, muriatic acid gas is procur- ed, and the metal is reduced.

11. Muriat of barytes, strontites, lime, potash, soda, and magnesia, perfectly dry, are, like the above metallic muriats, undecomposable by vitrified boracic and phosphoric acid : but they are all immediately decomposed by them, with the aid of the vapour of water ; there result, borats or phosphats, and muriatic acid gas :—They are not in any case decomposed by charcoal.

12. The same would certainly be the case with muriat of glucine, yttria, alumine, zircon and silex, if they could be obtained free of water.

13. When muriatic acid gas and oxyd of lead, very dry, are brought in contact, at a slightly elevated temperature, the gas is absorbed ; muriat of lead and water are formed. The same takes place with oxyd of silver, iron, &c.

14. The same results occur with barytes, lime and strontian, very dry, as with oxyd of lead.

15. Marine salt cannot be decomposed at the highest temperature, by sand or alumine ; but it is effected easily by either, when aided by the action of water. Muriats of barytes, potash, strontian and chalk, are in the same case with marine salt, in respect to sand, alumine and water.

16. Oxygenated muriatic acid gas, in contact with an excess of liquid ammonia, disappears ; forms a certain quantity of muriat of ammonia ; decomposes besides a certain quantity of the alkali, and gives place to a disengagement of azote gas, equal in volume to one-third of the oxygenated muriatic acid gas which disappears.

17. Sulphurous acid gas, nitrous gas, nitrous oxyd, have no action on oxygenated muriatic acid gas, if they are dry : but if moist, or in contact with water, they act suddenly on this acid, and give rise, the *first* to sulphuric acid and muriatic acid ; the second and third to the nitrous acid, and perhaps to nitric acid and muriatic acid.

18. The sulphites of lime, barytes, &c. very dry, are not attacked by the oxygenated muriatic acid *dry* ; but how little soever of water is in this acid, it disengages the sulphurous acid, and forms a muriat, and probably a sulphat.

19. When the fuming liquor of Libavius, and ammoniacal gas are brought into contact over mercury, the gas is absorbed with great heat ; no gas separates, and a solid substance is produced of a white colour, which, if heated, volatilizes entirely, with dense and acrid fumes. Whatever quantity of ammonia is employed, the result is the same. One cannot then by this means, separate the oxyd of tin from the liquor ; but if on this liquid, water is poured, and ammonia be then added, oxyd of tin immediately precipitates.

20. When phosphorus is treated with oxygenated muriatic acid gas, two compounds are obtained ; one liquid, the other solid. If the solid compound is saturated by heat, with ammoniacal gas, the action is energetic, the production

To obtain muriatic acid gas, let the tubulated gas bottle (plate ii. fig. 17) be about one fourth, or one third, filled with well dried muriate of soda (common salt) in lumps, not in powder. To this adapt the acid-holder, filled with concentrated sulphuric acid; and let the aperture of the bent pipe terminate under a jar filled with, and inverted in, quicksilver. Open the communication between the acid and the salt, by turning the cock, and immediately on the contact of these two bodies, an immense quantity of muriatic acid gas will be disengaged. A common or tubulated gas bottle, or tubulated retort, will answer sufficiently well for procuring the gas. The first portions, that come over, may be allowed to escape under a chimney; because they are contaminated by the admixture of the common air present in the bottle. The subsequent portions may be preserved for use; and the pure gas will exhibit the following qualities:

(a) It has a very pungent smell; and is sufficiently caustic to blister the skin, when applied to it for some time.

(b) When brought into contact with common air, it occasions a white cloud. This is owing to its union with aqueous vapour, which is always present in the atmosphere.

(c) It extinguishes a lighted candle. Before the flame goes out, the upper part of it assumes a greenish hue, the cause of which has not yet been explained. A white vapour also surrounds the extinguished wick, owing to the combination of water, produced by the combustion of the candle, with the muriatic acid gas.

(d) It is heavier than common air. Biot and Gay Lussac state its specific gravity at 1.278, and hence 100 cubic inches weigh, as nearly as possible, 39 grains; according to Sir H. Davy between 39 and 40.

(e) It effects the liquefaction of a piece of ice, almost as rapidly as it would be melted by a red-hot iron.

(f) It is very rapidly absorbed by water. A drop or two of water, admitted to a large jar full of this gas, causes the whole of it instantly to disappear. According to Mr. Kirwan, an ounce-measure troy of water absorbs 800 cubical inches (*i. e.* 421 times its bulk) of muriatic acid gas; and the water, by this absorption, is increased about one third its original volume. Dr. Thomson's experiments indicate a still larger absorption, *viz.* 515 cubical inches, or 308 grains by one cubic inch, equal to 252 grains, of water, at 60° Fahrenheit; the barometer standing at 29.4. Berthollet has shown that 100 grains of water absorb 12.467 grains of muriatic acid gas

of heat is great; and a white opaque powder is produced. If this powder is introduced into a green glass tube, and heated to redness, without the contact of air, nothing escapes, and it is not decomposed; but if heated with hydrat of potash it is instantly decomposed, ammoniacal gas is separated, and a muriat and phosphat are formed.

21. Oxygenated muriatic acid gas re-acts with force on ammoniacal gas, but in this re-action, no water is deposited;—15 or 16 parts of oxygenated muriatic acid gas absorb 45 of ammoniacal gas: giving rise to dry muriat of ammonia, and to a disengagement of five or six parts of azote.

deprived of all redundant water by passing it through a tube, surrounded by a freezing mixture. By this absorption, we obtain an acid of the specific gravity 1061.4; and hence it follows that acid of this density contains, in 100 grains, only 8.55 of real acid.

(g) When potassium is introduced into muriatic acid gas, dried by muriate of lime, it immediately becomes covered with a white crust; it heats spontaneously; and, by the assistance of a lamp, acquires, in some parts, the temperature of ignition, but does not inflame. If the potassium and the gas be in proper proportions, they both entirely disappear; a white salt is formed, and a quantity of pure hydrogen gas is evolved, which is equal to about one third the original volume of the acid gas. Eight grains of potassium, in an experiment of Sir H. Davy, effected the absorption of nearly twenty-two cubic inches of muriatic acid gas: and the quantity of hydrogen gas produced amounted to more than eight cubical inches. It is remarkable that potassium, by its action on muriatic acid gas, separates exactly the same quantity of hydrogen, as would arise from its agency on water. This has been considered as a proof, that the evolved hydrogen has its origin from water, which the gas is supposed to hold in combination. But the phenomena are equally well explained by admitting, that muriatic acid is decomposed by the potassium, which seizes the chlorine, and sets the hydrogen at liberty. And on the corpuscular theory of Mr. Dalton, whether potassium act on water or on muriatic acid, in each case an atom of hydrogen will be disengaged; since the metal must attract to itself either an atom of oxygen or of chlorine.

Various expedients were tried, by Sir H. Davy, to obtain muriatic gas from perfectly dry materials, with the view to determine, whether potassium is capable of detaching hydrogen from gas so prepared. But it was found that materials, which are capable of affording it when moist, yield no gas whatsoever, when in a perfectly dry state. None, for example, could be obtained by strongly heating a mixture of dry phosphoric or boracic acid with dry muriate of lime. This would appear, on first view, favourable to the opinion that water is essential to the constitution of muriatic gas. But it is equally consistent with the theory of chlorine, for it is by the combination of chlorine with the hydrogen contained in water, that the advocates of the new theory explain the formation of muriatic acid gas, under ordinary circumstances.

(h) When muriatic acid gas is electrified in contact only with glass, oxymuriatic acid and hydrogen gases are found, after the experiment, in quantity never exceeding $\frac{1}{3}$ th the original bulk of the gas. This result may either be explained by supposing that the water of muriatic acid gas is decomposed, and that the oxygen unites with the acid, while the hydrogen is liberated; or it may be accounted for on the new theory, which requires nothing more than the separation of the chlorine and hydrogen, constituting muriatic acid, by the agency of the electric fluid. When the experiment is made over mercury, the chlorine unites with that metal, and a mixture of muriatic acid and hydrogen gases remains.

(i) When muriatic acid gas and oxygen gases are electrified together, oxymuriatic acid is formed, directly, as the old theory would explain, by the union of the acid with oxygen; or, as the theory of chlorine teaches, the oxygen unites with the hydrogen of muriatic acid gas, and merely liberates oxymuriatic acid.

(k) When a small piece of barytes or strontites, obtained by the decomposition of the nitrate, and therefore free from water, is heated by means of a spirit lamp, in a retort filled with muriatic acid gas, the gas is first dilated, and is then rapidly absorbed. The barytes or strontites becomes red-hot, and the muriate, which is produced, runs into fusion.* At the close of the experiment, a sensible quantity of water is condensed. This may either have pre-existed in the muriatic acid gas, or it may have been formed, by the union of the hydrogen of the acid, with the oxygen of the earth which has been employed.

Process for preparing Liquid Muriatic Acid.

Into a tubulated retort, placed in a sand-bath, put eight parts of dried muriate of soda; and, to the tubulure, lute the bent tube (fig. 26, a) with fat lute. To the neck of the retort, affix a tubulated receiver (fig. 30, b) by means of the same lute; and to the aperture of this adapt a tube, twice bent at right angles, and furnished with Welter's contrivance for preventing absorption (fig. 31, b), the longer leg of which terminates beneath the surface of water contained in a two-necked bottle. From the other neck, let a second right-angled pipe proceed; and this may terminate in a similar manner, in a second bottle containing water; the total quantity of which, in all the bottles, may be about five parts. Let the junctures be all carefully luted; and, when they are sufficiently hardened, pour very gradually through the bent tube five and a half parts by weight of strong sulphuric acid, making the additions at several distant intervals. On each affusion of the acid a large quantity of muriatic acid gas will be liberated, and will be absorbed by the water of the first bottle, till this has become saturated. It will then pass on to the second bottle, and be there absorbed. The water employed may amount to half the weight of the salt, and may be equally distributed between the two bottles. These it is better to surround with cold water, or, still preferably, with ice or snow; because the condensation of the gas evolves considerable heat, which prevents the water from attaining its full impregnation. When the whole of the sulphuric acid has been added, and the gas no longer issues, let a fire be lighted in the furnace, beneath the sand-bath, removing the bent tube a, and substituting a well-ground glass stopper. This will renew the production of gas; and the temperature must be preserved, as long as gas continues to be evolved. At this period it is necessary to keep the luting, which connects the retort and receiver, perfectly cool; otherwise it will be apt to melt. To this juncture, indeed, I prefer the application of the clay and sand lute; but to apply this properly requires some practice. Towards

* Chevreul. 84 Ann. de Chim. 285.

the close of the process, a dark-coloured liquid is condensed in the first receiver, consisting of a mixture of sulphuric and muriatic acids. When nothing more comes over, the operation may be suspended, and the liquid in the two bottles must be preserved in bottles with ground stoppers. It consists of liquid muriatic acid.

The liquid muriatic acid may also be obtained by diluting the sulphuric acid with the water necessary for the condensation of the gas, and adding the dilute acid, when cold, to the salt in the retort. To the retort, an adapter may be luted with the clay and sand lute; and this may terminate in a large tubulated receiver, from the aperture of which a right-angled Welter's tube is conveyed beneath a few ounces of water, contained in a two-necked bottle. A fire must then be lighted under the sand-bath, and continued as long as any liquid comes over. The adapter and receiver must be kept cool, by the constant application of moistened cloths.

The proportions, directed by the London College of Physicians, in their Pharmacopœia of 1809, are those recommended by Vauquelin, *viz.* four parts of dried salt, three of sulphuric acid, and three of water, of which last one third is to be employed in diluting the acid, and two thirds to be put into the receiver. Mr. R. Phillips, however, finds that the water and acid are in unnecessary excess; and that the most economical proportions are 32 parts of salt, and 21.9 (say 22) of sulphuric acid, of density 1.850, which may be diluted with one third its weight of water, the remaining two thirds being placed, as before, in the receiver.* The weight of the acid produced should equal, or a little exceed, that of the salt employed.

If the muriatic acid, thus obtained, should contain sulphuric acid, which may be discovered by muriate of barytes occasioning a white precipitate, the acid is to be re-distilled from a fresh portion of muriate of soda. When prepared by Woulfe's apparatus, the product in the second bottle is always perfectly pure.

The acid, formed by the process of the College, has the specific gravity only of about 1.142; that of commerce is generally about 1.156; but by Woulfe's apparatus, and especially when the bottles are surrounded by ice or snow, it approaches 1.500. A fluid ounce of the specific gravity 1.142 dissolves 204 grains of marble; and the same quantity of sp. gr. 1.174 decomposes 240 grains. The intermediate degree of specific gravity, however, which has been mentioned, is best adapted for keeping; for the denser acid emits a large quantity of fumes, which are extremely inconvenient and injurious to all metallic instruments.

The caput mortuum consists of sulphate of soda with some undecomposed muriate of soda. The former may be obtained, in a crystallized form, by first driving off, by a strong heat, the excess of sulphuric acid that adheres to it; and then dissolving it in hot water. The product of sulphate of soda exceeds that of the muriate employed in the proportion of about eight to five.

Liquid muriatic acid has the following properties:

1. It emits white suffocating fumes. These consist of mu-

* On the London Pharmacop. p. 10.

riatic acid gas, which becomes visible by contact with the moisture of the air.

2. When heated in a retort, or gas bottle, muriatic acid gas is disengaged, and may be collected over mercury.

3. Liquid muriatic acid is not decomposed by the contact of charcoal, essential oils, or other combustible bodies.

4. When diluted with water, no remarkable elevation of temperature is produced.

5. In a perfectly pure state it is quite colourless; but it has frequently a yellowish hue. This may proceed, either from a portion of oxymuriatic acid, or of muriate of iron, but most commonly of the latter. This colour is instantly destroyed by a few drops of muriate of tin; but this addition, instead of diminishing, increases the impurity of the acid.

6. Muriatic acid combines readily with alkalis, and with most of the earths, both in their pure and carbonated states.

7. Liquid muriatic acid is specifically heavier than water. The correspondence between its specific gravity, and the quantity of real acid, which it contains, is shown by the following Table, given by Sir H. Davy in his Elements of Chemical Philosophy. It is constructed from experiments made with great care by Mr. E. Davy in the Laboratory of the Royal Institution.

Table showing 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	22.3		

SECTION II.

Oxymuriatic Acid, or Chlorine Gas.

I. THIS gas may be formed by either of the following processes :

Process 1. Into a stoppered retort introduce eight ounces of liquid muriatic acid, and four ounces of finely powdered manganese,

and apply the heat of a lamp. A gas will be produced, which may be received over water in the usual manner. From the foregoing materials about 160 cubical inches of gas may be obtained.

Process 2. Mix eight ounces of muriate of soda (common salt) with three ounces of powdered manganese; put them into a stoppered retort, and pour on them four ounces of sulphuric acid, which have been diluted previously with four ounces of water, and suffered to cool after dilution. Or the proportions recommended by The-nard may be employed, *viz.* 1750 muriate of soda, 450 oxide of manganese, water and sulphuric acid each 800. On applying a gentle heat gas will be produced, as in process 1. But as the gas is absorbed by contact with water, though not rapidly, it should be received, when it is intended to be kept, in bottles filled with, and inverted in, water of the temperature of 80° or 90° Faht. and provided with accurately ground stoppers. The stoppers must be introduced under water, while the bottle remains inverted, and no water must be left in the bottle.*

II. Oxymuratic acid gas has the following properties:

(a) It has a yellowish green colour; and this property has suggested the name *chlorine*.†

(b) It has a pungent and suffocating smell. In experiments on this gas, great care should be taken that it does not escape, in any considerable quantity, into the apartment; for its action on the lungs is extremely injurious and oppressive.‡

* The animal economy, possesses in some way, the power of decomposing the muriat of soda in sea water, and of setting free the oxymuriatic acid. Incapable as I am of explaining it, I am nevertheless fully satisfied of the fact. More than once when bathing in the sea, and long before I had any knowledge of chemistry, I was sensible of a very singular and uncommon smell, on emerging from the waves; nor did I ever meet with the same in any other situation, until I attended a course of lectures for the first time. The peculiar odour of the oxymuriatic gas, is such, as at once to recognise it by; and this I did on first inhaling it. Nor have I ever failed to admit its claim to my early acquaintance, whenever I have been engaged in its pursuit. I have likewise been assured by a friend, to whom the oxymuriatic gas is very familiar, that he had experienced the same sensation which I have described, when bathing in the sea; although it had never been the subject of consideration until I had called his attention to it. C.

† From *χλωρος*, green.

‡ The celebrated chemist Pelletier, is well known to have fallen a victim to his temerity in respiring this gas. It induced a rapid consumption, which at an early period of life, hurried him to the grave. From a accidentally respiring it some years ago, by the fracture of a retort and receiver filled with it, it produced in myself, all the effects of a violent pneumonia, accompanied with a copious expectoration for nearly a fortnight, and the weakness induced in my lungs, did not completely terminate under a month or six weeks. The first effect of the gas, was to excite a most powerful constriction of the glottis, and, as it seemed to my feelings, of the lungs themselves, with an absolute inability to effect a full inspiration. This inability continued to augment, my pulse became weak and thread-like, the consequence of depression; and an asthmatic cough, ensued, with disposition to vomit. The symptoms were not mitigated by free exposure to a purer air; and I obtained no relief until I lost at once, nearly thirty ounces of blood. The blood was black, and approached to that state called *dissolved*, so common in malignant fevers. The pulse rose by the evacuation, and the colour of the blood became more florid whilst the last portions were flowing from my arm. A sense

(c) It is heavier than common air (taking the statement of Gay Lussac) in the proportion of 2470 to 1000; and 100 cubic inches should, therefore, weigh 75.33 grains. Sir H. Davy finds them to weigh between 76 and 77 grains, at a mean temperature and pressure.

(d) By a temperature of $+ 40^{\circ}$ Fahrenheit, it is reduced into a liquid form, and is condensed on the sides of the vessel. But if the gas be previously dried by exposure to muriate of lime, it bears a cold of 40° below 0 without condensation.*

When a receiver, filled with this gas not artificially dried, is surrounded by snow, or pounded ice, the gas forms on its inner surface a solid concretion, of a yellowish colour, resembling, in its ramifications, the ice which is deposited on the surface of windows during a frosty night. By a moderate increase of heat, such as to 50° Fahrenheit, this crust melts into a yellowish oily liquid, which, on a farther elevation of temperature, passes to the state of a gas.

(e) Oxymuratic acid gas, in its ordinary state, destroys all vegetable colours. This may be shown by passing, into the gas confined by water, a piece of paper stained with litmus, the colour of which will immediately disappear. Hence the application of this gas to the purpose of bleaching, its power of effecting which may be shown by confining, in the gas, a pattern of unbleached calico. Chlorine gas, however, which has been carefully dried by solid muriate of lime, and into which perfectly dry litmus paper is introduced, produces no change of colour in the litmus, a sufficient proof that its bleaching power depends on the presence of water.

(f) This gas is absorbed by water; slowly, if allowed to stand over it quiescent, but rapidly when agitated.

1. The best method of effecting the impregnation of water with this gas, is by means of a Woulfe's apparatus, the bottles of which should be surrounded by ice-cold water.† The quantity of the gas,

of pain and oppression continued however, during the remainder of the day and night, with restlessness and tossing, accompanied by quick and small respiration; and followed by considerable cough and copious expectoration for several days. I have no doubt the copious bleeding tended to obviate an affection of my lungs; which would probably have terminated in phthisis.

I have likewise experienced the very rapid action of this extraordinary agent, on the Schneiderian membrane, which is not less remarkable in exciting coryza, than in its action just mentioned. By incautiously drawing up into my mouth a quantity of water fully impregnated with the gas, it was diffused instantly over the fauces, and back part of the nares; and in less than one quarter of an hour, I was under the complete influence of a violent catarrh or coryza, equal to any I have ever experienced from the usual exciting causes of that complaint. It continued with unremitting violence for about two hours, and then gradually subsided; leaving a considerable sense of soreness for several hours.

I have stated the above facts with the hopes that they may render all, who experiment on this substance, cautious in their proceedings. C.

* Sir H. Davy, Phil. Trans. 1811, p. 30.

† A very simple and efficacious mode of effecting the impregnation of water with this gas, is by means of a tubulated retort, whose beak is plunged beneath a body of water in a tubulated receiver; the water passes some distance up the neck of the retort, and as the pressure of the gas evolved, increases, slowly descends into the receiver; the gas there escapes, but finds an obstacle to its pas-

which water is capable of absorbing, appears, from the concurrent testimony of Davy and Dalton, to be twice its bulk. According to the proportions stated by Berthollet, 1000 grains of water, at the temperature of 43° Fahrenheit, take up 1073 grains of the gas, and acquire the specific gravity of 1003.

2. The watery solution, if perfectly free from common muriatic acid, has not the usual taste of an acid, but an astringent one. Its purity from muriatic acid may be ascertained by a solution of nitrate of mercury, which is precipitated by the common, but not by the oxygenized acid.

3. The watery solution has the colour and peculiar smell of the gas, and has a similar property of discharging vegetable colours. Hence it may be employed in bleaching.

After having exerted this effect, it will be found changed into common muriatic acid. This is explained, on the old theory, by its giving up oxygen to the colouring matter of the cloth. But on the theory of chlorine, the oxygen is supposed to be derived from water, the hydrogen of which passes to the chlorine and composes muriatic acid.

4. When the watery solution is exposed to a temperature a little above that of freezing water, the gas, which is combined with it, separates in the form of a liquid, heavier than water.

5. The oxygenized acid is not decomposed by the temperature of boiling water; for it may be raised in distillation, and again condensed without change.

6. When this solution is exposed to the direct rays of the sun, oxygen gas is obtained, and the acid passes to the state of muriatic acid, either because, according to the old theory, its oxygen becomes gaseous by the agency of light; or because, as the new theory supposes, water is decomposed, the chlorine uniting with its hydrogen, and its oxygen being set free.

Chlorine is susceptible of combination with various other bodies, and the compounds possess, in many instances, remarkable properties.

Chlorine with Oxygen, Euchlorine.

When hyper-oxymuriate of potash (a salt which will be afterwards described) is distilled, at a gentle heat, with weak muriatic acid, and the gas is received over mercury, it is found to differ essentially from chlorine. Its colour has a dense tint of brilliant yellow green; and its smell resembles that of burnt sugar, mixed with the peculiar smell of oxymuriatic acid. Water seems to take up eight or ten times its volume, and acquires an orange tinge. It

sage into the atmosphere, by means of a tube of safety fixed in the tubulure, containing a small column of water. Should the evolution of the gas diminish, the water passes slowly up the neck of the retort, until its beak is exposed; a body of air from the receiver then rushes up, and displaces the water. The retort and receiver are to be luted together with common bees wax. I have by this contrivance impregnated alkaline solutions, and formed the oxymuriates. A plan of the apparatus is given in the 10th plate. C.

has been called by its discoverer, Sir H. Davy, *Euchloric gas*, or simply *Euchlorine*. Gay Lussac has proposed for it the name of oxide of chlorine.

Euchlorine explodes by a gentle heat, applied to the vessel which contains it, and five parts in volume become six, consisting of a mixture of oxygen and chlorine gases, in such proportions that euchlorine must be composed of two in volume of chlorine and one of oxygen, the latter being condensed into half its bulk, or by weight of

Chlorine	.	.	.	81.44	.	.	.	100.
Oxygen	.	.	.	18.56	.	.	.	22.79.
<hr/>								
100.								

These proportions indicate that euchlorine is constituted of one atom of chlorine 33.5 + one atom of oxygen 7.5, and hence its atom must weigh 41.

When detonated with twice its volume of hydrogen gas, there is an absorption of more than two thirds of the mixture, and liquid muriatic acid is formed.

Mercury has no action on euchlorine at common temperatures. Antimony and copper burn in it, if introduced previously heated. Sulphur and phosphorus decompose it; and charcoal already ignited burns in it with a dull red light. Nitrous gas condenses it with red fumes.

Euchlorine destroys vegetable colours; but it first gives the blue a tint of red.

In almost all cases of vivid combustion, there is a condensation of the bodies which unite, but in the decomposition of euchlorine by heat, we have the remarkable phenomenon of an explosion, accompanied with heat and light, and an expansion of the elements, which are separated from each other.*

Another new compound of chlorine and oxygen containing a larger proportion, than euchlorine, of the latter element, has recently been discovered by Sir H. Davy † To procure it, 50 or 60 grains of the powdered hyper-oxy-muriate of potash are to be mixed with a small quantity of sulphuric acid. When thoroughly incorporated, a solid mass will result, of a bright orange colour. This is to be introduced into a small retort of glass, which is to be exposed to the heat of water gradually warmed, but prevented from attaining the boiling point, by an admixture of spirit of wine. The gas may be received over mercury, on which it has no action at common temperatures.

It has a much more brilliant colour than euchlorine; is much more rapidly absorbed by water; and has a peculiar aromatic smell,

* Although *remarkable*, it is not singular, for the compound next mentioned, expands even more than this; and the expansion of the constituents of gun-powder, has already been adverted to. They are all, strictly, subversive of some of the fine-spun doctrines of caloric. C.

† Phil. Trans. 1815, Part II.

not mixed with any smell of chlorine. It destroys vegetable blue colours, without first reddening them. When heated to about 212° Fahrenheit, it explodes with more violence, and a greater expansion of volume, than euchlorine, producing much light. After explosion over mercury, from 2.7 to 2.9 volumes appear, for every two of gas decomposed; and, of these, two are oxygen and the rest chlorine. A little chlorine is absorbed, however, by the mercury, and it is reasonable to conclude that the deep yellow gas is, in reality, composed of two in volume of oxygen, and one of chlorine, condensed into two volumes. If this be correct, the gas will consist, by weight, of one atom of chlorine 33.5, and four atoms of oxygen 30, and its atom will weigh 63.5.

It is decomposed, at common temperatures, by no combustible body, except phosphorus, which occasions an explosion when introduced into it, and burns, in the liberated gases, with great brilliancy.

Its saturated solution in water is of a deep yellow colour. It does not taste sour, but extremely astringent and corroding; and it leaves on the tongue a disagreeable and lasting impression. We have, therefore, no compound of chlorine and oxygen, possessed of acid properties; and, till this is obtained, it is not (as Sir H. Davy observes) correct to say that chlorine is capable of being acidified by oxygen.*

Chlorine with Nitrogen.

Chlorine and nitrogen gases have no action on each other; but a compound of chlorine and nitrogen may be formed, by passing the former gas through a solution of nitrate of ammonia, or of almost any ammoniacal salt, of the temperature of 40° to 50° Fahrenheit. The gas is rapidly absorbed, and a film appears on the surface, which soon collects into yellowish drops, that sink to the bottom of the liquor.

This yellowish and oily fluid is the most powerfully detonating compound with which we are acquainted. When gently warmed, it explodes with so much violence, that it is not safe to employ a quantity larger than a grain of mustard seed. Its discoverer, M. Dulong,† was severely wounded in his first experiments on this substance; and Sir H. Davy had a serious injury done to his eyes in repeating them. It is expedient, therefore, to proceed with great caution.

When a globule of this fluid is thrown into olive oil, turpentine, or naphtha, it explodes even without heat, and so violently, as to

* I do not know whether this compound has been named by Sir H. Davy. The term given to the euchlorine of Sir H. Davy, by Gay Lussac, of oxyd of chlorine, appears to be better calculated to subserve the interest of science. And since the gas under notice is an oxyd of superior oxygenation, we should call the former protoxyd of chlorine, and the latter peroxyd of chlorine—that is, if none of still higher oxygenation is discovered C.

† See An. de Chim. vol. 85.

shatter any glass vessel. The same effect ensues, when it touches phosphorus, or phosphorized alcohol or ether; but pure alcohol seems to deprive it of its explosive property, and renders it a white oily matter.

The specific gravity of the fluid, Sir H. Davy has determined to be 1.653, water being 1. It is not congealed, by exposure to the cold produced by snow and muriate of lime.

The products of its detonation are chlorine and nitrogen gases, but it is impossible to determine the bulk of these elements which are afforded by a given weight. The best method of analyzing it, is by its action on mercury, which unites with the chlorine, and sets the nitrogen free. From various experiments of this kind, Sir H. Davy concludes that it is composed of four in volume of chlorine to one in volume of nitrogen, or of

Chlorine	91.2
Nitrogen	8.8
	<hr/>
	100.

These proportions correspond best with the opinion, that it is constituted of one atom of nitrogen to two atoms of chlorine: but the coincidence is not so exact, as in the case of some other compounds, and the analysis requires confirmation.

Chlorine with Hydrogen.

Chlorine acts upon hydrogen either silently or with detonation, accordingly as the experiment is conducted.

1. Let a phial, provided with a well-ground stopper, be completely filled with a mixture of hydrogen gas, and oxy-muriatic gas, in equal bulks. Put the stopper into its place, and keep the bottle, 24 hours, inverted with its mouth under water. On withdrawing the stopper under water, nearly the whole of the gas will have disappeared; and the remainder will be absorbed by the contact of the water.

2. Mingle, in the detonating tube, (fig. 28 or 29.) equal volumes of hydrogen gas and of oxy-muriatic gas. When an electric spark is passed through the mixture, a detonation will ensue, and nearly the whole will be absorbed. But if the gases have been carefully dried by exposure to solid muriate of lime, their volume, after firing, will not be at all condensed, and muriatic acid gas, precisely equal to their joint bulk, will be obtained. By weight, one part of hydrogen gas requires 33.5 of oxy-muriatic or chlorine gas for saturation, and 34.5 of muriatic acid gas are produced.

The result of this experiment may either be explained, by admitting the direct combination of hydrogen and chlorine to constitute muriatic acid; or by supposing that the hydrogen unites with the oxygen of the oxy-muriatic acid, and that the water, thus formed, exists as an element of muriatic acid gas. In this instance the

theory of chlorine has certainly the advantage in point of simplicity.

If the weight of the atom of chlorine be determined from its union with hydrogen, it will be expressed by 33.5; and 33.5 of chlorine will be the equivalent to 7.5 of oxygen. When oxygen is made the decimal unit, as by Dr. Wollaston, the weight of the atom of chlorine will be expressed by 44.1, or in round numbers by 44. On the supposition that the oxy-muriatic acid is a compound of muriatic acid and oxygen, it must be constituted as follows :

Oxygen	22.65	100.	29.28
Muriatic acid	77.35	341.5	100.
	<hr/>	<hr/>	<hr/>
	100.	441.5	129.28

This would indicate the weight of the atom of muriatic acid to be nearly 26; and adding an atom of oxygen, the compound atom of oxy-muriatic acid would still weigh 33.5.

A remarkable fact, respecting the mutual action of oxy-muriatic acid and hydrogen gases, was discovered by Gay Lussac, and, without any knowledge of his experiments, by Mr. Dalton. A mixture of the two gases, in equal volumes, is slowly absorbed under ordinary circumstances; but if the direct rays of the sun happen to fall on the mixture, the two gases diminish with considerable rapidity; and, if the quantity be large, they even explode. This is a striking instance of the agency of light in promoting chemical combination. Blue light is more effective in producing the combination than red, but neither occasions the rapid combustion, which is excited by the direct rays of the sun.*

Chlorine with the Metals of the Alkalis and Earths, and with the Oxides of those Metals.

When potassium is heated in chlorine gas, it burns much more vividly than in oxygen; each grain absorbs 1.1 cubic inch of the gas, and a neutral compound is formed, precisely resembling that which results from heating potassium in muriatic acid gas. Sodium burns in chlorine with similar appearances, and condenses twice as much of the gas, as is absorbed by an equal weight of potassium.

When potassium or sodium, which have been made to absorb oxygen, are heated in chlorine gas, the latter disappears, and oxygen gas, precisely equivalent to what had been condensed, is liberated. Oxygen is expelled, also, by chlorine, from barytes, strontites, and lime, in the proportion of one measure for every two measures of chlorine that are condensed.

As the oxygen is always evolved in its original quantity, though the quantity of chlorine absorbed is variable, Sir H. Davy consi-

* Seebeck, 34 Nicholson's Journal, p. 220.

ders this as proving that the oxygen does not proceed from the chlorine, but from the oxide; and that chlorine is a simple body, which attracts the metals in question more strongly than oxygen attracts them.

Ammonia is decomposed by chlorine, sometimes with detonation. If both gases are dry, no water is produced, which Sir H. Davy observes should happen, if chlorine contained oxygen; but the products are muriatic acid, (from the union of the chlorine and hydrogen,) and nitrogen gas.* The muriatic acid, with the undecomposed alkali, forms muriate of ammonia.

Chlorine with Charcoal, Carbonic Oxide, and Carburetted Hydrogen.

When the charcoal of beech wood, finely powdered and perfectly dry, is poured into chlorine gas in its ordinary state, an inflammation ensues. But charcoal, intensely ignited by Voltaic electricity, in dry chlorine gas, effects no change, nor is any carbonic acid produced.†

Perfectly dry chlorine and carburetted hydrogen gases, in the experiments of Dr. John Davy, detonated without producing carbonic acid. Muriatic acid gas was obtained, and the charcoal was precipitated. But when the gases are fired over water, carbonic acid is obtained, the oxygen for which is furnished by the water. Mixtures of three or four parts of chlorine and one part of carburetted hydrogen over water, when exposed to the light of the sun, explode, and carbonic acid is generated; or, if the quantities are small, and indirect light only is admitted, the action of the gases goes on slowly, with similar results.

A mixture of equal volumes of chlorine and carbonic oxide gases, both dried by fused muriate of lime, and exposed, about a quarter of an hour, to bright sunshine, affords a peculiar compound, called by its discoverer, Dr. John Davy,‡ *Phosgene Gas*.§ The colour of the chlorine is destroyed by this combination, and the constituent gases are condensed into half their bulk. Hence it appears to be one of the heaviest gases known, 100 cubic inches being estimated to weigh 105.97 grains.

Phosgene gas has an intolerably pungent odour, and reddens litmus. Water changes it into muriatic and carbonic acid gases. The metals decompose it, and unite with the chlorine, a volume of carbonic oxide being liberated, equal to the bulk of the original gas. It condenses four times its volume of ammoniacal gas, and the product is a white neutral salt, from which the stronger acids

* Phil. Trans. 1814, p. 70.

† This incapability of being decomposed by charcoal, is perhaps the strongest evidence of the simple nature of chlorine. But how do we account for the ignition of charcoal, where no oxygen gas is present, to give off its presumed attendants, caloric and light? C.

‡ Phil. Trans. 1812.

§ This is the gas which Thenard called carbo-muriatic acid gas. It is a very long name, but is certainly infinitely better than the above uncouth and unscientific term. C.

disengage muriatic and carbonic acids; but acetic acid dissolves it without effervescence.

Chlorine with Sulphur and its Compounds.

Sulphur, when heated in contact with chlorine gas, absorbs it, and forms a singular compound first described by Dr. Thomson.* Ten grains absorb nearly 30 cubic inches of gas, which is nearly in the proportion of 15 (the weight of an atom of sulphur to 33.5, the weight of an atom of chlorine.) It appears, indeed, to be a true oxymuriate of sulphur.

This fluid is volatile below 200° Fahrenheit. Its colour is red by reflected light, but yellowish green by transmitted light. It emits fumes, which are peculiarly acrid, and which excite a copious flow of tears. Its specific gravity is 1.6. It decomposes water, the hydrogen of which forms, with the chlorine, muriatic acid; while the sulphur, with the oxygen of the water, composes sulphuric acid. Before dilution, however, it is not acid, and does not redden dry litmus paper.

Dry chlorine gas has no action on dry sulphurous acid gas; but if water be present, muriatic and sulphuric acids result from their mixture.

When chlorine gas is mixed with sulphuretted hydrogen gas, the phenomena vary with the proportions. When equal bulks are used, there is scarcely any condensation, and the residue contains $\frac{12}{20}$ ths of its bulk of muriatic acid gas. In this case, the sulphur is precipitated. But if enough of chlorine be used, besides the same product of muriatic acid, the sulphur is changed into oxymuriate of sulphur.

Chlorine and nitrous gases, separately dried by solid muriate of lime, do not combine on admixture; but when moisture is present, the chlorine decomposes water, forming muriatic acid with its hydrogen, while its oxygen condenses the nitrous gas.

The compound of chlorine and phosphorus will be described in speaking of the latter substance.

Chlorine with the Metals.

Almost every metal, in a state of minute division, takes fire spontaneously, and burns in this gas. The very malleable metals, such as gold, silver, &c. which can be reduced to extremely thin leaves, are best applied to the gas in this state. Others, as iron, zinc, copper, &c. must be introduced in the state of fine filings. The most readily oxydized metals burn with the greatest brilliancy. The best proportion is about 40 grains of each metal to 40 cubic inches of gas: and, into the bottom of the receiver a little sand may be poured, to prevent it from being broken.

Metallic antimony burns with a very brilliant white flame, and throws out sparks. Arsenic exhibits a fine green or blue flame, attended with sparks, and a dense white smoke; bismuth, a bluish flame; nickel, a yellowish white one; cobalt, a bluish white;

* Nicholson's Journal, 8vo. vol. vi.

zinc, a white flame and sparks; tin, a bluish white light; lead, a clear white flame; copper, a red and slowly spreading light; and iron, a bright red light. In all these experiments, the temperature of the gas should not fall short of 70° .

When chlorine is made to act on any metallic oxide, those of iron and arsenic excepted, the whole of the oxygen is expelled from the oxide, and the chlorine combines with the metal only. The description of these compounds, which have been ably investigated by Dr. J. Davy, will form a part of the history of the individual metals.

Nomenclature of the Compounds of Muriatic and Oxymuriatic Acids.

The combinations of muriatic acid continue to be termed *Muriates* in the modified nomenclature, proposed by Sir H. Davy. Thus muriate of magnesia, of alumine, and of ammonia, are correct expressions. But all compounds of chlorine with combustible bases, he proposes to designate by annexing the termination *ane* to the Latin name of the basis. The compound of chlorine and sulphur, he calls, for example, *sulphurane*; that of silver (*argentum*) and chlorine *argentane*; and so of the rest. Common salt, on the same principle, would be termed *sodane*. When these compounds are capable of uniting with an additional proportion of chlorine, he expresses that which has two proportions by the termination *ana* or *anea*. Thus copper (*cuprum*) with one proportion of chlorine is *cuprane*, and with two *cupraneana*.

It would have been more agreeable, however, to analogy with the combinations of oxygen, if the compounds of chlorine had received the name of *chloride*,* a termination conformable to that of *oxide*. In that case, the different compounds of chlorine with one base, might have been designated in the way proposed by Dr. Thomson for the oxides, the first being called *proto-chloride*, the second *deuto-chloride*, and so of the rest.

According to the views of Sir H. Davy and Gay Lussac, all the bodies described in the next section, excepting the muriates of ammonia, magnesia, and alumine, are to be considered strictly as *oxymuriates*, or compounds of chlorine with metallic bases. Common salt, for example, they conceive to be a compound, not of muriatic acid and soda, but of chlorine and sodium, at least in its dry state. Until these views, however, are more firmly established, I have deemed it unnecessary to separate bodies, so naturally allied by similarity of properties; and I shall continue, therefore, to class, with the muriates, some compounds, which, in the farther progress of science, will probably be removed to a different genus of salts.†

* I believe the French have adopted the use of this term. C.

† Strong as the proofs appear, in favor of the simple nature of chlorine, and of the prevailing opinions of the compounds, &c. of that substance, Dr. Murray continues warmly to oppose them; and with arguments equally powerful. C.

SECTION III.

*Muriates.*ART. 1.—*Muriate of Potash.*

MURIATE of potash may be obtained by saturating muriatic acid with carbonate of potash, and evaporating the solution till the salt crystallizes. These crystals have a cubical shape, and a bitter disagreeable taste; they dissolve in three times their weight of water at 60°, and in a rather less proportion of boiling water. They undergo little change when exposed to the air; they decrepitate when thrown on the fire, but abandon no part of their acid at a red heat.

Muriate of potash consists, in 100 grains,

		Acid.	Base.
According to Berthollet	. . of . .	33.34	66.66
————— Berzelius	. . — . .	35.81	64.19
————— Dr. Wollaston	. — . .	36.57	63.43

Berzelius, by decomposing 100 grains of the fused salt with solution of nitrate of silver, obtained 191.5 of luna cornea. According to Sir H. Davy, this salt is composed of 75 parts of potassium united with 67 chlorine, or 100 grains consist of

Potassium	. . . . .	52.8
Chlorine	. . . . .	47.2
		—————
		100.

These proportions are almost the same as those stated by Gay Lussac, viz. 100 chlorine + 111.31 potassium, all confirming that this salt is composed of an atom of each of its ingredients.

ART. 2.—*Muriate of Soda.*

Muriate of soda is that well known substance, common salt, which is become a necessary ingredient in the food of man, and is of essential utility in several of the arts.

I. Its composition may be proved, by the direct union of soda with muriatic acid.

But for purposes of experiment, the common salt may be employed, which is to be found in the shops. This may be purified, by adding to a solution of it in water a solution of carbonate of soda, as long as any milkiness ensues; filtering the solution, and evaporating it till it crystallizes.

II. Its qualities are as follow :

1. It crystallizes in regular cubes, which, when the salt is pure, are but little changed by exposure to the air. The common salt of the shops, however, acquires an increase of weight, in conse-

quence of the absorption of moisture. The various forms under which it appears, of stoved salt, fishery salt, bay salt, &c. arise rather from modifications in the size and compactness of the grain, than from any essential difference of chemical composition.

2. It requires, for solution, twice and a half its weight of water, at 60° of Fahrenheit, and hot water takes up very little more. Hence its solution crystallizes, not like that of nitre, by cooling, but by evaporation.

3. When heated gradually it fuses, and forms, when cold, a solid compact mass.

4. If suddenly heated, as by throwing it on red-hot coals, it decrepitates. It does not, however, after being dried at the temperature of boiling water, lose by ignition more than two or three parts of water *per cent.* and essentially it contains no water.

5. It is not decomposed when ignited in contact with inflammable substances, except with potassium, which sets at liberty half its weight of sodium.

6. When mixed with powdered charcoal or sulphur, and fused in a crucible, it does not undergo any decomposition or essential change.

7. It is decomposed by the carbonate of potash, the alkali of which combines with the muriatic acid of the salt, and the carbonic acid is transferred to the soda. Hence we obtain muriate of potash and carbonate of soda. A process for effecting this decomposition, on a large scale, is described by Westrumb, in *Crell's Journal*, English translation, ii. 127.

8. It is decomposed by the sulphuric acid in the mode already described. Nitric acid also separates the muriatic acid.

9. Muriate of soda is composed, in 100 grains,

		Acid.	Base.
According to Darcet . . . of . . .		49.27	50.73
———— Berard . . . — . . .		43.	57.
———— Dr. Marcet . . . — . . .		46.	54.
———— Berzelius . . . — . . .		46.55	53.44

From 100 grains of transparent rock salt, dissolved in water, and precipitated by nitrate of silver, I obtained 242 of luna cornea; Dr. Marcet, from 100 grains of pure artificial muriate of soda, fused before solution, obtained 241.6; Berzelius, 244.6; and Rose, 243.4. Now 100 grains of luna cornea may be stated, in round numbers, to denote 19 grains of real muriatic acid, so that it is easy, from this datum, to calculate the composition of common salt, or of any muriatic salt, which has been decomposed by nitrate of silver.

On the atomic system of Mr. Dalton, it should consist of an atom of muriatic acid combined with an atom of soda. But according to Sir H. Davy's view it is constituted of an atom of sodium, weighing twenty-two, with an atom of chlorine weighing 33.5, or of

Sodium . . .	40.5 . . .	100 . . .	68
Chlorine . . .	59.5 . . .	147 . . .	100
	100.	247	168

Dr. Wollaston assumes its constitution to be either 39.64 sodium + 60.36 chlorine; or, on the old theory of muriatic acid, he admits its composition as stated by Berzelius.

ART. 3.—*Muriate of Ammonia.*

1. If equal measures of ammoniacal gas and muriatic acid gas be mixed together, over mercury, they are immediately and totally condensed, a white cloud is formed, and a solid substance is deposited on the sides of the vessel.* This is the muriate of ammonia. For experimental purposes it may be procured in the shops, under the name of sal-ammoniac.

Berzelius, from 100 grains, precipitated by nitrate of silver, obtained 267.87 of luna cornea. Hence he calculates its composition, independently of water, to be

Acid . . .	60.8	. . .	100.
Ammonia . .	39.2	. . .	64.48
	<hr/>		
	100.		

But in its ordinary state the salt contains water, for when distilled with lime, the earth gains a greater increase of weight than the muriatic acid only could furnish. The proportions are, according to Berzelius,

Acid . . .	49.55
Base . . .	31.95
Water . . .	18.50
	<hr/>
	100.

This is one of the few salts, which, consistently with Sir H. Davy's views, can properly be considered as a true muriate. Its atomic constitution Mr. Dalton believes to be one atom of acid and two atoms of ammonia.

Muriate of ammonia exhibits the following properties :

(a) It is volatilized, without being liquefied or decomposed, and hence may be sublimed.

(b) It is readily soluble in water, three parts and a half of which, at 60° take up one of the salt. During its solution much caloric is absorbed. In boiling water, it is still more soluble; and the solution, on cooling, shoots into regular crystals.†

(c) It slightly attracts moisture from the air.

* In this case the caloric evolved by two gases becoming solid, is so trifling, that I think we must hesitate to admit the different states of cohesion of bodies, to depend solely on its presence. C.

† As muriat of ammonia is very soluble, but is pulverized with extreme difficulty, we can readily procure it in a sufficiently fine state for experimental pursuits, by solution and crystallization—drying the crystals thus formed. C.

(d) On the addition of a solution of pure potash, or pure soda, the alkali is disengaged, as is evinced by the pungent smell that arises on the mixture of these two bodies, though perfectly inodorous when separate.

(e) Though generally considered as a neutral salt, yet, if placed on litmus paper and moistened, Berzelius observes, that the paper is reddened after some moments, as it would be by an acid.

(f) It is decomposed by barytes, strontites, lime, and magnesia.

Process for obtaining Solution of Ammonia in water.

The following process is given by Mr. R. Phillips, as preferable to that of the London Pharmacopoeia.*

On 9 oz. of well burnt lime, pour half a pint of water, and when it has remained in a well closed vessel for nearly an hour, add 12 ounces of muriate of ammonia, and about $3\frac{1}{2}$ pints of boiling water. When the mixture has cooled, filter the solution; and, having put it into a retort, distil off 20 fluid ounces. The solution will have the specific gravity 0.954, which is quite as strong as it can be conveniently kept. If the solution be required to be more strongly impregnated, this will be best effected, by passing ammoniacal gas through it, from a mixture of equal parts of powdered lime and muriate of ammonia, by means of an apparatus similar to that described for the preparation of muriatic acid.

When a mixture of one part of powdered muriate of ammonia with from one to two of powdered carbonate of lime, (chalk,) both perfectly free from moisture, is distilled together in a retort, a solid white substance condenses on the inner surface of the receiver. This is the sub-carbonate of ammonia; and the process now described is that by which, with the substitution of proper subliming vessels, the sub-carbonate of ammonia is prepared for sale. This operation furnishes an example of double affinity. The carbonic acid, being transferred from the lime to the ammonia, forms sub-carbonate of ammonia; and the muriatic acid, passing to the lime, composes muriate of lime.

ART. 4.—*Muriate of Barytes.*

Muriate of barytes may be formed by heating pure barytes in chlorine gas, each measure of which disengages half a measure of oxygen gas from that earth. Or when barytes is heated in muriatic acid gas, the gas disappears, and the salt, which is produced, becomes red hot. But for purposes of experiment, muriate of barytes is best prepared, by dissolving either the artificial or native carbonate in muriatic acid much diluted; or, if neither of these can be had, the sulphuret.† The iron and lead, which are occasionally

* Remarks on the London Pharm. p. 34.

† The decomposition of sulphat of barytes by muriat of lime has already been mentioned as recommended by Thenard. C.

present in the carbonate, and are dissolved, along with the barytes, may be separated by the addition of a small quantity of liquid ammonia, or by boiling and stirring the solution in contact with a little lime; or, which is still better, by solution of barytes in water. When filtered and evaporated, the solution yields regular crystals, which have most commonly the shape of tables, bevelled at the edges, or of eight-sided pyramids, applied base to base. They dissolve in five parts of water, at 60° , or in a still smaller quantity of boiling water; and also in alcohol. They are not altered by exposure to the atmosphere; nor are they decomposed, except partially, by a high temperature. The sulphuric acid separates the muriatic; and the salt is also decomposed by alkaline carbonates and sulphates.

Fifty grains of ignited muriate of barytes give 68 of luna cornea. It is composed,

	Acid.	Base.
According to Mr. Aikin, of	26.86 . . .	73.14
———— Berzelius	26.23 . . .	73.77

And the crystallized salt consists,

	Acid.	Base.	Water.
According to Mr. Aikin, of	22.93 . . .	62.47 . . .	14.6
———— Berzelius	23.35 . . .	61.85 . . .	14.80

Its atomic constitution, according to Mr. Dalton, is 1 atom of acid and 1 atom of base; and the crystals consist of 1 atom of dry salt and 2 atoms of water. Sir H. Davy considers it as a compound of 1 atom of barium weighing 65, and 1 atom of chlorine 33.5. Hence 100 parts should consist of

Chlorine	34.
Barium	66.
	————
	100.

ART. 5.—*Muriate of Strontites*

May be obtained by following the same process as that employed in preparing the barytic salt. The solution affords long slender hexagonal prisms, which are soluble in two parts of water, at 60° ; and to almost any amount in boiling water. In a very moist atmosphere they deliquiate. They dissolve in alcohol, and give a blood-red colour to its flame.

Fifty grains of dry muriate of strontites give 85 of luna cornea, and hence the salt must consist of 67.5 base and 32.5 acid. This agrees very nearly with Kirwan's determination, but differs somewhat from Vauquelin's, viz. 61 base and 39 acid. According to Sir H. Davy's view, it is constituted of 29 parts strontium and 21 chlorine, or of

Strontium	58.
Chlorine	42.

Its atomic constitution, agreeably to this view, is one atom of metal weighing 45, and one atom of chlorine weighing 33.5. On the old theory, it should consist of one atom of strontites, and one atom of muriatic acid.

ART. 6.—*Muriate of Lime.*

This salt may be prepared by dissolving carbonate of lime in muriatic acid, or by washing off the soluble part of the mass, which remains after the distillation of the solution of pure ammonia from muriate of ammonia and lime. One hundred grains of carbonate give, according to Berzelius, 109.6 of fused muriate of lime.

The solution crystallizes in six-sided striated prisms, terminated by very sharp pyramids. If it be evaporated to the consistence of a syrup, and exposed to a temperature of 32°, it forms a compact mass, composed of bundles of needle-shaped crystals, crossing each other confusedly. The dry salt retains its acid at the temperature of ignition.

The crystals dissolve in half their weight of cold water, and to an unlimited extent in boiling water, being, in fact, soluble in their water of crystallization.—They deliquesce rapidly in the air, and enter into fusion when heated.* After being melted by a strong heat, the fused mass still contains water; for by ignition with iron filings, it yields much hydrogen gas. On the new theory of chlorine, however, this gas may proceed from the decomposition of muriatic acid. If fused in a crucible, and treated in the same manner as the nitrate of lime, the crystals yield a solar phosphorus, called, from its discoverer, *Homborg's phosphorus*. When mingled with snow, they produce intense cold, as has already been described.

Dry muriate of lime may be inferred, from an experiment of Dr. Marcet, to consist of

Muriatic acid	49.	. . . . .	100
Lime	51.	. . . . .	104
		<hr/>	
		100.	

One hundred grains of fused muriate of lime give, according to Davy, 250 grains of luna cornea; according to Berzelius 287.5. From experiments on its synthesis, Berzelius states its composition to be

* Several years ago, I obtained some very beautiful crystals of muriat of lime, in perfect cubes. For reasons not necessary to mention here, I put them into a vial of spirit of turpentine, which preserved them very effectually for a great length of time. Even yet, some portion of them remains. Their destruction appears to be owing to their dissolving in their water of crystallization during the heats of summer. Some crystals, such as those of nitrat of mercury, are speedily decomposed in turpentine, and the metal, partly revived, together with the water of crystallization, is found at the bottom. C.

Acid . . .	48.54
Lime . . .	51.46
<hr/>	
	100.

and that of the crystallized salt

Acid . . .	24.69
Lime . . .	25.71
Water . . .	49.60
<hr/>	
	100.

But, according to the theory of Sir H. Davy, the salt after being ignited consists of thirty-one chlorine and nineteen calcium, or of

Chlorine . . .	62.
Calcium . . .	38.
<hr/>	
	100.

ART. 7.—*Muriate of Magnesia.*

This is also a deliquescent and difficultly crystallized salt. It has an intensely bitter taste; is soluble in its own weight of water, or in five parts of alcohol. Unlike the preceding muriates, it is decomposed, but not entirely, by ignition.

According to Mr. Dalton, muriate of magnesia is constituted of 56.4 acid + 43.6 base. The compound of chlorine and magnesium, though supposed by Sir H. Davy to exist, has not yet been examined in a separate state. When heated, the combination, he remarks, is destroyed; the chlorine decomposes water, and escapes in the state of muriatic acid, and the oxygen of the water forms magnesia with the metal.

The muriates of magnesia and lime are generally contained in muriate of soda, and impart to that salt much of its deliquescent property. They impair, too, its power of preserving food. They are also ingredients of sea-water.

ART. 8.—*Muriate of Alumine*

May be formed by dissolving fresh precipitated alumine in muriatic acid; but the acid is always in excess. It is scarcely possible to obtain this salt in crystals; for, by evaporation, it assumes the state of a thick jelly. It is extremely soluble in water, and deliquescent when dry. In a high temperature it abandons its acid entirely. No compound (Sir H. Davy observes) exists, that can be considered as a compound of alumine and chlorine.

ART. 9.—*Muriate of Glucine.*

This salt is little known. Like all the salts of glucine it has a sweet taste, and crystallizes more readily than the nitrate.

ART. 10.—*Muriate of Zircon.*

Fresh precipitated zircon is readily dissolved by muriatic acid. The compound is colourless; has an astringent taste; and furnishes, by evaporation, small needle-shaped crystals, which lose their transparency in the air. It is very soluble in water and in alcohol. It is decomposed by heat, and by the saliva of the mouth. The gallic acid, poured into the solution, precipitates, if it be free from iron, a white powder. Carbonate of ammonia gives a precipitate, which is re-dissolved by an excess of the carbonate.

ART. 11.—*Muriate of Yttria.*

This compound has a striking resemblance to nitrate of yttria. Like that salt it dries with difficulty, and attracts moisture from the air. It does not crystallize, when evaporated, but forms a jelly.

SECTION IV.*Hyper-oxymuriates.*ART. 1.—*Hyper oxymuriate of Potash.*

THE properties of this salt were discovered by Berthollet. It may be formed by passing oxymuriatic acid gas, as it proceeds from the mixture of muriate of soda, sulphuric acid, and manganese (see Section II, Process 2) through a solution of caustic potash. This may be done by means of Woulfe's apparatus, using only one three-necked bottle in addition to the balloon. The tube which is immersed in the alkaline solution, should be at least half an inch in diameter, to prevent its being choked up by any crystals that may form. The solution, when saturated with the gas, may be gently evaporated, and the first products only of crystals are to be reserved for use; for the subsequent products consist of common muriate of potash only.*

The chemical changes that occur in the production of hyper-oxymuriate of potash may be explained either on the old or the new theory. Let us suppose the oxymuriatic acid, when first presented to the alkaline solution, to be divided into two portions; one of these gives up its excess of oxygen to the other half, and returns to the state of common muriatic acid, which, combining with the alkali, forms muriate of potash. The other portion, therefore, is oxygenized acid, *plus* a certain quantity of oxygen; and this, uniting with another portion of alkali, forms a salt, which Mr. Chenevix has termed hyper-oxymuriate. Strictly speaking, therefore, sim-

* As this is a troublesome process, it might be well to ascertain whether the apparatus I have before adverted to, might not be so modified, as to adapt it for the procuring of this salt on the large scale. C.

ple oxygenized muriates do not exist; for, in all this class of salts, the acid contains 65 per cent. of oxygen; whereas the oxygenized acid must contain, if any oxygen be present in it, only 22.65 per cent.

It would be equally consistent with the theory of chlorine, either to suppose that the oxymuriatic acid decomposes the water of the alkaline solution, forming, with its hydrogen, common muriatic acid, while another portion of chlorine unites with the oxygen thus set at liberty; or that the change consists in the decomposition of potash, the oxygen of part of which is transferred to another portion of alkali, while the oxymuriatic acid is partly expended in decomposing water and forming muriate of potash, and partly in composing a triple compound of chlorine, oxygen, and per-oxide of potassium. In this view, hyper-oxymuriate is constituted of 1 atom of potassium weighing 40.5, 1 atom of oxymuriatic acid = 33.5, and 6 atoms of oxygen = 45; or 100 parts consist of

Chlorine . . .	28.
Potassium . . .	34.
Oxygen . . .	38.
	<hr/>
	100.

On the theory of Mr. Dalton, one atom of oxymuriatic acid weighing 29, deprives five surrounding atoms of their oxygen, and constitutes one atom of hyper-oxymuriatic acid = 64, which unites with an atom of potash = 42. These numbers are not very remote from those deducible from Mr. Chenevix's analysis, according to whom this salt is composed of

Hyper-oxymuriatic acid .	58.3
Potash	39.2
Water	2.5
	<hr/>
	100.

The water, however, is in too small proportion to be considered as more than an accidental ingredient.

The hyper-oxymuriate of potash has the following qualities:

(a) It has the form of shining hexahedral laminæ, or rhomboidal plates.

(b) One part of the salt requires 17 of cold water for solution, but five parts of hot water take up two of the salt.

(c) It is not decomposed by exposure to the direct rays of the sun, either in a crystallized or dissolved state.

(d) When the hyper-oxy-muriate is submitted to distillation in a coated glass retort, it first fuses, and, on a farther increase of temperature, yields oxygen gas of great purity. A hundred grains of the salt afford 75 cubic inches of gas, (= about $25\frac{1}{2}$ grains,) containing not more than 3 per cent. of nitrogen gas. Berzelius, from the same quantity, obtained a much larger product of gas,

viz. 38.6 grains = 111 or 112 cubic inches.* And Gay Lussac found that 100 grains give 38.88 grains of oxygen, and 61.12 of muriate of potash, containing, he supposes, 28.93 chlorine and 32.19 potassium.

(e) The hyper-oxy-muriate of potash has no power of discharging vegetable colours; but the addition of a little of the sulphuric acid, by setting the oxygenized acid at liberty, develops this property.

(f) The salt is decomposed by the stronger acids, as the sulphuric and nitric acids. This will be proved by dropping a few grains of the salt into a little concentrated sulphuric acid. A strong smell will arise, and, if the quantities be sufficiently large, an explosion will ensue. The experiment should, therefore, be attempted with great caution. When this mixture is made at the bottom of a deep vessel, the vessel is filled with oxy-muriatic gas, which inflames sulphuric ether, alcohol, or oil of turpentine, when poured into it; and also camphor, resin, tallow, elastic gum, &c. (Davy.)

Muriatic acid, as has already been stated, disengages the oxygenized acid, and the addition of a few grains of the salt to an ounce measure of the acid, imparts to it the property of discharging vegetable colours.

(g) This salt exerts powerful effects on inflammable bodies.

1. Rub two grains into powder in a mortar, and add one grain of sulphur. Mix them very accurately, by gentle triture, and then, having collected the mixture to one part of the mortar, press the pestle down upon it suddenly and forcibly. A loud detonation will ensue. Or, if the mixed ingredients be wrapped in some strong paper, and then struck with a hammer, a still louder report will be produced.

2. Mix five grains of the salt with half the quantity of powdered charcoal in a similar manner. On triturating the mixture strongly, it will inflame, especially with the addition of a grain or two of sulphur, but not with much noise.

3. Mix a small quantity of sugar with half its weight of the salt, and on the mixture pour a little strong sulphuric acid.† A sudden and vehement inflammation will be produced.‡ This experiment, as well as the following, requires caution.

4. To one grain of the powdered salt, in a mortar, add about half a grain of phosphorus. The phosphorus will detonate, on the gentlest triture, with a very loud report. The hand should be co-

* 80 Ann de Chim. 28.

† A mixture of this kind is the basis of the matches, now generally used for the purpose of procuring instantaneous light. The bottle, into which they are dipped, contains concentrated sulphuric acid, which is prevented from escaping by a quantity of the fibres of amianthus. (*)

(*) I have already mentioned the facility of obtaining patents in this country. A person here, undertook to take out (or so gave it to be understood) a patent for the formation of these match lights! C.

‡ This experiment succeeds very well, if gum be employed in the place of sugar. C.

vered with a glove in making this experiment, and care should be taken that the phosphorus, in an inflamed state, does not fly into the eyes.—Phosphorus may also be inflamed under the surface of water by means of this salt. Put into a wine glass, one part of phosphorus with two of the salt; fill it nearly with water, and pour in, by means of a glass tube, reaching to the bottom, three or four parts of sulphuric acid. The phosphorus takes fire, and burns vividly under the water. This experiment requires caution, lest the inflamed phosphorus should be thrown into the eyes. (Davy.) Oil may also be thus inflamed on the surface of water, the experiment being made with the omission of the phosphorus, and the substitution of a little olive or linseed oil.

5. Hyper-oxy-muriate of potash may be substituted for nitre in the preparation of gunpowder, but the mixture of the ingredients requires extreme circumspection. It may be proper also to state, that this salt should not be kept mixed with sulphur in considerable quantity, such mixtures having been known to detonate spontaneously.

ART. 2.—*Hyper-oxy-Muriate of Soda.*

This salt may be obtained, by following the process already described, with the substitution of pure soda for potash. It is exceedingly difficult, however, to obtain it pure; because it nearly agrees, in solubility, with the common muriate of soda. It is soluble in three parts of cold water, and in rather less of hot, and is slightly deliquescent. It is soluble also in alcohol; but so also, according to Mr. Chenevix, is the common muriate. It crystallizes in cubes, or in rhomboids approaching the cube in form. In the mouth it produces a sensation of cold, and a taste scarcely to be discriminated from that of muriate of soda. In other properties it agrees with the similar salt with base of potash.

ART. 3.—*Hyper-oxy-Muriate of Ammonia.*

This salt cannot be procured by the direct union of the oxygenized acid with pure ammonia, because these two bodies mutually decompose each other; as will appear from the following experiments.

1. Fill a pint receiver with the oxygenized acid; and pour into it half a drachm of the strongest solution of ammonia that can be procured. A detonation will presently ensue.

2. Fill a four-ounce bottle with the oxygenized acid, and invert it in a cup containing four ounce-measures of the solution of pure ammonia. Presently the liquor will be absorbed, and a detonation will ensue, which will throw down the bottle, unless firmly held by the hand. In the bottle there remains a portion of nitrogen gas.

ART. 4.—*Remaining Hyper-oxy-Muriates.*

To effect the combination of barytes and strontites with the hyper-oxygenized acid, those bases must be dissolved in hot water, which must be kept hot while the current of gas is transmitted through the solution. Lime may also be combined with the oxygenized acid, either by passing the gas into a vessel containing lime, suspended in water by mechanical agitation, or by exposing dry hydrate of lime to streams of the gas, as it arises from the materials, described in the 2d section of this chapter.

This compound derives importance from its application to the art of bleaching; for it possesses, when perfectly saturated, bleaching properties; and in this state produces whiteness in the unbleached part of goods, without destroying any delicate colours which they may contain. The salt, with base of lime, is extremely deliquescent; liquefies at a low heat, and is soluble in alcohol. It produces much cold by solution, and a sharp taste in the mouth. Its composition and properties have been investigated by Mr. Dalton, in two memoirs published in the 1st and 2d volumes of Dr. Thomson's annals. He finds that the dry salt is a compound of two atoms of lime, one of acid, and six of water. By solution one half of the lime is deposited, and a compound of one atom of lime and one of acid is dissolved by the water. The dry salt is much impaired by being long kept. It contains per cent.

Oxy-muriatic acid	. . .	23.2
Lime	. . . . .	38.4
Water	. . . . .	38.4
		<hr/>
		100.

For an account of the remaining salts formed with this acid, Mr. Chenevix's paper may be consulted.

SECTION V.

Nitro-Muriatic Acid.

THIS acid is a compound of the nitric and muriatic acids, and may be formed most commodiously by mixing two parts of nitric acid with one of muriatic. Though the acids employed are both perfectly pale, yet the mixture becomes of a deep red colour, a brisk effervescence takes place, and pungent vapours of oxy-muriatic acid are evolved.

The nitro-muriatic acid does not form, with alkaline, or other bases, a distinct genus of salts, entitled to the name of nitro-muriates; for, when combined with an alkali, or an earth, the solution yields, on evaporation, a mixture of a muriate and a nitrate; and

metallic bodies dissolved in it yield muriates only. In the latter case, the nitric acid is decomposed, oxydizes the metal, and renders it soluble in muriatic acid. The most remarkable property of nitro-muriatic acid (that of dissolving gold) will be described in the chapter on that metal.

SECTION VI.

Murio-Sulphuric Acid.

MURIATIC acid gas is absorbed in considerable quantity by sulphuric acid. The compound has a brown colour, and when exposed to the air emits copious white fumes. It has no particular uses.

By the action of a mixture of fuming muriatic acid on sulphuret of carbon, Berzelius obtained a solid white crystalline body, resembling camphor, and possessing some remarkable properties. Its analysis afforded

Muriatic acid	48.74
Sulphurous acid	29.63
Carbonic acid (and loss) .	21.63
	<hr/>
	100.

It appears, therefore, to consist of two atoms of muriatic acid, one of sulphurous acid, and one of carbonic.

CHAPTER XV.

PHOSPHORUS,—PHOSPHORIC ACID,—PHOSPHOROUS ACID,—PHOSPHATES.

SECTION I.

Phosphorus.

I. PHOSPHORUS is an inflammable substance, and is known by the following external characters.

(a) It has generally a flesh-red colour, but, when carefully purified, may be obtained free from colour, and perfectly transparent. Its specific gravity is 1.77.

(b) It is so soft that it readily yields to the knife.

(c) It melts at about 90° Fahrenheit, and boils at 550° . When melted, it must be covered with water, in order to prevent it from inflaming.

(d) In the atmosphere it emits a white smoke, and peculiar smell; and a faint and beautiful light arises from it; but these appearances do not take place in air artificially dried.

II. Phosphorus is inflamed by the application of a very gentle heat. According to Dr. Higgins, a temperature of 60° is sufficient to set it on fire, when perfectly dry. It burns when heated to about 148° , with a very brilliant light, a white smoke, and a suffocating smell.

1. It may be set on fire by friction. Rub a very small bit between two pieces of brown paper; the phosphorus will inflame, and will set the paper on fire also.

2. In oxygen gas it burns with a very beautiful light; and also in nitrous oxide, and chlorine gases.

III. Phosphorus is volatile at 550° . Hence it may be raised by distillation; but, to prevent its taking fire on the application of heat, the retort should previously be filled with azotic or hydrogen gas, and the mouth of the retort be immersed in water.

To accomplish this, the quantity of phosphorus, which it is intended to rectify, should first be put into the retort, with a sufficient portion of water to cover it. The water must then be made hot enough to melt the phosphorus, which, on cooling, forms a compact mass, of the shape of the bottom of the retort. When cold, fill the retort, and its neck also, with water, and invert it in water. Displace the water by hydrogen gas, forced from a bladder through a bent pipe; keep the finger on the open end of the retort neck; place it in a sand bath; and immerse the mouth of it in water. Then apply heat very cautiously. A bladder should also be provided, furnished with a stop-cock and brass-pipe, and filled with hydrogen gas. During the distillation, the gas, in the retort, is absorbed, and it is necessary to add more from the bladder, otherwise the water will rush into the retort, and occasion an explosion.* By distillation, in this mode, phosphorus is rendered much purer. In the neck of the retort a substance is condensed of a beautiful red or carmine colour, which is a combination of carbon and phosphorus, or a *phosphuret of carbon*. Thenard, however, observes that phosphorus, however frequently distilled, cannot be freed entirely from charcoal, a minute quantity of which does not impair its whiteness or transparency.

The only information, which we possess, respecting the nature of phosphorus, is derived from the electro-chemical researches of Sir H. Davy. When acted upon by a battery of 500 pairs of plates in the same manner as sulphur, gas was produced in consi-

* It is difficult to imagine how an explosion can here take place. The cold water in which the retort has its mouth immersed, (from the absorption of the gas,) will rush, by atmospheric pressure, into the retort, and break it. The contents would then inflame by the contact of the oxygen gas; but I cannot perceive any source from which an explosion is to be apprehended. C.

derable quantities, and the phosphorus became of a deep red-brown colour. The gas proved to be phosphuretted hydrogen, and was equal in bulk to about four times the phosphorus employed. Hence hydrogen is probably one of its components.*

IV. Phosphorus may be oxygenized in various modes †

(a) By exposure to atmospheric air. Let a stick of phosphorus be placed in a funnel, the pipe of which terminates in an empty bottle. The phosphorus will be slowly oxygenized, and, after some time, will be changed into an acid, which will fall into the bottle in a liquid state.

A large quantity of acid may be obtained, if a number of sticks be thus exposed: and as they would be in danger of taking fire, if heaped together, each stick should be enclosed in a glass tube, of rather larger diameter than itself. These tubes must be disposed round a funnel, the pipe of which terminates in a bottle. The whole should be covered by a bell-shaped receiver, the air of which is to be frequently changed. The acid thus obtained is a mixture of *Phosphorus* and *Phosphoric* acids.

When phosphorus is burnt in highly rarefied air, three products are formed, a red solid comparatively fixed, and requiring a heat above 212° for its fusion—a white and easily volatile substance, which is combustible, soluble in water, and has acid properties—and a substance, which is strongly acid, and not volatile even at a white heat. The first appears to be an oxide of phosphorus; the second phosphorous acid; and the third phosphoric acid.

(b) Phosphorus inflames vividly in oxygen gas. When burnt in this manner, every hundred parts of phosphorus, according to Lavoisier, gain an addition of 154.‡

This result scarcely differs from Sir H. Davy's, who states that 100 grains of phosphorus condense 450 cubic inches or 153 grains of oxygen gas. The product, when the gas is more than suffi-

* The phosphuretted hydrogen is only four times the bulk of the phosphorus employed; yet it is said to be *probably one of its constituents*; why then are we to dispute the necessary existence of it in sulphur, from which it is produced in five times the amount? C.

† On the oxides of phosphorus, see Nicholson's Journal, vi. 132.

‡ In Lavoisier's experiments on this subject (vide Elements, p. 105, Philad. Edit. 1799,) he found $138\frac{1}{2}$ cubic inches absorbed by the combustion of about 45 grains of phosphorus. These $138\frac{1}{2}$ cubic inches, he estimates at 69.375 grains. And these, if reduced to hundredth parts, give 154 parts of oxygen to saturate 100 of phosphorus. Lavoisier estimates the weight of oxygen gas at *nearly half a grain* for each cubical inch (p. 101), but no other writer gives by any means such a weight to it. Dr. Henry at p. 95 of this work, gives the weight of 100 cubic inches of oxygen gas, from the authority of Allen and Pepys, (our latest experimenters on the subject) as only 33.82. Davy says, about 34 grains. Now if 100 cubic inches of this gas weigh only 34 grains, then if the weights above given by Lavoisier, are reduced to hundredth parts; 100 parts of phosphorus in combustion, will require not quite 105 parts of oxygen to saturate them, giving 205 parts of concrete acid! This vast difference has never that I know been adverted to; nor has the assertion of Lavoisier as to the weight of the gas, thus opposed by later authority, ever been noticed. C.

cient for the combustion of the phosphorus, is entirely phosphoric acid.

(c) By the nitric acid. If phosphorus be cautiously added, by a little at once, to nitric acid, heated in a retort, the nitric acid is decomposed, and its oxygen, uniting with the phosphorus, constitutes phosphoric acid. A tubulated retort must be used for this purpose; and its neck may terminate in the apparatus already described for procuring nitric acid. By this contrivance a considerable quantity of nitric acid will be saved.*

SECTION II.

Phosphoric Acid.

I. To prepare this acid, the process *b* or *c*, sect. I. may be employed; but the following is the most economical method.

On 20 pounds of bone, calcined to whiteness and finely powdered, pour 20 quarts of boiling water, and add eight pounds of sulphuric acid, diluted with an equal weight of water. Let these materials be well stirred together, and be kept in mixture about 24 hours. Let the whole mass be next put into a conical bag of sufficiently porous and strong linen, in order to separate the clear liquor, and let it be washed with water, till the water ceases to have much acidity to the taste. Evaporate the strained liquor in earthen vessels, placed in a sand heat, and, when reduced to about half its bulk, let it cool. A white sediment will form in considerable quantity, which must be allowed to subside; the clear solution must be decanted, and boiled to dryness in 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, which is the phosphoric acid in a glacial state; not, however, perfectly pure, but containing sulphate and phosphate of lime.—According to Fourcroy and Vauquelin, it is, in fact, a super-phosphate of lime, containing, in 100 parts, only 30 of uncombined phosphoric acid, and 70 of neutral phosphate of lime. The glacial acid, however, may be prepared from perfectly pure phosphoric acid. It is singular that, according to the experiments of Berthier, it contains at least one fourth its weight of water, a proportion which could scarcely have been expected in so hard a substance.

To procure the phosphoric acid in quantity, and at the same

* This observation of Dr. H. is worth notice. It will apply equally in many other cases;—as in forming oxalic acid;—if the retort be made simply to terminate in a tubulated receiver, whose tubulure has a slight connection with the external air; the large quantity of nitrous gas which escapes in the process, meeting with a continual supply of oxygen, is converted into nitrous acid, which condenses in the receiver by the fluid that distils over. In like manner, in dissolving platina in nitro-muriatic acid; a much smaller quantity of acid is required, by a similar mode than if the solution is made in an open vessel. C.

time perfectly pure, the oxygenation of phosphorus by nitric acid, is the most eligible process (*c*, of the preceding article). The undecomposed nitric acid must be separated by distillation in a glass retort, and the dry mass, when fused, affords glacial phosphoric acid.

II. The phosphoric acid has the following properties :

(*a*) When pure it dissolves readily in water. That obtained immediately from bones is rendered insoluble by the admixture of earthy salts. But the glacial acid prepared with nitric acid, is readily soluble.

(*b*) It is not volatile, nor capable of being decomposed by heat only, nor does it emit any smell when heated.

(*c*) It is composed, according to the experiments of Rose, the correctness of which is admitted by Dr. Wollaston, of

Phosphorus	.	.	46.72	.	.	100.
Oxygen	.	.	53.28	.	.	114.6
<hr/>						100.

But if 254 parts, as appears from the experiments of Lavoisier and of Davy, consist of 100 phosphorus, and 154 oxygen, 100 grains must contain 39.5 phosphorus and 60.5 oxygen. This would very nearly agree with the notion, that phosphoric acid is constituted of one atom of phosphorus, weighing 10, and two atoms of oxygen = 15, and the weight of its atom must, therefore, be 25.

(*d*) When distilled in an earthen retort with powdered charcoal, phosphoric acid is decomposed; its oxygen, uniting with the carbon, forms carbonic acid, and the phosphorus rises in a separate state. This is the usual and best mode of obtaining phosphorus.

The phosphoric acid may either be employed for this purpose in the state of glass, finely powdered, and mixed with its weight of pulverized charcoal; or to the evaporated acid of bones, when acquiring a thick consistence, powdered charcoal may be added, in sufficient quantity to give it solidity. In the latter mode, however, the materials are apt to swell, and to boil over. The mixture of acid and charcoal is then to be put into a stoneware retort, coated with Willis's lute, and the neck of which is lengthened out by a tin pipe. The open end of the pipe is to be immersed in a vessel of water. The heat is to be slowly raised, and at length made very intense. An enormous quantity of gas escapes, which takes fire on coming into contact with the atmosphere; and the phosphorus distils over in drops, which congeal in the water. As it is apt also to condense in, and to stop up, the neck of the retort and tin pipe, it must be occasionally melted out of these, by a shovel full of hot cinders, held under them. The process is rather a difficult one; and though it is proper that the student should repeat it once, in order to complete a course of experiments, it will be found more economical to purchase the phosphorus which may be required for experiments.

Phosphorus may also be procured, by adding to urine a solution

of lead in nitric acid, which precipitates a phosphate of lead. This, when well washed, dried, and distilled in a stoneware retort, yields phosphorus :* or a solution of phosphate of soda (which may be bought at the druggists), mixed with one of acetite of lead, in the proportion of one part of the former salt to $1\frac{1}{2}$ of the latter, yields a precipitate of phosphate of lead, from which phosphorus may be procured by distillation.

SECTION III.

Phosphates.

WITH alkaline and earthy bases, the phosphoric acid composes a class of salts called Phosphates, which have the following generic characters.

1. When heated with charcoal, they are not decomposed, nor is phosphorus obtained.

2. They melt, before the blow-pipe, into a hard globule, sometimes transparent, at others opaque.

3. They are soluble in nitric and muriatic acids, without effervescence, and are precipitated from those acids by lime-water and pure ammonia.

4. They are decomposed, in part, by sulphuric acid, and yield a liquor which, on evaporation and distillation with charcoal, affords phosphorus.

The phosphate of soda is the only one of these salts which has any important use. It has been introduced into medicine, by Dr. Pearson, as a purgative, the purposes of which it answers, unaccompanied by any nauseous taste. The phosphate of lime, besides being found in the earth in a mineral form, constitutes a large part of the solid matter of animal bones.

As an enumeration of these salts can scarcely be interesting to the general student, and as the properties of the various salts, already described, furnish abundant discriminating characters of the different alkalis and earths, I deem it sufficient to refer, for a detailed account of them, to Dr. Thomson's Elements, or La Grange's Manual.

SECTION IV.

Phosphorous Acid—Phosphites.

PHOSPHOROUS acid cannot, according to Sir H. Davy, be obtained pure by exposing cylinders of phosphorus to atmospheric air ; for, when thus prepared it always contains phosphoric acid. It can on-

* See Crell's Journal, Translation, iii. 36.

ly be procured in a state of purity, first, by subliming phosphorus through corrosive sublimate; then mixing the product with water, and heating it, till it becomes of the consistence of syrup. The liquid obtained is a compound of pure phosphorus acid and water, which becomes solid and crystalline on cooling. It is acid to the taste, reddens vegetable blues, and unites with alkalis.

When the compound of phosphorus and chlorine formed in the first stage of the foregoing process, is brought into contact with water, the water is decomposed; its hydrogen uniting with chlorine composes muriatic acid; and its oxygen combining with phosphorus forms phosphorous acid.

The phosphorous acid exhales a disagreeable foetid odour; and yields, when heated, penetrating white vapours. When heated in a glass ball, blown at the end of a small tube, a gas issues from the orifice of the tube, which inflames on coming into contact with the atmosphere. Hence it appears to contain an excess of phosphorus. The residuum in the ball is phosphoric acid. From the experiments of Rose on the phosphoric acid, Gay Lussac infers that, conformably to his own hypothetical views, phosphorus acid must consist of

Phosphorus	.	.	56.81	.	.	100
Oxygen	.	.	43.19	.	.	76
<hr/>						
100.						

These proportions do not differ materially from those stated by Sir H. Davy. From a comparison of the composition of the phosphorous and phosphoric acids, it will appear, that the oxygen of the latter is not a multiple of that of the former, by any entire number; but bears to it the proportion of 3 to 2. Hence it is probable, that there is an oxide of phosphorus, not yet demonstrated by experiment, consisting of 100 parts of phosphorus, and 38 oxygen. This proportion of oxygen, multiplied by two, would give the phosphorous, and by three the phosphoric acid. And the atom of phosphorus, agreeably to this view, would be represented by 20, for 38:100::7.5:20 very nearly. The atom of the oxide would then be denoted by 27.5; that of phosphorous acid by 35; and that of phosphoric acid by 42.5.

The combinations of phosphorous acid with alkaline and earthy bases are called phosphites.

The phosphites differ considerably in their characters from phosphates.

1. They exhale a smell of phosphorus.
2. When heated, they emit a phosphorescent flame.
3. Distilled in a strong heat, they yield a little phosphorus, and are converted into phosphates.
4. They detonate, when heated with oxy-muriate of potash.
5. They are changed into phosphates by nitric, and by oxy-muriatic acid.

SECTION V.

Binary Compounds of Phosphorus.

I. PHOSPHORUS is susceptible of combination with sulphur, and affords a compound, the properties of which vary, according to the proportion of its ingredients. It may be obtained by melting these substances together in a tube, the mouth of which is loosely stopped by paper; or by fusing these two bodies, very cautiously, and in small quantities, at the bottom of a Florence oil flask, nearly filled with water. The process is attended with some danger; and requires several precautions, which will be suggested by the essays of Messrs. Accum and Briggs, published in the 6th and 7th volumes of Nicholson's Journal. The compound is much more fusible and combustible, than the separate components.

II. Phosphorus combines with the pure fixed alkalis, and with earths, and composes the class of phosphurets. That of lime is the most readily formed, and exhibits, extremely well, the properties of these compounds. It is prepared as follows:

Take a glass tube, about 12 inches long, and one third of an inch diameter, sealed hermetically at one end. Let this tube be coated with clay, except within about half an inch of the sealed end. Put first into it a drachm or two of phosphorus, cut into small pieces, and then fill the tube with small bits of fresh burnt lime, of the size of split peas. Stop the mouth of the tube loosely with a little paper, in order to prevent the free access of air.—Next, heat to redness that part of the tube which is coated with clay, by means of a chafing-dish of red-hot charcoal; and, when the lime may be supposed to be ignited, apply heat to the part containing the phosphorus, so as to sublime it, and to bring the vapour of it into contact with the heated lime. The lime and phosphorus will unite, and will afford a compound of a reddish-brown colour.

If the carbonate of lime be substituted for pure lime, the carbonic acid is decomposed. Its carbon is set at liberty, and appears in the state of charcoal; while its oxygen unites with the phosphorus; and the phosphoric acid, thus produced, forms phosphate of lime. In this experiment, carbonic acid is decomposed by the conspiring affinities of phosphorus for oxygen, and of lime for phosphoric acid, though the former affinity only would be inadequate to produce the effect.

The phosphuret of lime has the remarkable property of decomposing water at the common temperature of the atmosphere; and the water afterwards contains phosphite, not phosphate, of lime.* Drop a small piece of it into a wine-glass of water, and in a short time bubbles of phosphuretted hydrogen gas will be produced; which, rising to the surface, will take fire, and explode. If the phosphuret of lime be not perfectly fresh, it may be proper to warm the water to which it is added.

* Gay Lussac, 85 Ann. de Ch. 206.

Into an ale-glass put one part of phosphuret of lime, in pieces about the size of a pea, (not in powder,) and add to it half a part of hyper-oxy-muriate of potash. Fill the glass with water, and put into it a funnel, with a long pipe, or narrow glass tube, reaching to the bottom. Through this pour three or four parts of strong sulphuric acid, which will decompose the hyper-oxygenized salt; and the phosphuret also decomposing the water at the same time, flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light. (Davy.)

Another combination of phosphorus, the properties of which render it a fit subject of amusing experiments, is the phosphuretted hydrogen gas.

ART. 3.—*Phosphuretted Hydrogen Gas.*

I. This gas may be procured, by boiling, in a retort, a little phosphorus with a solution of pure potash. The water is decomposed; its oxygen, uniting with the phosphorus, forms phosphoric acid, which combines with the alkali, while the hydrogen dissolves another portion of phosphorus, constituting phosphuretted hydrogen gas.—This gas may also be obtained, by putting into five parts of water half a part of phosphorus, cut into very small pieces, with one of finely granulated zinc, and adding three parts of strong sulphuric acid. This affords an amusing experiment. The gas is disengaged in small bubbles, which cover the whole surface of the fluid, and take fire on reaching the air; these are succeeded by others, and a well of fire is produced. (Davy.)

In preparing this gas, the body of the retort should be filled, as nearly as possible, with the alkaline solution;* otherwise the gas, when produced, will inflame and diminish the air within the retort, and the water will ascend from the trough. This accident may be effectually prevented, by previously filling the retort with hydrogen gas†

* The phosphorus should first be melted, under water, in the retort; which is to be emptied when the phosphorus has congealed, and then entirely filled by the alkaline solution. Of this, a sufficient portion is to be displaced by hydrogen gas, forced through a bent pipe from a bladder.

† This experiment, which, by the account above given, is a very troublesome one, is really one of the most simple and easy in the practice of chemistry. By the plan I am about to mention, I have repeatedly extricated the gas in torrents from a retort of a quart measure;—and I generally employ one in my lectures of from half a pint to a pint. By knowing the sources of danger or difficulty in any experiment, we are enabled to obviate them. Now these are two fold in the extrication of phosphuretted hydrogen. 1. That arising from atmospheric air in the retort, by which an explosion ensues, as soon as the gas extricated comes in contact with it. 2. At the conclusion of the process, the retort is chiefly filled with aqueous vapour, which by condensation, from the cessation of a boiling heat in the ingredients of the retort, would establish a vacuum, did not the atmospheric pressure force the water up into the retort; but by the colder fluid thus coming in contact with the glass at the surface of the liquid in the body of the retort, this vessel is frequently broken, and the contents discharged. The retort likewise is often tilted up by the weight of the water rushing into it, as well as by the impulse its velocity communicates, and any phosphuret-

II. The properties of this gas are the following :

(a) It takes fire immediately on coming into contact with the air. This may be shown by letting it escape into the air, as it issues from the retort, when a very beautiful appearance will ensue. A circular dense white smoke rises in the form of a horizontal ring, which enlarges its diameter as it ascends, and forms a kind of corona.

(b) When mixed suddenly with oxygen gas, it detonates. One measure requires $1\frac{1}{2}$ of oxygen for saturation.

This experiment should be made cautiously, and in small quantity. But in a tube only three tenths of an inch in diameter, the mixture does not detonate.

(c) The same phenomenon ensues on mixing it with oxy-muriatic acid gas, or with nitrous oxide.

When mingled with any of these gases, it should be passed up by not more than a bubble or two at once.

(d) Sulphurous acid and phosphuretted hydrogen gases, when mingled together, mutually decompose each other.

(e) It deposits phosphorus, by standing, on the inner surface of the receiver, and loses its property of spontaneous accension. It is, also, decomposed by electricity, without any change of volume.

(f) Its specific gravity is very variable. Sir H. Davy has obtained it, from phosphorus and alkaline lixivium, of all specific gravities from 400 to 700, and Mr. Dalton states it at 850, air being 1000. The quantity absorbed by water is stated by the former at $\frac{1}{40}$ its bulk, and by the latter at $\frac{1}{27}$.

(g) Two measures of the gas heated with potassium become three, and phosphuret of potassium is formed.

Phosphorus is also soluble in oils; and, when thus dissolved, forms what has been called liquid phosphorus, which may be rubbed on the face and hands without injury. It dissolves too in ether, and a very beautiful experiment consists in pouring this phosphoric ether in small portions, and in a dark place, on the surface of hot water.

The phosphoric matches consist of phosphorus extremely dry, and hydrogen in it is instantly inflamed, and an explosion ensues. Without any other trouble than that of preparing a *boiling solution of potash*, with which I fill both the retort, and the vessel in which its mouth is dipped, all danger is avoided, and the process may continue until the phosphorus is gone. The gas extricated in the retort, by a lamp heat, finds no oxygen to produce an explosion; it continues therefore to augment, and gradually forces down the alkaline solution in the neck, until it escapes itself at the beak, and passes through the hot solution in the bowl into the air, when it inflames. Should the heat slacken, and an absorption ensue, nothing passes up into the retort, but a hot solution of the alkali from the bowl; and as the retort is tied down, the sudden impulse, and weight acquired, is incapable of tilting up the mouth of the retort above the fluid, so as to admit any air, which might induce an explosion, should any of the gas be still in it. A general idea of the apparatus is given in the 10th plate; and after nine or ten years use, during which I have never broken a single retort, or met with any accident, (although before I fell upon this plan, I suppose I had lost twenty,) I can safely recommend its adoption. In the common mode recommended, we are also confined to the use of very small retorts of two or three ounce measures. C.

minutely divided, and perhaps a little oxygenized. The simplest mode of making them is to put a little phosphorus, dried by blotting-paper, into a small phial; heat the phial, and when the phosphorus is melted, turn it round, so that the phosphorus may adhere to the sides. Cork the phial closely; and it is prepared. On putting a common sulphur match into the bottle, and stirring it about, the phosphorus will adhere to the match, and will take fire when brought out into the air.

ART. 4.—*Hydro-phosphoric Gas.*

By heating solid phosphorous acid out of the contact of air a large quantity of elastic fluid is generated, which may be collected by a proper apparatus, and has singular properties.

It has a disagreeable smell, but is not so offensive as phosphuretted hydrogen. It does not explode spontaneously, but detonates violently when heated with oxygen to about 300° Fahrenheit. It explodes in chlorine with a white flame. Water absorbs about $\frac{1}{8}$ its volume. Its specific gravity was found by Sir H. Davy to be to that of hydrogen as 12 to 1.

Potassium doubles its volume, and the residue is pure hydrogen. Sulphur occasions the formation of sulphuretted hydrogen, equal in volume to twice the original gas. Three parts of it in volume condense more than five of oxygen; and one in volume absorbs four of chlorine.

For this gas, its discoverer, Sir H. Davy, has proposed the name of hydro-phosphoric gas.* It appears to be constituted of two atoms of hydrogen and one of phosphorus; and the hydrogen in it is condensed into half its bulk.

Its formation appears to be owing to the decomposition of water, the oxygen of which, with part of the phosphorous acid, forms phosphoric acid, while the hydrogen dissolving the excess of phosphorus in another portion of phosphorous acid, composes the peculiar gas.

ART. 5.—*Combinations of Phosphorus with Chlorine.*

When phosphorus is introduced into chlorine gas, it takes fire and burns with a pale flame, and a white solid substance condenses on the sides of the vessel. Each grain of phosphorus absorbs about nine cubical inches of gas. The solid produced is volatile at a temperature below 212° . It acts violently on water, and decomposes it, the hydrogen of the water producing muriatic acid with the chlorine, and the phosphorus forming phosphoric acid with the oxygen. This substance, in its dry state, contains no oxygen, and is

* Here we have another instance of the inaccuracy arising from the application of the same term to bodies of a different nature. *Hydro-sulphuret*, an union of *hydrogen* with sulphur. *Hydro-phosphoric acid*, an union of water and dry phosphoric acid. *Hydro-phosphoric gas*, an union of *hydrogen* and of solid phosphorus. Our nomenclature is undoubtedly deserving of revision, on this, as on many other points. C.

constituted of phosphorus and chlorine, in the proportion of 20 of the former to 67 of the latter.

Another compound of phosphorus, with a less proportion of chlorine, may be formed, by passing the vapour of phosphorus through heated corrosive sublimate. It is a liquid of the specific gravity 1.45. It does not redden dry litmus paper; but its fumes become acid by decomposing the aqueous vapour in the air. It consists of chlorine and phosphorus in the proportion of 20 to 33.5. Both these compounds were discovered by Sir H. Davy, who has termed the latter *phosphorane* and the former *phosphorana*.

CHAPTER XVI.

BORACIC ACID.

I. THIS acid is very rarely found native; and, for purposes of experiment, is obtained from the purified borax of commerce, by one of the following processes:

1. To a solution of borax, in boiling water, add half its weight of sulphuric acid, previously diluted with an equal quantity of water. Evaporate the solution a little; and, on cooling, shining scaly crystals will appear, which consist of boracic acid. Let them be well washed with distilled water, and dried on filtering paper.

2. Let any quantity of borax be put into a retort, with half its weight of sulphuric acid, and half its weight of water. Boracic acid may be obtained by distillation, and may be purified, by washing in water, &c., as before. By neither of these processes, however, is it obtained perfectly pure; for electrical analysis discovers in it a minute portion both of alkali and of sulphuric acid. (Davy.)

II. Boracic acid has the following qualities:

1. It has the form of thin white scales, is destitute of smell; and nearly so of taste. Its specific gravity is 1.479.

2. It fuses, when heated, and loses its water of crystallization. If the heat be increased suddenly, before it has lost its water of crystallization, it sublimes; but, otherwise, it melts into a glass, which is permanent in the strongest fire, and has the specific gravity 1.803.

3. It is generally described as soluble in twelve parts of cold water, and in three or four of boiling water; but, according to Sir H. Davy, even boiling water does not take up above $\frac{1}{30}$ of its weight.

4. This solution reddens vegetable blue colours, and effervesces with alkaline carbonates.

5. It is soluble in alcohol, and the solution burns with a beautiful green flame.*

* A very interesting comparative experiment is exhibited by three cups, the two exterior holding, the one a solution of nitrate of copper in alcohol, the other one of the boracic acid; and the intermediate, a solution of nitrate of strontian in alcohol. The carmine flame of the last, is pleasingly contrasted with the different coloured green flames of the other solutions. C.

The boracic acid, which had resisted all other means of analysis, has at length yielded to the attempts of Sir H. Davy to decompose it by the action of Voltaic electricity. When slightly moistened with water, and exposed, between two surfaces of platina, to a battery of 500 pairs of plates, an olive-brown matter immediately began to form on the negative surface, which gradually increased in thickness, and at length became almost black. It was not changed by water, but dissolved with effervescence in warm nitrous acid. When heated to redness on platina, it burned slowly, and gave off white fumes, which had acid properties. A black mass remained, which, when examined by the magnifier, appeared vitreous at the surface, and evidently contained a fixed acid.

*Boron.**

As this peculiar combustible substance was a non-conductor of electricity, it was found impossible to obtain it in this way, except in very thin films. By the action of potassium, however, it was procured in large quantities. Twelve or fourteen grains of boracic acid were heated, in a green glass tube, with the same quantity of potassium.† A most intense ignition ensued; and the potassium, where it was in contact with the boracic acid, entered into vivid inflammation. A quantity of hydrogen gas appeared, equal to about twice the bulk of the acid. To collect the results, tubes of metal were employed; for the most part of brass, which appears to answer best. The residue in the tube was dissolved in water, and the insoluble part collected on a filter. Its properties are described as follows:

1. It is in the form of a powder, in colour of the darkest shade of olive. It is very friable, and not sufficiently hard to scratch glass. It is a non-conductor of electricity.
2. When it has been dried at only 100° or 120° , it gives off moisture by increase of temperature. In the atmosphere it takes fire, at a heat below that of boiling olive oil; and burns with a red light, and scintillations like charcoal.
3. It is not decomposed by heat in a platina tube, though raised to whiteness. The only change in it appears to be an increase of specific gravity.

* Called at first by Sir H. Davy *boracium*; presuming it to be metallic, which subsequent experiment did not appear to warrant. This might have been a sufficient warning to Sir Humphrey, not to be so precipitate in naming every newly discovered body before he was fully acquainted with its properties, &c. and indeed it would be by no means improper, that other scientific characters should be consulted, in establishing the nomenclature. C.

† In the 16th vol. of Schweiger's Journal, we have the following method laid down for procuring boron, from borax (sub-borat of soda) by Mr. Doeberiner. After fusing the borax and reducing it to fine powder, we add one-tenth its weight of lampblack. The mixture is put into a gun barrel closed at one end, and at the other having a tube to collect the gas. It is then heated for two hours at a white heat. There is a disengagement of much gaseous oxyd of carbon, and when the process is completed, we find in the barrel a compact mass, of a greyish black colour, which is to be pulverised, and which after frequent wash-

4. In oxygen gas it burns with a most brilliant light, and is partly converted into boracic acid, and partly into a black substance, which requires a higher temperature for its inflammation, and produces a fresh quantity of boracic acid.

5. In oxymuriatic acid gas, it takes fire at common temperatures, and boracic acid is regenerated with a portion of the black matter already described.

6. It was not soluble either in nitrogen or hydrogen gases.

7. It decomposed the nitric and sulphuric acids, and boracic acid was produced.

8. It combined with alkalis, and gave pale olive coloured compounds, from which dark precipitates were separated by muriatic acid.

9. It slowly combined with melted sulphur, which acquired an olive tint; but with phosphorus scarcely any union seemed to take place. Neither did it combine with mercury.

These qualities are sufficient to show that the combustible substance, obtained from boracic acid, and constituting its base, is different from every other known species of matter. Sir H. Davy has, therefore, proposed for it the term BORON. As to its nature, he is of opinion that it is probably a compound, and that one of its ingredients, which enters into alloy with potassium and with iron, is the true basis of the boracic acid. The olive coloured substance, whose properties have been already described, he believes to consist of this basis, united with a little oxygen; that when farther oxydized it forms the black matter; and that, in its full state of oxygenation, it constitutes boracic acid.

The proportion of ingredients in the boracic acid has not been accurately determined. It is stated, merely as an approximation, that it consists of one part by weight of inflammable base united with two parts of oxygen. In the black substance, Sir H. Davy supposes that about three parts of the inflammable base are combined with only one of oxygen.

Boracic acid combines with alkalis and earths; but the only important combination, which it forms, is with soda. This compound is found native in India, and is brought to this country, under the name of tincal, or brute borax, which when purified, affords the borax of the shops. In the borate of soda, the alkaline ingredient is in excess, and hence the salt converts vegetable blue colours to green. It is therefore, in strictness, a sub-borate.

Sub-borate of soda crystallizes in prisms with six irregular sides. It effloresces in the air. It fuses when ignited; loses its water of

ing in boiling water, and once with hydro-chloric acid (muriatic acid), yields a pulverulent substance of a greenish black, resembling boron, excepting that it is still mixed with a little charcoal. Mr. Doebereiner thinks the carbon begins by reducing the soda, and that it is the sodium which then reduces the boracic acid: He believes therefore that we should procure much more of the boron, by adding to the borax one half its weight of soda or potash, and double the quantity of carbon to that above stated. *Annales de Chimie*, 1816. C.

crystallization ; and leaves a glass, which is transparent when cold, and which is of great use in experiments with the blow-pipe. The salt dissolves in twelve parts of cold water, or in six of boiling water. It is susceptible of combination, by fusion, with silex and with alumine ; and hence is employed in making artificial gems.

For a description of the remaining borates, I refer to the 2d volume of Thomson's System of Chemistry, or the 1st volume of La Grange's Manual.

CHAPTER XVII.

FLUORIC ACID.

I. THE fluoric acid may be obtained from a substance found abundantly in Derbyshire, under the name of *fluor spar*. In converting this spar to ornamental purposes, small pieces are broken off, which may be had at a cheap rate.

Pure fluoric acid has never yet been obtained in a gaseous state ; for we are acquainted with it, as a gas, in only two forms, viz. of combination with silex, and with boracic acid.

Silicated fluoric gas may be prepared by pouring on fluor spar, finely powdered, and mixed with half its weight of powdered glass, an equal weight of strong sulphuric acid. It may be received over mercury in glass vessels, the transparency of which it does not impair. Its specific gravity is very great, 100 cubic inches weighing 110.78 grains.

By causing a known volume of it to be absorbed by liquid ammonia, Dr. John Davy separated the silex, which formed 61.4 per cent. of the weight of the gas. When the gas is absorbed by water, much of the silex is deposited, and it retains only 54.5 per cent. of that earth in combination. To this liquid, Dr. Davy gives the name of *subsilicated fluoric acid*.

Water absorbs about 263 times its bulk of the gas, and the solution may be kept in glass vessels* without corroding them.

It condenses twice its volume, and no other proportion, of ammoniacal gas, forming a dry white salt, which is slightly acid, deposits some silex when dissolved in water, and when its concentrated solution is boiled in glass vessels, powerfully corrodes them. When an excess of liquid ammonia is added, the whole of the silex is precipitated, and a pure fluuate of ammonia is obtained.

Potassium, heated in silicated fluoric gas, takes fire, and burns with a deep red light. In an experiment of Sir H. Davy, after the combustion, the whole of the fluoric acid was found to be destroyed, and no gas left but a residuum of hydrogen. But from fluoric

* This is not strictly the case ; it does corrode them, but in a degree far inferior to the silicated gas. It is sufficiently strong nevertheless to be employed for etching on glass. C.

acid, long exposed to calcined sulphate of soda, hardly one tenth its bulk of hydrogen could be thus developed.

The bottom of the retort, in these cases, was covered with a substance of various colours, in some parts chocolate, in others yellow, which, being heated in contact with air, burned slowly, lost its colour, and became a white saline mass. In oxygen gas, it burned with an absorption of oxygen, but not with any great intensity, reproducing silicated fluoric acid gas.

By the action of this substance on water, fluoric acid and potash were generated; and some chocolate coloured particles were separated by the filter, which, when dried, and heated in oxygen gas, burned and absorbed oxygen. By this combustion, fluoric acid was also generated.

Hydro-fluoric Acid.

The fluoric acid may be obtained *in a liquid state*, from fluor spar and twice its weight of strong sulphuric acid, by using a leaden retort and leaden receiver. An ingenious apparatus, invented for this purpose by Mr. Knight, is described and figured in the 17th volume of the *Philosophical Magazine*.* The receiver should be surrounded with snow or pounded ice.

The liquid acid must be preserved in leaden or silver bottles, as it soon corrodes and penetrates glass ones. Its volatility, however, is such that it is extremely difficult to confine it. In this state of watery solution, it readily combines with alkalis, and forms soluble compounds. Its combinations with the earths are for the most part highly insoluble. The fluates have no properties that can render them interesting to the student, except the use of the alkaline ones as tests, which will be described in a subsequent part of the work.

To the liquid solution of fluoric acid, Gay Lussac and Thenard have given the name of *silici-fluoric acid*. Its specific gravity, Sir H. Davy finds to be 1.0609. By adding water, in very small quantities at once, its specific gravity is gradually increased to 1.25, a property observed in no other liquid. When suddenly mixed with water, it becomes very hot and even boils; it emits dense and noxious vapours; acts instantly and strongly on glass; and powerfully affects the skin, on which it raises painful pustules, or, if in sufficient quantity, occasions deep and dangerous ulcers.—A small piece of potassium thrown into it, detonates violently.

The principal use of hydro-fluoric acid is for destroying the polish of glass; but for this purpose it is adviseable to prepare it in a state of considerable dilution, by receiving the gas into water, contained in a leaden vessel. It may, also, be employed to etch on glass, as copper is engraved by aqua fortis.

* An apparatus for the same, is given in the *Recherches Physico-Chimiques* of Gay Lussac and Thenard C.

Nature of Fluoric acid.

The experiments of Sir H. Davy, made in 1808, led him to conclude, chiefly from the action of potassium on silicated fluoric gas, that the fluoric acid is a compound of oxygen with a combustible basis. But as all acids, so constituted, are decomposed by galvanic electricity, their base being determined to the negative, and their oxygen to the positive pole, he has lately* submitted liquid fluoric acid to this test, after having first ascertained, by the result of its combination with ammoniacal gas, that, in its strongest form, it contains no water. Considerable difficulty was experienced in making the necessary exposure of the liquid to electricity, (partly in consequence of the dangerous fumes which it emitted) and in collecting the products. At the negative pole, a gas was evolved, which, from its inflammability, appeared to be hydrogen. The platina wire at the positive pole was rapidly corroded, and covered with a chocolate powder, the properties of which seem not to have been examined.

When fluate of ammonia was treated with potassium, no evidence was obtained of its containing oxygen. Charcoal, also, intensely ignited in fluoric acid gas, gave no carbonic acid. The most simple way of explaining the phenomena appears, therefore, to Sir H. Davy, to be by the supposition, that the fluoric acid, like the muriatic, is composed of hydrogen, and a peculiar base, possessing, like oxygen and chlorine, a negative electrical energy, and hence determined to the positive surface. For this base, which, like chlorine, he believes to combine at once with metals, the name of *fluorine* has been proposed. This substance, from its strong affinities and decomposing agencies, has not yet been exhibited in a separate state; nor have any of the attempts to detach it from its combinations by chlorine or oxygen, (on the presumption that the attraction of one of those bodies for the metals might be superior to that of fluorine,) been hitherto successful.

The number representing the atom of *fluorine*, as deduced from the composition of fluor spar, is 17.1; and fluor spar must be composed of 20 calcium and 17.1 fluorine. On the whole, Sir H. Davy is disposed to estimate the weight of the atom of fluorine at less than half that of chlorine, and to fix it at 33, which is equivalent, on Mr. Dalton's scale, to 16.5.

Fluoboric Acid.

With the view of obtaining fluoric acid gas perfectly free from water, both Sir H. Davy and Gay Lussac appear to have had recourse to the same experiment, *viz.* that of distilling perfectly dry boracic acid with fluate of lime. When these substances were exposed to a strong heat in an iron tube, in the proportion of one part of the former to two of powdered fluor spar, a gas was collected in great quantity, which exhibited singular properties, and to which Messrs. Gay Lussac and Thenard have given the name of *gas*

* Phil. Trans. 1813, part 2; and 1814, part 1.

fluoborique, or fluoboric acid gas. It may, also, be obtained by distilling in a retort 1 part of vitreous boracic acid with two of fluor spar and 12 of sulphuric acid. One hundred cubic inches weigh 73.5 grains.

This gas, according to the latter chemists, appears to contain no water, and to have so strong an affinity for it as to take it from other gases which hold water in combination. Hence, when mixed with most of those gases, on which it does not exert a chemical action, such as atmospheric air, it loses its transparency and becomes cloudy.

With ammoniacal gas it unites in two proportions. If the alkaline gas be put first into the tube, equal measures combine together, and the compound is neutral. But if we admit fluoboric gas by bubbles to the alkaline gas, we obtain a compound, with an excess of base, consisting of one measure of fluoboric gas to two of ammonia.

Fluoboric gas is absorbed copiously by water, which takes up 700 times its bulk, and acquires the specific gravity 1.77. The saturated solution has the causticity and aspect of strong sulphuric acid; requires for ebullition a temperature considerably exceeding 212° Fahrenheit; and is condensed again in striæ which contain much gas. From analogy, Gay Lussac supposes that nitric and even sulphuric acids, are, in their pure states, equally elastic with this.

When potassium or sodium was heated in fluoboric gas, Gay Lussac and Thenard obtained fluat of potash or soda, and the base of the boracic acid.

The liquid acid acts almost as intensely as sulphuric acid on vegetable substances. It blackens paper, and affords a true ether with alcohol. It has no effect in corroding glass.

From analysis, Gay Lussac and Thenard, as well as Sir H. Davy, have determined it to be a compound of boracic and fluoric acids, in proportions not yet ascertained.

CHAPTER XVIII.

IODINE AND ITS COMPOUNDS.

IODINE was discovered accidentally, about the beginning of the year 1812, by M. Courtois, a manufacturer of saltpetre at Paris. In the processes for procuring soda from the ashes of sea weeds, he found his metallic vessels much corroded; and in searching for the cause, he made this discovery. Specimens of the new substance were given to M. M. Desormes and Clement, who read a short memoir upon it, at a meeting of the Institute of France, in November, 1813. Its properties and combinations have since been ably investigated by Vauquelin;* by Gay Lussac;† by Sir H. Davy;‡ and by Gaultier de Claubry and Colin.§

* 90 Ann. de Chim. 206.

‡ Phil. Trans. 1814.

† 91 Ann. de Chim.

§ 90, 91, & 93 Ann. de Chim.

When all the soda has been separated by crystallization from a solution of kelp or barilla, or from the ley of ashes of marine plants, that afford the mineral alkali, in order to procure iodine from the residuary liquor, concentrated sulphuric acid is to be poured upon it, in a retort furnished with a receiver. The iodine passes into the receiver, under the form of beautiful violet vapours, which are condensed in crystalline plates, having the aspect of plumbago. To purify it from the redundant acid, that comes over with it, the iodine may be redistilled from water, containing a very small quantity of potash, and afterwards dried by pressing it between folds of blotting paper.*

General Properties.—Iodine is a solid, at the ordinary temperature of the atmosphere. It is often in scales, resembling those of micaceous iron ore; sometimes in large and brilliant rhomboidal plates; and occasionally in elongated octohedrons.† Its colour is bluish black; its lustre metallic; it is soft and friable, and may easily be rubbed to a fine powder. Its taste is very acrid, though it is sparingly soluble in water, which does not take up above one 7000th part of its weight.‡ Its specific gravity, at 60° Fahrenheit, is 4.946. It is a non-conductor of electricity; and possesses, in a high degree, the electrical properties of oxygen and chlorine, being determined to the positive pole of a galvanic arrangement. When applied to the skin, it produces a yellow stain, but this disappears as the iodine evaporates.

Iodine is fusible at 225° Fahrenheit, and under the ordinary pressure of the atmosphere, is volatilized at a temperature somewhere near 350°, forming a gas 117.71 times denser than hydrogen, or, according to Sir H. Davy, weighing 95.27 for 100 cubic inches. The volatilization of iodine at the heat of boiling water, which happens when it is distilled with that fluid, depends on its affinity for aqueous vapour. The colour of its vapour is a beautiful violet, and hence its name (from *ἰώδης*, violaceous).

Action of Oxygen.—Iodine undergoes no change by being heated in contact with oxygen gas, or with hyper-oxy muriate of potash. It will appear, however, in the sequel, that, by the intervention of euchlorine, it admits of being combined with oxygen, and that it then furnishes a peculiar acid with that body.

Action of Nitrogen.—Azotic gas has no action on iodine, but a compound of iodine and nitrogen will be described in speaking of the effect of ammonia.

Action of Water.—It has no power of decomposing water, even when the mixed vapours of the two substances are passed through a red hot tube.

Action of Hydrogen.—The affinity of iodine for hydrogen is very strong, and it absorbs that basis from hydrogen gas, and detaches it

* More minute directions for its preparation are given in the Phil. Mag. xl. 57, 141, and 209.

† Dr. Wollaston has described the form of its crystal in Thomson's Annals, v. 237.

‡ Its odour is somewhat allied to that of chlorine. C.

from several of its combinations, affording, as the result, a distinct and well characterized acid.

If iodine be heated in dry hydrogen gas, an expansion of its volume takes place; an acid gas is formed, which is very absorbable by water, and acts so much on mercury that it cannot be preserved long over that metal. A similar gaseous compound is formed, by exposing iodine to sulphuretted hydrogen gas. But it is best prepared, in quantity, by the action of moistened iodine and phosphorus on each other, the phosphorus being in excess, and the mixture distilled in a retort. The gas may be received into a vessel filled with common air, which it expels by its superior gravity. Gay Lussac recommends, instead of a retort, a small bent tube, which after putting the iodine into it, is to be inverted over mercury; the air, which it contains, is to be expelled by a glass rod, that almost fills its capacity; and the phosphorus is to be brought into contact with the iodine, by introducing it through the mercury. As soon as the contact takes place, the acid gas is disengaged, and may be collected by putting the open end of the tube under a glass jar standing inverted in mercury.

No sooner does the gas come into contact with the mercury than it begins to be decomposed; and if the contact be prolonged a sufficient time, or agitation be used, the decomposition is complete. The iodine unites with the mercury; and there remains a volume of hydrogen gas, which is exactly one half that of the acid gas. It is decomposed, in a similar manner, by all metals except gold and platina.

The acid gas is colourless, its taste is very sour, and its smell resembles that of muriatic acid gas. Its specific gravity was found by experiment to be 4.443; by calculation it should have been 4.428.

The acid gas is rapidly decomposed by being heated in contact with oxygen gas, which detaches the hydrogen. Chlorine also, instantly deprives it of hydrogen, and produces muriatic acid gas; and the iodine re-appears in the form of a beautiful violet vapour. It is composed, by weight, according to Gay Lussac, of 100 iodine and 0.849 hydrogen.

For this compound Sir H. Davy has proposed the name of *hydroionic acid*, and Gay Lussac that of *hydriodic acid*. I prefer the latter; because it is easier, by varying its termination, to express its combinations with alkaline and other bases.

Hydriodic acid gas is plentifully absorbed by water; the solution is fuming, and has the density of 1.7. To prepare this liquid in quantity, Gay Lussac recommends to put powdered iodine into water, and to pass sulphuretted hydrogen gas through the mixture. The hydrogen unites with the iodine, and the sulphur is precipitated. The liquid may be concentrated by evaporation. Till it attains the temperature of 257° , water only distils; above this point, the acid itself is volatilized, and remains stationary at $262\frac{1}{2}^{\circ}$, its density being then 1.7.

The liquid acid is slowly decomposed by contact with air; its hydrogen being attracted by the oxygen of the atmosphere, and a

portion of iodine liberated, which gives the liquor a colour, of intensity proportionate to the quantity of free iodine. Concentrated sulphuric acid, nitric acid, and chlorine decompose it, and separate iodine. With solutions of lead, it gives a fine orange precipitate; with solution of per-oxide of mercury, a red one; and with silver, a white precipitate, insoluble in ammonia.

When submitted to galvanic electricity, the liquid hydriodic acid is rapidly decomposed; iodine appears at the positive, and hydrogen at the negative pole. It dissolves zinc and iron, with a disengagement of hydrogen gas, which proceeds from the water. It has no action on mercury, though the gas so powerfully affects that metal. It is decomposed by those oxides, which hold their oxygen loosely, and combines with the rest, forming a genus of neutral salts, called *hydriodates*.

In general, the hydriodates are readily soluble in water. Those of potash and barytes are not decomposed by heat, except oxygen is in contact with them; the salt with base of lime is wholly, and that with base of magnesia partially, decomposed at high temperatures.

Charcoal does not combine with iodine.

Sulphur and iodine unite at a gentle heat, and a black radiated compound is formed, resembling sulphuret of antimony. It is easily decomposed by a degree of heat a little higher than that at which it was formed, and iodine is detached in vapour.

Phosphorus and iodine combine at the temperature of the atmosphere, according to Sir H. Davy, evolving much heat, but no light; but, according to Thenard, with a disengagement both of light and heat.* The result is a *phosphuret of iodine*, of a reddish brown colour, the solidity, fusibility, and volatility of which vary with the proportions of its ingredients. If both the phosphorus and iodine are dry, no gas is given out during their combination; but when slightly moistened, hydriodic acid is formed, by the union of iodine with the hydrogen of the water; a little sub-phosphuretted hydrogen is produced; and phosphorus acid remains in solution. The hydriodic acid gas is also formed, when the phosphuret of iodine, produced from dry materials, is added to water.

Potassium and iodine.—Potassium burns in the vapour of iodine with a pale blue light,† and without the disengagement of any gas. The substance produced is white; fusible at a red heat; and soluble in water. It has a peculiar acrid taste. When acted upon by sulphuric acid, iodine is set at liberty. The same compound is obtained, by heating potassium in hydriodic acid gas, which is decomposed, and yields half its volume of hydrogen gas. To this compound Sir H. Davy has given the name of *iode of potassium*, the term *iode* being a generic one for the compounds of iodine with the metals and other combustible bases; but Gay Lussac has proposed (what appears to me more appropriate) the name of *iodure*.

* I have repeatedly witnessed the evolution of light, on the combination of these two substances. C.

† Here is combustion without the presence of oxygen. C.

When *iode* or *ioduret* of potassium, silver, mercury, or lead, is heated in chlorine gas, iodine is expelled, and hence the affinity of chlorine for those metals surpasses that of iodine. Sulphuric acid extricates some iodine, and occasions a production of hydriodic and sulphurous acids. Oxalic, acetic, sulphurous, and phosphoric acid have no action on the iodurets.

Iodine and alkalis.—When iodine in vapour is passed over ignited hydrate of potash, oxygen is disengaged, and a compound is formed, precisely similar to that, which results from the combination of iodine and potassium. Hence the affinity of iodine for potassium exceeds that of oxygen; and the same may be said of several other metals, though not of all, their oxides being decomposed by iodine. From subcarbonate of potash, it displaces two volumes of carbonic acid and one of oxygen.

When iodine is thrown into a moderately strong solution of potash, rendered perfectly caustic, it is dissolved; and, during its solution, crystals fall down, which may be obtained abundantly, by saturating the liquid with iodine. To obtain these crystals pure, they must be washed with alcohol of a specific gravity, between .860 and .920. They are sparingly soluble in water; have a taste like hyper-oxy muriate of potash; deflagrate with charcoal; and when heated give oxygen gas, and ioduret of potassium. With sulphuric acid, they afford iodine, oxygen, and sulphate of potash.

The liquid, which has ceased to yield these crystals, affords, on evaporation, a salt identical with ioduret of potassium. In this case, Sir H. Davy imagines the potash is decomposed; one part of it combines with iodine; and the oxygen, thus set at liberty, unites with the other part and with iodine. In his view, therefore, the deflagrating salt is a triple compound of oxygen, iodine, and potassium, and is called an *oxyiode*; but Gay Lussac supposes that the iodine is oxygenated, and forms an acid, which he calls *iodic acid*; and that this, uniting with potash, composes *iodate of potash*. By acting with iodine on solution of barytes, a similar compound was formed with that earth, which, when decomposed by sulphuric acid, gave, he supposes, a mixture of that acid with *iodic acid*. But the product, in this case, Sir H. Davy has since shown, is a compound of sulphuric acid with oxyiodine, which will presently be described.

Dry ammoniacal gas is absorbed by iodine without decomposition; the product is at first very viscid, and has a metallic aspect; but by an excess of ammonia, it loses these properties, and becomes of a very deep brownish red. When iodine is added to liquid ammonia, one part of it unites with the hydrogen of the alkali, and forms hydriodic acid, while another portion of iodine combines with the azote, and falls down in the form of a black powder. This compound of azote and iodine detonates with a very gentle heat, and even with the slightest touch.

Iodine and chlorine.—Iodine absorbs less than one third its weight of chlorine, and forms a peculiar acid which may be called *chlo-*

riode, or *chloriodic acid*,* and its compounds *chloriodates*. According to Gay Lussac, indeed, two compounds result, the one of a fine orange yellow colour, containing the largest proportion of chlorine, the other orange red. Both are solid and crystalline; deliquesce when exposed to the air; are fusible into an orange liquid; and give an orange coloured gas. The watery solution takes more iodine, and acquires a deeper colour; but if agitated with chlorine, it is deprived of colour, and when poured in that state, into solution of potash, the deflagrating salt is precipitated. From liquid ammonia, the colourless liquid precipitates a white detonating compound; but the coloured solution throws down the darker compound, which detonates on the slightest touch, and is, indeed, identical with that, procured by the direct action of iodine on ammonia.

Chloriodic acid (or *chlorure of iodine*, as it is called by Gay Lussac) precipitates the salts of iron, lead, tin, and copper; probably in the state of oxyiodes.

It has been observed by Gay Lussac, that, in order to convert the whole of a quantity of alkali into the deflagrating salt, without any of the hydriodate, (which otherwise is produced in greater proportion than the oxyiode) it is necessary, first, to combine the iodine with chlorine; and, after dissolving the compound in water, to saturate it with alkali.

Iodine and Euchlorine.—When iodine is exposed to euchlorine, Sir H. Davy has recently discovered,† that there is an immediate action; its colour changes to bright orange; and a liquid is formed. By the application of a gentle heat, the orange compound of chlorine and iodine is expelled, and a compound of oxygen and iodine remains. This substance is a white semi-transparent solid; it has no smell, but a strong astringent sour taste. Its specific gravity is such, that it sinks in sulphuric acid.

When decomposed by heat in a pneumatic apparatus, it is resolved into oxygen gas and pure iodine; and it is, therefore, termed by Sir H. Davy, *oxyiodine*. Thirteen grains afforded 9.25 cubical inches of oxygen gas, = 3.14 grains. Hence it is composed of

Iodine	. .	75.85	. .	100.	. .	314.8
Oxygen	. .	24.15	. .	31.84	. .	100.
		<hr/>		<hr/>		<hr/>
		100.		131.84		414.8

On the supposition that *oxyiodine* is composed of five atoms of oxygen and one of iodine, the atom of iodine may be deduced to weigh 117.15. Now it is remarkable, that assuming hydriodic acid to consist of one atom of iodine and one of hydrogen, the weight of the atom of iodine is 117.77; for as .849 to 100 (the

* Thus, according to the above observations, we have no less than three acids, formed by the combination of the same base with three distinct substances, oxygen, hydrogen, and chlorine! where now are we to look for the *acidifying principle* of the French school? C.

† Phil. Trans. 1815, part 2.

proportions in which hydrogen and iodine combine) so is 1 to 117.77. If 10 represent the atom of oxygen, then the atom of iodine will weigh 150.62.

Oxyiodine is very soluble in water, and is slightly deliquescent. Its solution first reddens, and then destroys, vegetable blues, and reduces other vegetable colours to a dull yellow. When evaporated sufficiently, it becomes a thick pasty substance, and at length, by a cautiously regulated heat, yields oxyiodine unaltered.

When heated in contact with inflammable bodies, or with the more combustible metals, detonations are produced. Its solution in water rapidly corrodes all the metals, and even acts on gold and platina, but especially the first.

When its solution is poured into solutions of alkalis, or alkaline earths, or when made to act on their carbonates, triple compounds are formed of oxygen, iodine, and the metallic bases, called by Sir H. Davy, *oxyiodes*; and by Gay Lussac, it would appear improperly, *iodates*. With solution of ammonia, it composes oxyiode of ammonia; and from the soluble salts of barytes and strontites, it precipitates their respective oxyiodes. Forty-eight grains of oxyiode of potassium, when decomposed by heat, afforded Sir H. Davy 31 cubic inches = 10.5 grains, of oxygen gas.

Oxyiodine enters into combination with all the fluid or solid acids, which it does not decompose. Sulphuric acid, dropped into a saturated solution of it in hot water, precipitated a solid, which, on cooling, formed rhomboidal crystals of a pale yellow colour. This compound is fusible; and, with a heat properly regulated, may be sublimed unaltered. Hydronitric and hydrophosphoric acids afford analogous compounds. Oxalic and liquid muriatic acids decompose it. All its acid combinations redden vegetable blues; dissolve gold and platinum; and when added to alkalis or earths, afford common neutral salts, and their respective oxyiodes. In their crystalline state, the compounds of oxyiodine and acids are most probably hydrates; the acids carrying with them, into combination, their definite proportion of water.

For the watery solution of oxyiodine, Sir H. Davy has proposed the name of *oxyiodic acid*, and is disposed to regard it as a triple compound of iodine, hydrogen, and oxygen; or an *oxyiode of hydrogen*.

Iodine and Metals.—All the metals, with the aid of heat, unite with iodine, and form *iodes* or *iodurets*, analogous to sulphurets. When these compounds are placed in contact with water, it is decomposed, and a hydriodate of the respective metal is produced, the water furnishing hydrogen to the iodine and oxygen to the metal.

Nature of Iodine.—Iodine, from all that we yet know respecting it, is to be considered as a simple or elementary body, having a very striking analogy with chlorine, which it resembles, 1stly, in forming one acid by uniting with hydrogen, and a different acid with oxygen; 2dly, in its effects on vegetable colours; 3dly, in its affording, with the fixed alkalis, salts which nearly approach in characters to hyper-oxy muriates; and 4thly, in its electrical habitudes.

Its discovery, indeed, lends strong support to that theory, which considers chlorine as a simple body, and muriatic acid as a compound of chlorine and hydrogen. In the property of forming an acid, whether it be united with hydrogen or with oxygen, iodine bears, also, an analogy to sulphur; and it is remarked by Gay Lussac of the combinations of chlorine, iodine, and sulphur, with the elements of water, that while the acids, which they respectively form with oxygen, have their elements strongly condensed, those formed with hydrogen have their elements very feebly united. Sulphur has the strongest affinity for oxygen, then iodine, and lastly chlorine. But for hydrogen chlorine has a stronger attraction than iodine, and iodine than sulphur.

The source of iodine in nature has been investigated with much ability by M. Gaultier de Claubry,* the first part only of whose memoir has yet reached me. His first experiments were directed to the analysis of the several varieties of *Fucus*, the combustion of which furnishes the soda of sea-weeds.† Before these vegetables are destroyed by combustion, he ascertained that iodine exists in them in the state of *hydriodate of potash*; and that the calcination only destroys the vegetable matters, with which it is combined. As the hydriodate of potash is a deliquescent salt, it remains in the mother liquor, after separating the carbonate of soda, and most of the other salts, by crystallization. In the course of these experiments, M. de Claubry found that starch is one of the most delicate tests of the presence of iodine, and if added to any liquid containing it, with a few drops of sulphuric acid, iodine is indicated by a blue colour, of greater or less intensity. In this way, he detected iodine in the decoction of the *Fucus Saccharinus*, &c.

CHAPTER XIX.

OF THE GENERAL PROPERTIES OF METALS.

THE metals compose a class of bodies, which are not more interesting from their application to the common arts of life, than from the facts which they contribute to the general principles of chemical science. Only seven or eight were known to the ancients; but the class has been enlarged, within the last century, by the discovery of twenty new ones. In addition to the recently discovered bases of the alkalis and earths, the following appear to have a sufficient claim to be considered as distinct metals.

* Ann. de Chim. xciii. 75.

† The fuci of our own coasts afford this substance very readily by the process detailed. C.

1. Gold.	10. Iron.	19. Cobalt.
2. Platina.	11. Nickel.	20. Manganese.
3. Silver.	12. Tin.	21. Chrome.
4. Mercury.	13. Lead.	22. Molybdena.
5. Rhodium.	14. Zinc.	23. Uranium.
6. Palladium.	15. Bismuth.	24. Tungsten.
7. Iridium.	16. Antimony.	25. Titanium.
8. Osmium.	17. Tellurium.	26. Columbium.
9. Copper.	18. Arsenic.	27. Cerium.

Of a class comprehending so many individuals, it is not easy to offer a general description; but it will be found that they are all characterised by one or more of the following properties.

1. With the exception of the newly discovered bases of the alkalis and earths, they are distinguished by a high degree of specific gravity; the lightest of the metals (tellurium) being considerably heavier than the most ponderous of the earths. They are, perhaps, the only solid bodies, whose specific gravity is affected by mechanical means; or, in other words, whose particles can be brought permanently into a state of nearer approximation by external pressure. In consequence of this property, several of the metals undergo material changes in their specific gravity, by the mechanical operations of rolling, hammering, &c. It may be questioned, whether the metals are heavier, in consequence of the greater specific gravity of their individual atoms, or from a greater number of atoms being aggregated into a given volume. The former, however, is most probably the case, though it must be acknowledged that their specific gravity is by no means *exactly* proportional to the weight of their atoms.

2. They are opaque, at least in the state in which they generally occur to our observation. Gold, however, beat into leaves $\frac{1}{288000}$ th of an inch in thickness, transmits a faint greenish light, when held between the eye and the direct light of the sun.

3. They possess various degrees of lustre, and it is of so peculiar a kind, that it has been termed by mineralogists the *metallic lustre*, and referred to as a known standard in the description of other minerals. Some of the metals possess this property in so remarkable a degree, as to be applicable to highly ornamental purposes. Polished steel takes place of all the metals in the perfection of its lustre; but some of the class (as cobalt and nickel) appear to be susceptible of it in only a small degree.

4. The metals are excellent reflectors, not only of light but of caloric; and hence they are the best materials for the composition of burning mirrors. From the experiments of Mr. Leslie, they appear to possess this property in the following order, the highest number denoting the greatest reflecting power.

Brass	100
Silver	90
Tinfoil	85

Planished block tin	80
Steel	70
Lead	60
Tinfoil softened by mercury	50

In general, the reflecting power was found by Mr. Leslie, to be proportioned to the degree of polish, and to be impaired by every thing that diminished this quality. A tin reflector, for example, had its reflecting power diminished nine tenths by being rubbed with sand paper.

5. Metallic bodies are, of all others, the best conductors of electricity. Their property of electro-motion has already been described, in the chapter on the chemical agencies of electricity and galvanism.

6. They are, also, excellent conductors of caloric.

7. One of the most useful properties of the metals is their *malleability*, or capacity of being extended by the blows of a hammer. In this quality, gold takes place of all the rest. The gold-leaf, which is sold in books, is so extremely thin, that less than five grains cover a surface of about $272\frac{1}{4}$ square inches; and the thickness of each leaf does not exceed $\frac{1}{282000}$ th part of an inch. All the metals, however, are not malleable. Gold, platina, silver, palladium, mercury, (in its frozen state,) copper, iron, lead, tin, zinc, and nickel,* are the ones to which this property belongs. The rest, on account of their brittleness, were formerly called *semi-metals*. But since, even in these, a diminishing progression of malleability may be observed, the distinction, though retained in common language, is very properly rejected from chemical and mineralogical systems.

8. All the metals that have been described as malleable (with the exception, perhaps, of nickel) are also *ductile*, or may be drawn drawn out into wire. In this respect, also, gold appears to take precedence of the rest, for it may be drawn out into wire not thicker than a human hair.

9. Wires of the same diameter, but of different metals, are found to be incapable of sustaining very different weights. This arises from their variable *tenacity*, which is estimated by gradually adding weights till the wire is broken. From the experiments of Guyton Morveau, the following are the utmost weights, which wires of 0.787 of an English line in diameter can support without breaking.

	lbs. deul. avoird. 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†

* On the authority of Richter.

† 71 Ann. de Chim. 189.

The tenacity of tin is greatly inferior to that of gold; and lead has still less tenacity than tin, and even than some sorts of wood.

10 Some of the malleable and ductile metals have, also, a high degree of *elasticity*. This property fits them for being applied to the mechanical purpose of springs. Steel and iron are, in this respect, superior to all other metals.

Besides the circumstances of agreement in their physical qualities, which have been enumerated, the metals resemble each other, also, in their chemical properties. Some of these resemblances it may be proper to state, for the purpose of avoiding unnecessary repetitions.

The metals, so far as we know at present,* are simple or elementary bodies, and may be arranged in the class of simple combustibles. They were formerly, indeed, considered, but on very insufficient evidence, as composed of a combustible base, peculiar to each metal, united with a general principle of inflammability, which received the name of *phlogiston*. When the metals are exposed to a strong heat, the first change which is produced in them is that they melt, or run into fusion. This effect takes place, in the different metals, at very different temperatures. Some of them may be made to boil, and are actually converted into vapour, at a heat considerably below redness; while others require a very intense heat for their fusion. By a sufficient elevation of temperature, it is probable, however, that they would all be volatilized; for platinum itself, which does not melt at a less heat than 176° of Wedgwood, has been observed to boil, when placed in the focus of a powerful burning lens.† In some of the metals, no farther change is produced by the application of heat with the free access of air; and they return, on cooling, to their former condition. But other metals undergo a very remarkable change. Their cohesion, lustre, malleability, tenacity, and all the properties that have been described as characteristic of them, are destroyed. Though their *absolute* weight is increased, yet they become *specifically* lighter, and they are distinguished by a new train of properties not observed in the metals themselves.

These changes have been very differently explained, at different periods in the history of chemical science. On the theory of phlogiston, they were accounted for by assuming that the metals, during the process of exposure to air at a high temperature, abandon their phlogiston, which, it was supposed, unites with the air and renders it *phlogisticated*, and consequently unfit for supporting the combustion of other inflammable bodies. The hypothesis, however, could no longer be maintained, when it was proved that the

* "So far as we know." This must be admitted not to be proof! but since the metals are inflammable, it is presumable, although not perhaps at present capable of demonstration, that, like other bodies of that nature, they owe their inflammability to a certain principle common to them all; which principle is most probably hydrogen, or as it should be more appropriately denominated, phlogiston. The evidence of such a principle in metals, appears fully to balance what is stated against it. C.

† Annales de Chimie, lxi. 92.

metals, so far from losing weight, become heavier after the operation; and though various attempts were made, by modifications of the theory, to accommodate it to this fact, yet none of them can be considered as having been at all successful.*

The theory, which is now almost universally admitted, as best explaining the phenomena in question, though suggested by the hints furnished by preceding discoveries, was first reduced to a systematic and consistent form by Lavoisier. The metals, according to the views of this enlightened philosopher, undergo the changes that have already been described, in consequence of the absorption of oxygen from the air. Hence, while the metallic body becomes heavier, the air, in which the process is performed, should sustain a proportional diminution of weight. That this is the fact, admits of being demonstrated; and still more readily and satisfactorily, if we employ oxygen gas instead of common air. A certain quantity of gas (or the whole indeed, under favourable circumstances) disappears; and the increase of weight in the metal is found, on examination, to be precisely† equal to that of the gas which has been condensed. In some cases, we can even go farther; and separate the oxygen from the metal by the mere application of heat, the oxygen being recovered in the state of gas, and the metal returning to a metallic state. More satisfactory evidence than this could scarcely be required of the nature of the change which takes place; and it may be admitted, therefore, as an established truth, that metals lose their metallic form, in consequence of their combination with oxygen. The process has been called by Lavoisier *oxidation*, and the result of it an *oxide*. For the former term, however, Mr. Chenevix, influenced by reasons which are stated in his work on chemical nomenclature, has proposed to substitute that of *oxidizement*. In the following pages, I shall employ both these expressions indiscriminately.

The phenomena and results of the oxidizement of metals are not the same in all cases, but differ very considerably with respect to different metals.

1. Some metals are oxidized by mere exposure to atmospheric air at the ordinary temperature, and even to air which has been de-

* After the proof given on a former occasion, that the junction of only $\frac{1}{12000}$ part of ammonium, (or of some principle connected with it) to mercury, diminished the specific gravity of that metal from 13.5 to less than 3, we are not to be surprised at any changes that may result from chemical combination. That light and caloric, are undoubtedly principles of levity, if the doctrines of the French school are all well founded, can scarcely be denied; since in all the processes detailed by Lavoisier, in which continual torrents of heat and light escape, the substances operated on, were absolutely of equal weight, after, as before. If these substances are material, must we not consider them as possessing weight? However inappreciable that weight may be, we must either admit that in the operations referred to, weight, to the extent of their loss, must have been sustained; or consider them, like the old phlogiston, principles of absolute levity! C.

† The loss of caloric and light from the oxygen gas, to the contrary notwithstanding! C.

prived of its hygrometric water.* Arsenic, manganese, and the new metals discovered by Sir H. Davy, are perhaps the only ones, which have been proved to possess this property. Others, it is true, as lead and copper, are changed by the action of the air, but extremely slowly, and not without the conjoined operation of moisture.

2. Other metals undergo this change, but not without a considerable increase of their temperature. Iron, zinc, copper, tin, &c. when heated to redness, lose their metallic lustre, and are slowly converted into variously coloured oxides. In some instances, the process is accompanied with so abundant an extrication of light and heat, as to exhibit a vivid inflammation. This happens, chiefly, with some of the volatile metals. Arsenic and zinc, for example, when projected into a red-hot crucible, emit a brilliant flame. In other metals, the process is unaccompanied by any remarkable phenomena, and is known to have taken place only by its results.

To convert the metals into oxides, there is a *degree* of heat, which is peculiar to each metal, and even to different oxides of the same metal. Mercury, for example, is oxidized, at a degree of heat, which produces no change on iron; and lead at one degree of temperature becomes minium, at another massicot.

3. With the exception of mercury, the metals, which have been called perfect, (comprehending, also, gold, platina, silver, and palladium,) are not oxidized, even by the combined operations of air and of an increased temperature. Gold, silver, and other metals of this kind, may be kept for many days in fusion, without undergoing any change. That they have an affinity, however, for oxygen, and are even capable of taking it from atmospheric air, is proved by the effect of an electrical or galvanic battery. By the former, the wires of the perfect metals are, at the same moment, dispersed into smoke and oxidized; and by transmitting a powerful discharge, through any of the perfect metals beaten into thin leaves, the metal burns with a remarkable degree of splendour.

4. All metals that are oxidized by atmospherical air, are still more readily oxidized by oxygen gas. In many cases, a metal, which undergoes this change slowly and invisibly by the action of air, takes fire in oxygen gas, and exhibits a bright inflammation. For example, it has already been shown, that an iron wire may be entirely consumed in oxygen gas.

These are the most simple cases of metallic oxidizement. In order that the changes, which have been described, may take place, it is only necessary that there should exist a stronger affinity between oxygen and the metal, than between the oxygen and light (and perhaps the electricity) which constitute the gas. In other cases, the phenomena are more complicated, and the metal acquires oxygen by the decomposition of some other compound. Of these sources of oxygen, the most important, if not the only ones, are water, the acids, and other oxides; or compounds containing one or more of these substances.

* This is not quite so admissible. It would be perhaps difficult to prove the complete privation of water in the air. C.

I. Water gives up its oxygen to those metals only, which manifest a powerful affinity for that basis, and, generally speaking, to those which are most efficient in decomposing atmospherical air. The newly discovered metals of Sir H. Davy decompose it with a rapidity, which amounts to actual inflammation; but, in general, the change is slow at common temperatures. Iron filings, for example, when moistened with water, and confined in an inverted jar over mercury, become very gradually oxidized, and evolve hydrogen gas. But water, brought into contact with red-hot iron, is rapidly decomposed, and hydrogen gas is disengaged in torrents.

II. All those acids, in which oxygen has been proved to exist, and especially those which Dr. Thomson has called *supporters of combustion*, and the neutral salts containing them, are efficient means of oxidizing the metals. In general, the less strong the affinity of the acid base for oxygen, the more rapidly is the metal oxidized. Those acids, that have not been proved to contain oxygen (except the oxymuriatic, the presence of oxygen in which is still a subject of controversy) are remarkably inert in their action on metals; and the same inactivity belongs to other acids, in which the oxygen and base are held combined by a powerful affinity. Thus concentrated sulphuric acid, at the temperature of the atmosphere, scarcely attacks any of the metals; because the oxygen and sulphur, of which it consists, forcibly attract each other. On the other hand, the nitric and nitro-muriatic acids, in which there exists a large quantity of loosely combined oxygen, readily abandon a part of it, and act on the metals with considerable energy.* Even the perfect metals are oxidized by the last acid; and thus we obtain proof that the resistance, which the perfect metals show to the action of oxygen gas, is not owing to their want of affinity for that basis, but to the predominance of other opposing forces.

Some of the acids, which do not, in their concentrated state, act upon metals, acquire the power of oxidizing them when diluted with water. This is true of the sulphuric and muriatic acids, to either of which we may apply iron or zinc, without any change ensuing. But on adding water, the metal disappears, and hydrogen gas is abundantly evolved. Now it is a principle, to which no exception has yet been discovered, that a metal cannot, in its perfectly metallic state, unite with any acid. In order to be dissolved, it must first be brought into the state of an oxide; and in the case which has been just now stated, no substance, capable of furnishing oxygen, is in contact with the iron except water. As an additional proof that water is, in this instance, the source of the oxygen, it has been ascertained that no portion of the acid is decomposed; but that the same quantity of acid exists in combination with oxide of iron, as was originally submitted to experiment.†

* And if on metals, why is it to be denied in the case of procuring nitrogen from flesh? C.

† The observations formerly made respecting the denial of the decomposition of nitric acid, in procuring nitrogen from flesh, will equally apply here. It is, I think, absolutely impossible to credit the *necessity* of the presence of the

By measuring the quantity of hydrogen gas, evolved in experiments of this kind, it is not difficult to calculate how much oxygen the metal has acquired; since every 100 cubic inches of hydrogen gas indicate the transference to the metal of about 17 grains of oxygen. Equal weights of different metals evolve different quantities of hydrogen gas, in consequence of their combining with different quantities of oxygen. If one metal, for example, in order to become soluble in sulphuric acid, require 40 per cent. of its weight of oxygen, and another only 20 per cent., the former will disengage twice as much hydrogen gas as the latter. The same metal, also, in different states, may evolve different quantities of hydrogen. If for example, the metal be already a little oxidized, it will set at liberty less hydrogen than if it were perfectly metallized. On this principle, the different proportions of real metal in several varieties of iron and steel have been investigated, the most perfectly metallized iron yielding, of course, the most hydrogen gas.

The phenomena, observed during the solution of a metal, and those attending the solution of its oxide, in the same acid, are essentially different. For the most part, a metal is dissolved with effervescence, an appearance always occasioned by the escape of gas. Iron, it has already been stated, effervesces strongly during its solution in dilute sulphuric acid; but the black oxide of that metal is taken up silently, and without any discharge of gas.

III. The metals may be oxidized by the transfer of oxygen from other metallic oxides. Thus when iron filings are distilled with the red oxide of mercury, the oxygen passes to the iron, and the mercury is revived or appears in a metallic state. In a similar manner, the oxides held in solution by acids, are decomposed by immersing, in the solution, other metals. When copper, for example, is immersed in a solution of nitrate of mercury (consisting of oxide of mercury and nitric acid) the latter metal is deprived of its oxygen by the former, and appears on the surface of the copper in a revived state. The nitrate of copper, which is thus produced, is precipitated by iron, which has a stronger affinity than copper for oxygen. A variety of similar examples might be given, in which the precipitating metal takes oxygen from that which is precipitated. In cases of this sort, it must be confessed that the comparative affinities of the acid for the oxides of the two metals have some share in the effect, but much less than the affinities of oxygen separately considered. The precipitated metal, also, is seldom quite pure, but contains a portion of the metal, which has caused the precipitation.

By an attentive examination of facts of this kind, Lavoisier has been able to deduce the proportion of oxygen necessary to the solution of different metals, according to this analogy: *As the quan-*

acids, (which yet we know to be the case) if their decomposition is denied. The doctrine of disposing affinities, brought forward by most writers to explain the processes stated, has justly been called absurd, by Dr. Henry. Nor am I disposed to admit the fact of the exact quantities of acid *after as before*, without the experiment being accurately repeated. C.

tity of the PRECIPITANT is to that of the PRECIPITATED metal, so is the quantity of oxygen necessary for the solution of the precipitated to that necessary for the solution of the precipitant. Thus it has been found by experiment that 135 grains of mercury are necessary for the precipitation of 100 grains of silver from the nitric acid. It is evident, then, that 135 grains of mercury require, to become soluble, the same quantity of oxygen as 100 grains of silver; and, therefore, as 100 to 135, so is the quantity, necessary to render soluble 100 grains of mercury, to that necessary for the solution of 100 grains of silver. Now eight grains of oxygen are necessary to the solution of 100 grains of mercury; and therefore 10.8 grains are required for the solution of 100 grains of silver. By an extension of the same experiments to other metals, Lavoisier formed a table of the quantity of oxygen necessary for the solution of all the metals; but I omit giving it in this place, because subsequent discoveries have pointed out several inaccuracies, which it contains.

Such are the principal means of effecting the oxidation of metals. Different individuals of the class, it has already been stated, combine with different proportions of oxygen; and the same metal, it may now be added, is susceptible of different degrees or stages of oxidation. Iron, for example, when united with oxygen in the proportion of 29.5 grains to 100 grains of metal, composes a *black* oxide; and with 43.5 parts of oxygen to 100 of metal, it constitutes a *red* oxide. These different oxides of the same metal have not only different colours; but each of them is characterized by a distinct train of chemical properties, and especially by different habits with respect to the acids. Thus the black oxide of iron readily unites with muriatic and sulphuric acids; but the red oxide less easily. The salts with base of the first oxide afford a white precipitate with triple prussiate of potash; and none at all with the gallic acid, or with sulphuretted hydrogen. But the salts, in which the iron is at the maximum of oxidation, give a deep blue compound with the triple prussiate, and a black one with the gallic acid.

It is an interesting question, whether the same metal is capable of uniting with oxygen, in all proportions between the maximum and minimum, or whether it does not rather combine with that principle in a few proportions only, between which there are no intermediate compounds. Are there, for example, only two oxides of mercury, the *black*, consisting of 100 parts of metal united with four of oxygen; and the *red*, composed of the same quantity of metal and eight parts of oxygen? The determination of this point requires more precise and multiplied appeals to experiment, than have hitherto been made. But in a great variety of cases, where the question has been accurately investigated, different oxides of the same metal do appear to contain oxygen, in proportions which are simple multiples of each other; and the fact will probably be established with respect to all other oxides. It is by no means necessary, however, that the possible number of oxides of any one metal

should be limited, as Proust has supposed, to two; for it is perfectly consistent with the atomic hypothesis that there may be three, four, or even a greater number.

It had been long known that of different oxides of the same metal, the one which contains a larger proportion of oxygen is capable of saturating more acid, than the one which contains less. Two of the illustrations, which are given of this principle, are furnished by the muriates of copper and the muriates of mercury. Corrosive muriate of mercury is composed of the red oxide of that metal, united with muriatic acid; and the sub-muriate (calomel) consists of the black oxide, combined with the same acid. Now it is remarkable that, according to the experiments of Thénard, the oxygen in the red oxide is just double of that in the black; and that the acid in the corrosive muriate is, also, precisely double that in the sub-muriate. Similar facts have been ascertained by Proust, with respect to the two muriates of copper, as appears from the following statement.

The green { 100 copper.
muriate { 24.57 oxygen.
consists of { 83.18 acid.

The white { 100 copper.
muriate of { 12.28 oxygen.
of { 41.59 acid.

The same law appears, also, from the experiments of Sir H. Davy, to hold good with respect to the oxides of potassium and sodium. To this principle, an important addition has lately been proposed by Gay Lussac,* and supported by a variety of illustrations; viz. *that the quantity of acid, which different metals require for saturation, is in direct proportion to the quantity of oxygen in their oxides.* Let us suppose, for example, that of any two metals, A combines with twice as much oxygen as B; then, a given weight of the oxide of A will neutralize twice as much acid as an equal weight of the oxide of B.

The solubility of the metallic salts, it has been observed by Gay Lussac, bears a proportion to the quantity of oxygen in the oxides; and consequently to the quantity of acid, with which that oxide is combined. Salts, in which the metal is at the minimum of oxidation, are generally those which are most insoluble. This is the fact with respect to the salts of lead, silver, and mercury; for these are metals which, at the minimum of oxidizement, take very little oxygen, and consequently very little acid. Corrosive muriate of mercury, also, which contains the largest proportion of oxygen and acid, is much more soluble than the submuriate, in which both the oxygen and acid are present in considerable less quantity.

An important law has been deduced by Berzelius† from the com-

* Mémoires d'Arcueil, ii. 159, or 37 Phil. Mag. 200;

† 79 Ann. de Chim. 127.

parison of a great number of facts; viz. that in all neutral salts, the oxygen of the acid is a multiplication of that of the base by some entire number. The law, he apprehends, may be expressed more generally in the following terms. *When two oxidated substances enter into a neutral combination, the oxygen of that which, in a galvanic circle, would be attracted to the positive pole, is a multiplication, by an entire number, of the oxygen of that, which would be deposited at the negative pole.* For example, 279 parts of protoxide of lead contain 19.95 parts of oxygen, and saturate 100 parts of sulphuric acid, which contain 59.85 parts of oxygen. Now the oxygen of the oxide $19.95 \times 3 = 59.85$, which is precisely the oxygen of the acid. The same coincidence holds good in a variety of other instances.

There is a certain state of oxidation, peculiar to the different metals, in which they are most readily acted upon by the several acids. Iron and manganese, for example, at the maximum of oxidizement, are altogether insoluble in nitric acid; but readily dissolve in it, when combined with a smaller proportion of oxygen. Even when once brought into combination with that acid, the oxide, by attracting a farther quantity of oxygen, from the atmosphere or from any other source, is separated in the state of an insoluble precipitate. This principle explains the change, which is produced in solutions of iron, by keeping them exposed to air. The oxides of iron and manganese, saturated with oxygen, are soluble, however, in the less oxygenated acids; for example, in the sulphurous or nitrous, which first deprive the oxide of part of its oxygen, and then dissolve the less saturated oxide.

Beside the class of acids, which are the best solvents of the metals, alkaline solutions act upon metallic substances. The water, which holds the alkali in solution, is decomposed; its hydrogen is disengaged, and its oxygen transferred to the metal; and the oxide, thus produced, is taken up by the alkaline liquor. The oxides ready formed, are also, in several cases, dissolved by liquid alkalis. When a pure alkali is added to a metallic solution, the metal is precipitated in the state of an oxide; but the precipitate is seldom quite free from alkali, and the metallic oxide, in a few instances, instead of appearing in a separate form, is dissolved by the alkali. When alkaline carbonates are employed instead of pure alkalis, for the precipitation of metallic solutions, the oxide combines with carbonic acid, and appears in the state of a metallic carbonate.

The compounds of ammonia with metallic oxides are of more importance than those of the other alkalis, and have obtained the generic name of AMMONIURETS. They may be formed, either by acting on the metals with liquid ammonia, the water in which is decomposed and furnishes a metallic oxide, which unites with the alkali. Or they may be produced, by exposing the oxides to ammoniacal gas, at the temperature of the atmosphere. At least fifteen oxides, or rather hydrated oxides, may be brought into combination with ammonia, viz. oxide of zinc; deutoxide of arsenic; both the oxides of copper; oxide of silver; tritoxide and tetrox-

ide of antimony; oxide of tellurium; protoxides of nickel, cobalt, and iron; peroxide of tin; deutoxide of mercury; and deutoxides of gold and platina.

The ammoniurets are decomposed by a strong heat; the oxygen of the oxide uniting with the hydrogen of the alkali, and the azote of the latter being set free. In some cases, as in that of ammoniuret of gold, this decomposition is attended with a loud explosion.

The oxides, existing in metallic solutions, are decomposed by inflammable substances. Light only is sufficient for the decomposition of some of them. Hydrogen gas, charcoal, sulphur, phosphorus, and the compounds of hydrogen with the three last bodies, when brought into contact with the solutions of perfect metals at common temperatures, attract the oxygen from the metal, and occasion its appearance in a metallic form. In this way, several beautiful appearances may be produced, which will be described in treating of the individual metals.

The oxides themselves are decomposed when exposed to a strong heat in contact with hydrogen, charcoal, or phosphorus. The two first, or substances containing them, are chiefly employed for the decomposition of those oxides, which occur as natural productions. The oxide, mixed with a portion of inflammable matter, is exposed to an intense heat; and, in order to obtain it in a coherent mass, and not in the small grains which would otherwise be formed, some substance is generally added, which is capable of being melted, and of allowing the metal to subside through it. Substances of this kind are called *fluxes*, and the process is termed the *revival* or *reduction* of the metal.

If only one oxide had existed of each metal, it would have been easy, by applying the general principles of chemical nomenclature, to have distinguished them by names sufficiently expressive of their composition. But as the metals are susceptible of several stages of oxidizement, it is difficult to find terms, which sufficiently express the characteristic distinctions of several oxides of the same metal. The existence of only two oxides would have greatly simplified their nomenclature; for, in this case, we might have applied the term *oxide* to the metal fully saturated with oxygen, and of *oxidule* to the compound at an inferior stage of oxidizement, as has been done by several of the French chemists. In the present state of the science, however, this nomenclature is inadmissible; and the specific name has been derived from some external character, chiefly from that of colour. Thus we have the black and red oxides of iron; and the black and red oxides of mercury. In some instances, the denominations, which have been proposed by Dr. Thomson for the metallic oxides, may be advantageously adopted. When there are several oxides of the same metal (supposing that the proportions of oxygen and metal in each are definite) he has proposed the terms *protoxide*, *deutoxide*, *trioxide*, &c., signifying that the metal is in its first, second, or third stage of oxidizement. Or if two oxides only of any metal are

known, he suggests the appellation of *protoxide* for that at the minimum, and of *peroxide* for that at the maximum of oxidation.

A similar difficulty has been experienced, also, with respect to the neutral salts with metallic bases; for when different oxides of the same metal combine with a given acid, the resulting salts require to be distinguished by appropriate names. This has sometimes been done by prefixing the word oxygenized (or for brevity oxy-) to the salt containing the most highly oxidized metal; as the muriate and oxy-muriate of mercury. The latter term, however, is improper; because, in strictness, it can only be applied to the compounds of oxy-muriatic acid with different bases; whereas what is meant to be expressed is merely a compound of ordinary muriatic acid, with mercury in its highest state of oxidizement. If the principle, assumed by Gay Lussac, should be confirmed by farther investigation (*viz.* that the acid in metallic salts is proportional to the oxygen in the oxides), it will be more easy to derive a specific name from the proportion of acid than from that of oxygen. Thus we shall have the muriate and submuriate of mercury. But till greater precision is acquired in our knowledge of this class of bodies, it may be well to continue to derive the specific name of the salt from some obvious quality; as the *green* and *red sulphates of iron*, the *white* and *green muriates of copper*, &c.

The following Table exhibits, at one view, the composition of most of the metallic oxides.

Table shewing the Proportions of Oxygen with which the Metals combine.

Metals.	No. of Oxides.	Colour of Oxides.	100 of Metal take Oxygen.	Authority.
Gold	1	Brownish black	10.01	Oberkampff.
Platina	1	Black	8.287	Berzelius.
	2	..	16.38	
Palladium	1	..	14.209	Ditto.
Rhodium	1	..	6.71	Ditto.
	2	..	13.42	
	3	..	20.13	
Iridium	1	Blue	..	Tennant.
	2	Red	..	
Silver	1	Olive	7.925	Berzelius.
Mercury	1	Black	4	Thenard.
	2	Red	8	
Copper	1	Red	12.5	Proust and Berzelius.
	2	Black	25.	

Metals.	No. of Oxides.	Colour of Oxides.	100 of Metal take Oxygen.	Authority.
Iron	1	Black	29.5	Berzelius.
	2	Red	44.25	
Tin	1	Grey	13.5	Gay Lussac.
	2	White	27.	
Lead	1	Yellow	7.70	Berzelius.
	2	Red	11.08	
	3	Puce	15.60	
Nickel	1	Ash grey	27.	Tupputi. Thenard.
	2	Black	unknown	
Zinc	1	White	24.41	Gay Lussac.
Bismuth	1	Yellow	11.28	Lagerhielm.
Antimony	1	Dull white	18.60	Berzelius.
	2 (acid)	Snow white	27.90	
	3 (acid)	Yellow	37.20	
Arsenic	1 (acid)	White	34.93	Dr. Thomson.
	2 (acid)	Ditto	52.4	
Cobalt	1	Blue	19.8	Proust.
	2	Black	33.25	
Manganese	1	Green	14.05	Dr. John. Berzelius.
	2	..	28.10	
	3	..	42.16	
	4	Black	56.21	
Molybdena	1	Blue	34.	Bucholz.
	2 (acid)	White	50.	
Tellurium	1	Yellowish	20.5	Klaproth
Tungsten	1	Black	..	Bucholz.
	2 (acid)	Yellow	25.	
Uranium	1	Black	..	Ditto.
	2	Yellow	25.	
Titanium	1	Blue	..	Vauquelin.
	2	Red	..	
	3	White	..	
Tantalum	..	White	..	
Cerium	1	White	17.41	Hisinger.
	2	Fawn	26.115	

Many of the metallic oxides have an attraction for water, which they manifest by being soluble in it, or by reducing it to a solid or gelatinous form. The soluble oxides are potash, soda, barytes, strontites, and lime; the deutoxide of arsenic, and the oxide of osmium. There are a few others, which are soluble in a very small degree, not exceeding one thousandth of the weight of the water, viz. oxide of molybdena, deutoxide of mercury, tritoxide and tetroxide of antimony.

The compounds of oxides and water, in which the latter exists in a condensed state, are termed *HYDRATES*, or *HYDRO-OXIDES*.* The hydrates of potash, soda, and barytes retain the water which constitutes them such, at the temperature of ignition, and it can only, indeed, be expelled by bodies that have a stronger affinity for the alkali or earth. The hydrates of the remaining earths are decomposed by the heat of ignition. The hydrated oxides of the common metals are obtained, by adding a solution of pure potash, soda, or ammonia, to the solution of the oxide in sulphuric, muriatic, or nitric acid. The precipitate, washed repeatedly with water, is to be collected on a filtre; and, if dried, the heat employed must be as gentle as possible; for a slight elevation of temperature is sufficient to expel the whole water, and to leave only an oxide.

The hydrated oxides are, for the most part, much more soluble in acid than the oxides. According to Berzelius, they are definite compounds, in such proportions, that the oxygen of the water is equal in weight to that of the oxide. This principle requires, however, to be established by a greater number of facts.

Beside the important class of compounds, which result from the union of metals with oxygen, the metals are capable, also, of entering into combination with hydrogen, sulphur, chlorine, phosphorus, and charcoal. They afford, also, by uniting with each other, an interesting class of compounds called *metallic alloys*.

I. THE COMPOUNDS OF METALS WITH HYDROGEN are neither numerous nor of much importance. When water is decomposed by certain metals, at the same time that the oxygen combines with one portion, the hydrogen, which is disengaged in the state of gas, takes up a minute quantity of metal. This is the case, in a small degree, with iron; still more with zinc; and most remarkably with arsenic and tellurium, both of which afford compounds, having several remarkable properties.

II. THE COMBINATIONS OF METALLIC BODIES WITH SULPHUR have been divided by Vauquelin† into three classes, viz. 1st, the compounds of metals with sulphur, which alone are with propriety called *sulphurets*; 2dly, the compounds of sulphur with metallic oxides termed *sulphuretted oxides*; and 3dly, those of sulphuretted

* Here we again find the adjunct *Hydro-* for the fourth time. Surely we ought to employ terms sufficiently distinct to characterize the combinations of hydrogen and of water. Our nomenclature, with all its beauties, is miserably defective in perspicuity on many occasions. C.

† Annales de Chimie, xxxvii. 57.

hydrogen with metallic oxides, which may be called *hydro-sulphuretted oxides*.

1. All the metals, with the exception of gold, zinc, and tin, are, in their metallic state, susceptible of combination with sulphur. In order to effect their union, it is sufficient that one of the bodies be brought into a fluid state; and as sulphur is readily fusible, a very moderate heat only is required for the purpose. Thus a mixture of 45 parts of iron filings with 15 of sulphur, or of 40 parts of copper filings with 15 of sulphur, when heated in a glass tube, combines, the moment the fusion of the sulphur is accomplished. The phenomena are very remarkable, consisting in a sudden and bright glow, like that of intense ignition. During combination, however dry the materials may have been, it appears from the experiments of Mr. Clayfield,* that a quantity of elastic fluid is liberated, amounting to nine or ten times the bulk of the mixture, and consisting of sulphuretted hydrogen and sulphurous acid. The former probably arises from the sulphur, and the latter from the metallic filings, which may have been partially oxidized by the process of washing and drying.

In these compounds, the properties of the metals cease to be apparent; for the sulphurets are brittle; have colours different from those of the metals; and, when artificially formed, are destitute of lustre. The quantity of sulphur, with which different metals are capable of uniting, varies with each metal. The same metal, also, in some instances, is susceptible of combination with different quantities of sulphur, and of affording compounds, characterized by a distinct train of properties. Thus the compound of 100 parts of iron with 58½ of sulphur is brittle and of a dark grey colour; has little or no lustre; and is attracted by the magnet. But 100 parts of iron with 117 of sulphur form a yellow compact compound, of sufficient hardness to strike fire with steel; and having so much lustre, as to have been often mistaken by the ignorant for gold. When different sulphurets of the same metal exist, the sulphur, in those which contain the larger proportion, is an exact simple multiple of the sulphur in those which contain the less.

The following Table exhibits the composition of several of the metallic sulphurets:

100 Parts of		Unite with Sulphur.		Authority.
Gold	. . . . .	24.39	. . . . .	Berzelius.
Platina 1st.	. . . . .	8.287	. . . . .	Ditto.
—— 2d.	. . . . .	16.38	. . . . .	Ditto.
Palladium	. . . . .	14.209	. . . . .	Ditto.
Silver	. . . . .	14.9	. . . . .	Ditto.
Copper	. . . . .	25.6	. . . . .	Ditto.
Iron 1st.	. . . . .	58.75	. . . . .	Ditto.
—— 2d.	. . . . .	117.	. . . . .	Ditto.

* Note to Mr. Davy's paper on alkalis. (Philosophical Transactions, 1808.)

100 Parts of		Unite with Sulphur.	Authority.
Tin	1st.	27.234	Dr. John Davy.
	2d.	54.5	Ditto.
Lead		15.92	Berzelius.
Nickel	1st.	51.5	E. Davy.
	2d.	77.	Ditto.
Zinc		48.84	Dr. Thomson.
Bismuth		22.52	Lagerhielm.
Antimony		37.25	Berzelius.
Arsenic	1st.	33.3	
	2d.	75.	
Cobalt		39.8	Proust.
Molybdenum		67.	

Metallic sulphurets can only be partially decomposed by heat; and though this assertion appears to be contradicted by the effect of roasting these compounds; yet it is to be considered that the metals, when heated with the contact of air, absorb oxygen, and thus lose their affinity for sulphur. The sulphuret of one metal may, in many instances, be decomposed by another metal. Thus when sulphuret of mercury is distilled with a proper proportion of iron filings, the sulphur passes to the iron, and the mercury comes over in a metallic state.

Concentrated sulphuric acid* with the assistance of heat, acts upon metallic sulphurets, and is converted into sulphurous acid, which, being volatile, escapes. Metals which, in their separate state, were dissolved by dilute sulphuric acid, continue sensible to its action, after being combined with sulphur. When dilute sulphuric acid, however, acts on such compounds, instead of hydrogen gas simply, we obtain sulphuretted hydrogen. It is chiefly the compounds with the minimum of sulphur, that produce this effect; for the *super-sulphurets*, or those containing a farther proportion of sulphur, resist the action of this solvent.

Concentrated muriatic acid has no effect on sulphurets; but the diluted acid acts like the diluted sulphuric. Nitric acid is decomposed by the metallic sulphurets; nitrous gas is disengaged; and sulphur is precipitated.† In this case, though all nitric acid contains water, yet sulphuretted hydrogen is not formed, because the acid yields its oxygen more easily than water.

Sulphurets, composed of metals, which powerfully attract oxygen, and the oxides of which have moreover an affinity for sulphuric acid, absorb oxygen from the atmosphere, and pass to the state of *sulphates*. In this way most of the sulphate of iron is formed, which occurs in commerce. But if the metal has either a strong affinity for sulphur, or a weak one for oxygen, then the conversion into a sulphate does not happen, as in the sulphurets of copper, antimony,

* Berthollet, *Annales de Chimie*, xxv. 256.

† Vauquelin, *loc. cit.* 65.

and mercury.* The sulphuret of iron containing a full proportion of sulphur resists, also, the conjoined action of air and moisture.

2. In general, the metals have a stronger affinity than their oxides for sulphur. But there are a few cases, in which certain metals are incapable of combining with sulphur, till they are brought into the state of oxides. These are chiefly zinc, mercury and manganese, the compounds of which with sulphur may be called *sulphuretted oxides*. Other metals, also, are capable of affording similar compounds; but in general their affinity for sulphur diminishes, in proportion to the quantity of oxygen which they hold in combination.

These compounds act on acids, somewhat differently from the mere sulphurets. If the metal be only oxidized at its minimum, they yield sulphuretted hydrogen with diluted muriatic and sulphuric acids, and nitrous gas with nitric acid. But in their perfectly oxidized state, they dissolve without effervescence, and the sulphur remains unaltered.

3. Sulphuretted hydrogen enters into combination with a few of the metals, with mercury and silver for example; but it unites, in general, more readily and permanently with their oxides. From such compounds the sulphuretted hydrogen is detached in a gaseous state by some concentrated acids, which seize the metallic oxide. Most of the sulphuretted oxides, also, undergo, in process of time, spontaneous decomposition, in consequence of the union of the hydrogen and oxygen which they contain, and which, by combination, form water. When this happens, the oxide is partly reduced, and the sulphur unites with the deoxidized metal. Hence the same sulphuretted oxide varies in composition, according to the period which has elapsed since its preparation.

When we precipitate a metallic solution by sulphuretted hydrogen alone, or by its compounds with alkalis, we obtain either a metallic sulphuret or a hydro-sulphuret. In the first case, the hydrogen of the sulphuretted hydrogen takes all the oxygen of the oxide; and the sulphur forms a true sulphuret with the reduced metal. In the second case, the sulphuretted hydrogen unites directly with the oxide, without decomposing it, and its proportion is such that the hydrogen is sufficient to saturate all the oxygen of the oxide. The quantity of hydrogen, then, which is destroyed, or may be destroyed, depends on the state of oxidizement of the metal, and so also does the quantity of sulphur. Now if metals, as appears probable, are susceptible of oxidation in only a few determinate degrees, it follows that by precipitations of this kind, we may obtain metallic sulphurets with fixed proportions, which may be easily calculated from the known quantity of oxygen in the oxide, and the known composition of sulphuretted hydrogen.† Thus the law of fixed proportions will be extended to the compounds of metals with sulphur; and another step will be made, towards establishing the

* Berthollet, loc. cit. 256.

† Gay Lussac, *Memoires d'Arcueil*, ii. 175.

important general principle in chemical philosophy, which has been so ably illustrated, in other cases, by Mr. Dalton.

4. Hydroguretted sulphurets of metals and their oxides may be obtained by precipitating metallic solutions with the hydroguretted sulphurets of alkalis. In sulphuretted oxides, it has been observed by Berzelius,* the oxygen of the oxide is to the hydrogen of the sulphuretted hydrogen, precisely in the proportion necessary to constitute water. The oxides of all metals, he adds, which have for oxygen a greater affinity than hydrogen has, may unite with sulphuretted hydrogen. In the compounds thus produced, the metal, sulphur, hydrogen, and oxygen exist in such proportions, that the oxygen is precisely sufficient to change the sulphur into acid, the metal into protoxide, and the hydrogen into water. But if the affinity of the metal for oxygen be inferior to that of hydrogen, the oxide is then reduced, and water and a sulphuret are generated. Thus the alkalis, the earths, and protoxides of zinc and manganese, afford, with sulphuretted hydrogen, saline combinations; but the oxides of lead and copper are decomposed by it.

It had been generally supposed that metals, which have a great affinity for oxygen, and which decompose water, (as manganese, iron, zinc, uranium, nickel, cobalt, &c.) are not precipitated from their solutions by sulphuretted hydrogen, except with the concurrence of double affinities. Gay Lussac, however, has shown† that the compounds of these metals with the weaker acids (as the acetic, tartaric, and oxalic) are decomposed by sulphuretted hydrogen, and produce hydro-sulphurets of the respective metals. When a still weaker solvent of the metal is employed, the decomposition is more easily effected. Thus the ammoniurets of iron, nickel, &c. are entirely decomposed by that gas; and this furnishes an excellent process for obtaining pure hydro-sulphurets; for the alkaline hydro-sulphurets, commonly employed for this purpose, are almost always contaminated with sulphur. Those metals which are not precipitable by sulphuretted hydrogen, become so, when acetate of potash is added to their solutions.

III. All the metals are susceptible of combinations with CHLORINE or OXYMURIATIC ACID. When exposed to the gas in a state of minute division, produced either by filing or beating them into leaves, they combine with it, for the most part, with the appearance of combustion. But silver, lead, nickel, cobalt, and gold unite with chlorine, without the extrication of heat and light.

The results of these combinations are differently explained in the old and the new theory. According to the former, the metal attracts oxygen from oxymuriatic acid gas; and the oxide unites with the muriatic acid. According to the new theory, the metal unites directly with chlorine; and the combustion is produced merely by the intensity of chemical action. Consistently with the former view, the products of the combustion should be called muriates. Conformably with the latter, we may either, with Sir H.

* 79 Ann. Chim. 129.

† 80 An. Ch. 205.

Davy, designate them by terminating the Latin name of the metal in *ane* or *anea*; or we may give them the appellation, *chlorides*; or, as Gay Lussac has proposed, that of *chlorures* or *chlorurets*.*

From the greater number of metallic oxides, chlorine expels the whole of the oxygen and takes its place; and when muriatic acid gas is made to act upon them water appears, and compounds are obtained, resembling those formed by the direct union of the metals with chlorine.

Chlorine combines with the metals in different proportions, which are expressed in the following Table of the result of experiments, carefully made by Dr. John Davy:

Metals.	Decl.		Decl.		
	Grains.	Pts.	Grains.	Pts.	
Copper . . .	60	+	32.77		Chlorine = Cuprane.
	67	+	67.20		Ditto = Cuprane.
Tin . . .	55	+	33.40		Ditto = Stannane.
		+	67.00		Ditto = Stannanea.
Iron . . .	29.5	+	33.60		Ditto = Ferrane.
		+	55.50		Ditto = Ferranea.
Manganese	28.4	+	33.60		Ditto = Mangesane.
Lead . . .	97.2	+	33.80		Ditto = Plumbane.
Zinc . . .	34.5	+	34.40		Ditto = Zincane.
Arsenic . .	21.9	+	33.6		Ditto = Arsenicane.
Antimony	42.5	+	34.60		Ditto = Antimonane.
Bismuth . .	67.5	+	34.20		Ditto = Bismuthane.

IV. IODINE when heated with the metals, combines with all of them, and forms a class of compounds called, by Sir H. Davy, *iodes*, and by Gay Lussac, *iodures* or *iodurets*. They are all insoluble, and when placed in contact with water decompose it; hydriodic acid and an oxide of the metal are formed; and these last, uniting together, compose a hydriodate.

V. Several metals have an affinity for phosphorus, and form a class of compounds called *METALLIC PHOSPHURETS*. The best method of effecting this combination is to expose the metals to heat, in contact with phosphoric acid and charcoal. The charcoal deprives the phosphorus of oxygen; and the de-oxygenized phosphorus unites with the metal. Metals, however, that have a strong affinity for oxygen, decompose the phosphoric acid, and unite with its base, without the intervention of charcoal. The metallic phosphurets have not hitherto been applied to any useful purpose; and it is sufficient, therefore, to refer to the description of them by

* If the principles upon which the present nomenclature of chemistry are to be considered as proper, we cannot well assent to the new terminations proposed by Sir H. Davy. That it however requires a complete revision, is I think demonstrated by the endless synonymes which are constantly introducing; and which greatly retard the progress of the science. Whether the terms of *chloride* or *chloruret* are more legitimate, must greatly depend on the issue of the dispute as to the nature of oxymuriatic acid. C.

Pelletier, in the first and thirteenth volumes of the *Annales de Chimie*.

VI. The compounds of metals with carbon are called CARBURETS. That of iron and carbon, the properties of which vary according to the proportion of the two ingredients, is the only one of importance. It will be described in its proper place.

VII. The metals are, for the most part, capable of uniting with each other. For this purpose, they require to be brought into a state of fusion; and, even when melted, considerable care is necessary to form a permanent compound. If one metal is considerably heavier than the other, it is apt to sink to the bottom of the fluid mass. Nothing can show this in a more striking manner, than a fact which has been stated by Mr. Hatchett. He found that when gold, which has been melted with a proportion of copper or other metals, is cast into bars, the moulds for which are placed vertically, the lower part of the bar contains more gold in proportion than the upper part.

There are a few of the metals that do not unite by being fused together. This is the case with lead and iron; but even in such cases we are scarcely, perhaps, entitled to deny all affinity; for some of the metals, which were formerly thought incapable of combination, have been made to combine by circuitous processes. This is the fact with respect to iron and mercury.*

In the new nomenclature, the word ALLOY is retained as a general term for all combinations of metals with each other; and the specific name is derived from that of the metal, which prevails in the compound. Thus in the *alloy of gold with silver*, the gold is to be understood as being in greatest proportion; in the *alloy of silver with gold*, the silver is the principal ingredient. The compounds of mercury with other metals, at a very early period of chemistry, were called AMALGAMS†, and as the name does not lead to any erroneous notions, it may still be retained to denote this sort of alloys.

The metals in general are capable of uniting with each other in unlimited proportions; but in a few instances, it appears probable, though it is not absolutely proved, that they unite in certain proportions only.

This proposition has been ably maintained by Berzelius, as well as by Dalton. Potassium, the former observes, gives with mercury two crystallized compounds, one of which contains twice as much potassium as the other. The *arbor Dianæ* is a definite compound of silver and mercury. When zinc and copper are distilled together, a certain quantity of zinc comes over, but the rest cannot be raised by heat. From a fused mixture of antimony, iron, and copper with much tin, metallic crystals separate on cooling,

* Aikin, in *Philosophical Magazine*.

† Although the name of amalgam does not lead to any erroneous idea, yet no good reason can be assigned for retaining it; the term alloy is so completely admitted to designate the combinations of metals amongst themselves, that when we can get rid of (at best) an useless synonyme, it seems proper to do so. C.

containing definitive proportions of the component metals. Whenever, indeed, the new compound has an opportunity of separating from the fused mass, it appears to be formed in established proportions.

By combination, the metals undergo a considerable change of properties, and acquire new ones, not observable in the separate metals.

1. The specific gravity of an alloy is seldom the mean of those of its component parts. Thus an alloy of silver with copper or tin, or one of silver or gold with lead, has a greater than the mean specific gravity. An alloy, also, of silver with mercury, though the former metal is specifically lighter than the latter, possesses so much acquired density as to sink in quicksilver. In other cases, on the contrary, the specific gravity of the compound falls short of the mean of that of its components, or there appears to be a degree of dilatation, as in the alloys of gold with copper, iron, or tin. To estimate exactly, however, either the increase or diminution of density, requires an attention to several circumstances.*

2. The ductility and malleability of metals is generally changed by combination; and, for the most part, these qualities are impaired. Even two metals, which separately are both malleable and ductile, are rendered brittle by combination. This is very remarkably the case with an alloy of gold and lead, the latter of which, even in the trivial proportion of half a grain to an ounce of gold, renders the alloy quite destitute of tenacity. In such cases, it has been supposed that a true chemical union does not take place, and that the newly added metal is merely mechanically interposed between the particles of the other, the cohesion of which it thus impairs. This explanation, however, can scarcely be admitted as satisfactory; and, among other arguments in proof of the existence of chemical union, it may be remarked, that gold is rendered brittle by being kept in fusion in the vicinity of melted tin, the vapour of which it seems capable of attracting.

3. The hardness of metals is varied by combination. Gold, by combination with a small quantity of copper, and silver by a minute proportion of the same metal, acquire such an increase of hardness, that these additions are always made to gold or silver which is to be exposed to wear. By a small addition of gold, iron is said to gain so much hardness, as to be even superior to steel for the fabrication of cutting instruments.

4. Change of colour is a common effect of the combination of metals. Arsenic, for example, which resembles steel, and copper which has a red colour, afford a compound which has nearly the whiteness of silver.

5. The fusibility of compound metals is different from what might have been inferred from that of their components. Platina, for example, is rendered easily fusible by arsenic, and a compound of lead, tin, and bismuth melts at a temperature below that of boiling water, though the most fusible of the three (bismuth) requires for

* See Aikin's Dictionary, article Alloy.

fusion a much higher degree of heat. This is the principle of *solders*.

6. Metals have their volatility increased by being combined with other metals, which are more volatile than themselves. Gold, separately, requires an intense heat for its volatilization; but when an amalgam of gold with mercury is distilled, a quantity of gold passes over with the quicksilver.

7. By chemical union with each other, the metals have their tendency to combine with oxygen considerably increased, partly in consequence of the diminution of their cohesion, but partly, also, perhaps, in consequence of their forming a galvanic combination. Lead, when amalgamated with mercury, is oxidized by merely shaking the compound with water. Lead and tin, melted together, acquire such an increase of affinity for oxygen, that, at the moment of combination, they actually inflame. By the oxidation of either ingredient in any of these alloys the compound is destroyed. The oxide of lead, for example, separates from mercury in the form of a black powder. Hence, also, a pellicle of oxide is generally observed on the surface of melted solders, which is renewed as soon as it is removed.

From a comparison of the resemblances among metals, both as to physical and chemical properties, several arrangements of them have been formed into smaller classes. Besides the subdivisions, which have been already mentioned, into noble and base metals, and into entire metals and semi-metals, other classifications have been contrived. Fourcroy has proposed to divide them into five orders. 1. The *brittle and acidifiable* includes four species, viz. arsenic, tungsten, molybdena, and chrome. 2. The *brittle and simply oxidizable* are seven (nickel having been transferred by Richter to a different class), viz. titanium, uranium, cobalt, manganese, bismuth, antimony, and tellurium. 3. The metals, that are *oxidizable and imperfectly ductile*, are mercury and zinc. 4. The *ductile and easily oxidizable* are tin, lead, iron, and copper. 5. The *very ductile and difficult of oxidization* are silver, gold, palladium, and platina.

A better arrangement, however, appears to me to be that which has been proposed by Dr. Thomson, in the third edition of his *System of Chemistry*. He divides the metals into four classes. The **FIRST CLASS** comprehends the *malleable metals*, which are fourteen in number, viz. gold, platina, silver, mercury, palladium, rhodium, iridium, osmium, copper, iron, nickel, tin, lead, and zinc. The **SECOND CLASS** includes the *brittle and easily fused*, viz. bismuth, antimony, tellurium, and arsenic. The **THIRD CLASS**, metals *that are brittle and difficultly fused*. These are cobalt, manganese, chrome, molybdena, uranium, and tungsten. The **FOURTH CLASS** are called *refractory metals*; because they have never yet been exhibited in a perfectly metallic form, but always in combination with more or less oxygen. These are titanium, columbium, and

cerium.* In this order, I shall now proceed to describe the individual metals.

FIRST CLASS.

MALLEABLE METALS.

SECTION I.

Gold.

To obtain gold in a state of purity, one part by weight may be dissolved in three of nitro-muriatic acid (composed of one part by weight nitric, and two muriatic acids.) To the clear liquid, a solution of green sulphate of iron must be added. The gold will be precipitated in the state of a fine powder, and, after being washed first with diluted muriatic acid, and then with distilled water, may be either preserved for solution in powder, or fused into a mass.

I. The external qualities of gold are the following:

1. It has an orange or reddish yellow colour; and may be brought to assume a degree of lustre inferior only to that of steel, platina, silver, and mercury.

2. Its specific gravity varies a little according to the mechanical processes which it has undergone; but it may be stated, on the average, at 19.3.

3. It exceeds all other metals in ductility and malleability, and may be beaten into leaves $\frac{1}{280000}$ th of an inch in thickness.

4. It is considerably tenacious; for a wire only $\frac{78}{1000}$ ths of an inch diameter will sustain a weight of 150lbs.

II. Gold may be melted by a moderate red-heat; viz. at about 32° of Wedgwood's pyrometer, or 1300° Fahrenheit. The intense heat of a glass-house furnace has no other effect than to keep it in fusion. And even exposure to Mr. Parker's powerful burning lens, for several hours, occasioned no loss of weight. After fusion, it crystallizes in short quadrilateral pyramids.

III. Pure gold is not oxydized by exposure to heat with the access of air; but it may be brought to the state of a purple oxide by transmitting, through gold leaf or wire, either a powerful electrical or galvanic discharge.

IV. Sulphuric, nitric, and muriatic acids have separately no evident action on gold; but the last mentioned, Proust has observed, by long boiling with finely divided gold, dissolves a small portion.

* Tantalum has lately been shown by Dr. Wollaston to be identical with columbium.

V. The proper solvents of gold are the oxymuriatic and nitromuriatic acids. Oberkampf * prefers the former, because a purer solution is obtained, and one which can more easily be had free from an excess of acid. Gold leaf, introduced into chlorine gas, takes fire and burns. But if gold leaf be suspended in water, into which chlorine gas is passed, it is dissolved, and the solution may be concentrated by evaporation.

To dissolve gold in nitro-muriatic acid, Vauquelin† reverses the usual proportions, and mixes two parts by weight of muriatic acid with one of nitric. Three parts of an *aqua regia* so composed, are equivalent, he finds, to four made with the common proportions.

The solution of gold (in whatever way prepared) has an orange yellow colour; but this, Oberkampf asserts, is owing to an excess of acid, and it passes to a brownish red, as soon as the redundant acid is neutralized or expelled by heat. The solution should, therefore, be evaporated to dryness, and the dry mass (care being taken not to heat it too strongly) redissolved in water. The solution gives a purple stain to the skin, and is susceptible of crystallization.

Muriate of gold, prepared by the solution of the metal either in oxymuriatic or nitromuriatic acid, is decomposed by solutions of fixed alkalis, and yields a precipitate, which differs greatly in colour, according to the circumstances of the experiment. If it has a yellow colour and a styptic taste, it is a *sub-muriate*. To avoid this, it is necessary to use a considerable excess of alkali, and then the precipitate is of a brownish black colour. It is this, which Oberkampf considers as the true oxide of gold. It should be dried with extreme care, for too much heat drives off a part of its oxygen.

VI. This oxide is decomposed entirely by heat, without passing through any inferior stage of oxidation; oxygen gas comes over; and pure gold remains. The mean of three experiments of Oberkampf shows, that 100 parts of gold combine with 10.01 oxygen; but Berzelius states the oxygen at 11.982. It is probable that this compound is the *peroxide* of gold, and that there is also a *protoxide*, with half as much oxygen as the former; but its existence has not yet been demonstrated, and at present we are acquainted with only one oxide of this metal. If no other can be proved to exist, the atom of gold must be estimated to weigh 75, for as 10 to 100, so is 7.5 to 75.

VII. It is necessary to observe, that the entire decomposition of muriate of gold is not effected by the alkalis, and that the liquor holds in solution a triple salt of gold, alkali, and muriatic acid.

VIII. A solution of pure ammonia separates from the solution by nitro-muriatic acid an oxide of gold, and a portion of ammonia, uniting with the oxide, forms a compound which detonates very loudly in a gentle heat, and is termed *fulminating gold*.

To obtain this compound, add a solution of ammonia in water, or

* 80 Ann. de Chim. 140.

† 77 Ann. de Chim. 322.

the pure liquid ammonia, to diluted muriate of gold; a precipitate will appear, which will be redissolved if too much alkali be used. Let the liquid be filtered, and wash the sediment, which remains on the filter, with several portions of warm water. Dry it by exposure to the air, without any artificial heat, and preserve it in a bottle, closed, not with a glass stopper, but merely by a cork. A small portion of this powder, less than a grain in weight, being placed on the point of a knife, and held over a lamp, detonates violently. The precise temperature, which is required, is not known, but it appears to exceed 250° Fahrenheit. At the moment of explosion, a transient flash is observed. The principal force is exerted downwards; and hence two or three grains, exploded on a pretty strong sheet of copper, will force a hole through it. Neither electricity nor a spark from the flint and steel are sufficient to occasion its detonation; but the slightest friction explodes it, and serious accidents have happened from this cause.

This detonation is explained as follows: Fulminating gold is composed of an oxide of that metal, combined with ammonia. When its temperature is raised, the ammonia is decomposed; the hydrogen of the alkali unites with the oxygen of the oxide, and reduces the gold to a metallic state; and nitrogen gas, and probably aqueous vapour, are liberated in a highly expanded state. The violent impulse of these aëriiform products, on the surrounding atmosphere, appears to be the cause of the loud noise that is occasioned by the explosion of this compound. A similar explanation may be applied to other fulminating compounds of metallic oxides with ammonia; such as those of silver and mercury, which will be described hereafter.

Fixed alkalis throw down, from nitro-muriate of gold, the yellow oxide already alluded to.

IX. The solution of gold is also decomposed by certain combustible bodies, which attract the oxygen from the gold, and restore it to a metallic state. (a) Into a dilute solution of muriate of gold, contained in a glass jar, put a long narrow slip of charcoal, and expose the whole to the direct light of the sun. The gold will be revived, and will appear on the charcoal in a metallic state, exhibiting a very beautiful appearance. The same change ensues without light, if the solution be exposed to a temperature of 212° .

(b) Moisten a piece of white taffeta ribband, with the dilute solution of gold, and expose it to a current of hydrogen gas from iron filings, and dilute sulphuric acid. The gold will be reduced, and the ribband will be gilt with the metal. By means of a camel's hair pencil, the gold may also be so applied as to exhibit regular figures, when reduced.

(c) The same experiment may be repeated, substituting phosphuretted hydrogen for common hydrogen gas. The reader, who wishes for a detail of various experiments of a similar kind, may consult an Essay on Combustion, by Mrs Fulhame, published by Johnson, London, 1794, and also Count Rumford's paper, in the Philosophical Transactions, 1798, page 449.

X. Gold is precipitated from muriatic acid, in a metallic form,

by a solution of green sulphate of iron. This depends on the affinity of the protoxide of iron for a further quantity of oxygen, which it takes from the oxide of gold.

XI. When a sheet of tin is immersed in a solution of nitro-muriate of gold, the oxide of gold is precipitated of a purple colour; and, when scraped off and collected, forms the *purple powder of Cassius*, much employed in enamelling. Or the metallic salt, largely diluted with water, may be put into a glass vessel with a few pieces of grain tin. In a short time, the liquor will become of the colour of red wine, and a very light flocculent precipitate will begin to precipitate, leaving the liquor clear. This when well washed and dried, has a deep purple colour, and is the precipitate of Cassius. The same precipitate is obtained by mixing a solution of gold with a recently made solution of tin in muriatic acid.

The composition and colour of the precipitates of gold, by muriate of tin at the minimum, have been shown, by Oberkampff, to be very variable. The colour approaches more to a violet, as the salt of tin bears a larger proportion to that of gold; and the colour, communicated by the precipitate to porcelain, has the same variable character. When the muriate of gold is in excess, the precipitate has more of a rose colour. A violet compound was proved on analysis to contain 60 per cent. of oxide of tin, and 40 of metallic gold; and one of a fine purple consisted of $20\frac{1}{2}$ oxide of tin and $79\frac{1}{2}$ gold.

XII. Gold is precipitated from its solvent by ether, but the oxide of gold is instantly re-dissolved by the ether, and forms the ethereal solution of gold. This solution is advantageously applied to the gilding of steel scissars, lancets, and other instruments, which it protects from rust with a very small expenditure of gold.

XIII. When a current of sulphuretted hydrogen gas is passed through a solution of gold, a black precipitate falls down. This is a true sulphuret of gold, which gives up its sulphur on the application of heat. It is composed of

Gold	80.39	100.
Sulphur	19.61	24.39
	<hr/>	<hr/>
	100.	124.39

The sulphuret, thus prepared, is more uniform in its composition, than that which is precipitated by alkaline hydro-sulphurets; for these contain a variable proportion of sulphur, which is thrown down along with the gold.

The sulphuret of gold is soluble in hydro-sulphuret of potash. Liquid potash takes up a part, and leaves a yellow powder, which is metallic gold. The alkaline hydro-sulphurets do not dissolve gold, however minutely divided, till sulphur is added, when probably a sulphuret of gold is formed, on which the hydro-sulphuret is capable of acting.

XIV. Gold may be combined with phosphorus, either by preci-

pitating its solution with sulphuretted * hydrogen, or, as Mr. E. Davy discovered, by heating finely divided gold with phosphorus in a tube deprived of air. It has a grey colour, and a metallic lustre; is decomposed by the heat of a spirit lamp; and contains about 14 per cent. of phosphorus.

XV. The methods of purifying gold, by the operations of cupelling and quartation, would lead into too long details. They are very perspicuously described by La Grange, in the 44th chapter of his Manual, and in Aikin's Chemical Dictionary, article Gold. To the former work; to Lewis's Philosophical Commerce of the Arts; and to Mr. Hatchett's paper, in the Philosophical Transactions for 1803, I refer also for information respecting the alloys of gold with other metals. It may be proper, however, to add that gold, which is too soft, in its pure state, for many purposes, has its hardness greatly increased by being melted or alloyed with a small proportion of copper. It is a singular fact, that some kinds of copper, which do not themselves appear defective in any respect, totally destroy the ductility of gold. This appears to be owing to the contamination of the copper with a very small quantity of lead and antimony, of either of which metals only about $\frac{1}{1920}$ th in weight is sufficient to produce this injurious effect.

The degree of purity of gold is expressed by the number of parts of that metal, contained in 24 parts of any mixture. Thus, gold, which, in 24 such parts, (termed *carats*,) contains 22 of the pure metal, is said to be 22 carats fine. Absolutely pure gold, using the same language, is 24 carats fine: and gold alloyed with an equal weight of another metal, 12 carats fine.

SECTION II.

Platina.

I. PLATINA, in the state in which it reaches this country, is contaminated by the presence of eight or ten other substances; and, in fact, is merely an ore of platina. It had been discovered in no other places than Choco and Santa Fé, in South America, until about two years ago, when Vauquelin detected it in some grey silver ores from Estremadura; and, more lately, it has been brought from St. Domingo, and from the gold mines of Brasil. The general aspect of the ore of platina is that of small grains or scales, of a whiter colour than iron, and extremely heavy. Various processes have been contrived for its purification;† but the one, which is the most simple and practicable, appears to me to be that of Count Moussin Poushkin, communicated by Mr. Hatchett in the

* The term *sulphuretted* is a mistake in the English copy; the sense requires it to be phosphureted. C.

† See Aikin's Dictionary, article Platina.

ninth volume of Nicholson's Journal.* It is unnecessary, however, to detail these processes; as the metal may now be had, in a pure state, at a reasonable price; among other places, at Cary's, No. 182, Strand, London.

II. Platina has the following properties:

1. It is a white metal, resembling silver in colour, but greatly exceeding it, and indeed all other metals, in specific gravity, which may be stated at 22 or 23, or, according to Sir H. Davy, at 21.3. It may be drawn into wire about the 2000th part of an inch in diameter, and beat into very thin plates.

2. It is extremely difficult of fusion. It may be melted, however, by the blow-pipe, with the aid of oxygen gas. A globule, also, weighing 29 grains, boiled violently in the focus of a lens about three feet in diameter.†

3. It is not oxydized by the long-continued and concurrent action of heat and air. To obtain its oxides, we must have recourse to a circuitous process. The nitro-muriate of platina is to be decomposed by lime water, and the precipitate re-dissolved in nitric acid. This solution being evaporated, and heated so as to drive off the acid, a brown powder remains, which is the oxide of platina *at the maximum*, and which contains in 100 parts 13 of oxygen. This oxide, very carefully heated, passes to a green colour, and loses six parts of oxygen, seven only remaining, combined with 93 of metal. It is proper, however, to state, that Sir H. Davy did not succeed in the repetition of these experiments.

Berzelius ‡ describes two oxides of platina. The protoxide is precipitated from the muriate by an excess of potash. Its colour is black, and it consists of

Platina	92.35	100.
Oxygen	7.65	8.287
	<hr/>	<hr/>
	100.	108.287

The peroxide has been obtained only in combination. It is composed of

Platina	85.93	100.
Oxygen	14.07	16.38
	<hr/>	<hr/>
	100.	116.38

5. Platina has the property of *welding*,§ which belongs to no other metal but this and iron.||

* A process for purifying platina, by the intermediation of zinc, is described by Descotils in the 64th volume of the *Annales de Chimie*, page 334, or 37 Phil. Mag. 65.

† 69 Ann. de Chimie, 93.

‡ 87 Ann. Ch. 126.

§ Two pieces of wrought iron, raised to a white heat, become covered with a kind of varnish; and, when brought into contact, may be permanently united by forging. This is called the welding of iron.

|| Sodium appears to possess a property analogous to welding. See p. 162. C.

6. It is not acted on by any other acid than the nitro-muriatic and oxy-muriatic.* The former is best adapted to effect this solution. Sixteen parts of the compound acid are to be poured on one of the laminated metal, and exposed to heat in a glass vessel; nitrous gas is disengaged, and a reddish-coloured solution is obtained, which gives a brown stain to the skin.

When this solution is evaporated, and heated to whiteness, chlorine gas is disengaged, and may be collected in a proper apparatus. The dry compound, investigated by Mr. E. Davy, gave 18.5 per cent. of chlorine; but this is considered by him only as an approximation.

7. The muriate of platina may be crystallized by careful evaporation. The salt has a very acrid taste, and is deliquescent. It is decomposed by heat, and an oxide of platina remains, which is reduced to a metallic form by ignition with charcoal.

8. The muriate of platina has the characteristic property of being precipitated by a solution of muriate of ammonia. By this character, platina is distinguished from all other metals, and may be separated when mingled with them in solution. The precipitate, thus obtained, is decomposed by a strong heat, and leaves pure platina.

9. Muriate of platina is not precipitated by prussiate of potash, nor by sulphate of iron. If any precipitate ensue, it is owing to contamination with other metals.

10. It is precipitated of a dark green colour by the gallic acid as present in tincture of galls. The precipitate becomes gradually paler by standing.†

11. When pure potash is poured into the muriatic solution, a precipitate ensues, which is not an oxide of platina, but a triple compound of that oxide with the alkali and acid. With soda, also, it forms a triple combination. This is best obtained, by adding to nitric acid, in a retort, platina, with twice its weight of muriate of soda, and applying heat till about four fifths of the fluid have come over. The remaining liquor forms, on cooling, fine prismatic crystals, sometimes four or five inches long; and either reddish-brown, like titanium; yellow, like amber; or of a beautiful coquelicot colour.‡

12. Muriate of platina is decomposed by ether, and an etherized solution of platina is obtained; which may be applied to the same uses as the similar solution of gold. It is decomposed, also, by sulphuretted hydrogen,§ and a black powder is obtained, which becomes reddish brown with an excess of the precipitant, but re-assumes its black colour, on exposure to the air. Its composition cannot be investigated easily, for the sulphur passes so rapidly to the state of sulphuric acid, as, during the desiccation of the powder, to destroy the paper on which it was collected. The direct

* Mr. P. Johnson has shown that platina, by being alloyed with silver and gold, is rendered soluble in nitric acid. 40 Phil. Mag. 1.

† La Grange, ii. 272.

‡ Nicholson's Journal, 8vo. ix. 67.

§ Berzelius.

combination of platina and sulphur was found by Mr. E. Davy to give an intusible black powder, containing about 16 per cent. of sulphur.*

Phosphorus and platina may be united, either by passing phosphuretted hydrogen into a solution of the muriate, or, according to Mr. E. Davy, they combine directly in exhausted tubes with vivid ignition. The result is a bluish grey powder, infusible, and containing 17 per cent. of phosphorus.

13. Platina is acted upon by fusion with nitrate of potash, and also with pure fixed alkalis. The latter property diminishes considerably the utility of platina as a material for crucibles.

14. The most delicate test of the presence of platina is muriate of tin. A solution of platina, so dilute as to be scarcely distinguishable from water, assumes a bright red colour, on the addition of a single drop of the recent solution of tin.

15. Platina combines with potassium and sodium, and affords brittle compounds. It unites also with most metals.† In the proportion of only $\frac{1}{16}$, it renders gold pale; it amalgamates with mercury; and diminishes the fusibility of the fusible metals. Its alloys, however, have been but little investigated.

16. Platina has been discovered by Dr. Wollaston to be a remarkably slow conductor of caloric. When equal pieces of silver, copper, and platina, were covered with wax, and heated at one end, the wax was melted $3\frac{1}{2}$ inches on the silver; $2\frac{1}{2}$ on the copper; and 1 inch only on the platina. Its expansion by heat is considerably less than that of steel; which, between the temperatures of 32° and 212° is expanded about 12 parts in 10,000, while the expansion of platina is only about 10. From trials made by Mr. Scott of Dublin, it appears to possess sufficient elasticity to be applicable to the making of pendulum springs for watches.‡

SECTION III.

Silver.

SILVER is a metal, which admits of a degree of lustre, inferior only to that of polished steel. Its specific gravity, after being hammered, is 10.51. In malleability, ductility, and tenacity, it exceeds all the metals, except gold. Its fusing point, as determined by Dr. Kennedy, is 22° of Wedgwood's pyrometer. By considerably raising this heat, it may be volatilized; and, by slow cooling of the fused mass, it may be made to assume a regular crystallized form.

Its chemical properties are the following:

I. Silver is difficultly oxydized by the concurrence of heat and

* See his Memoir on some of the Combinations of Platina, Phil. Mag. vol. 40.

† See Darçet on the Alloys of Platina with Silver. 89 Ann. de Ch. 135.

‡ Nicholson's Journal, xxii. 148.

air. The *tarnishing* of silver is owing not to its oxidation merely, but to its union with sulphur, as Proust has satisfactorily shown.

By transmitting a galvanic or electric discharge through silver wire, it is oxydized; and by long exposure of silver to heat, with free access of air, it is at length converted into an olive-coloured glass. The oxide of silver may, also, be obtained by decomposing nitrate of silver with solution of barytes; and, after washing the precipitate sufficiently, heating it to dull redness. It has an olive colour, and is composed, according to Sir H. Davy, of 100 parts of silver united with 7.3 oxygen, or, according to Dr. Wollaston, 7.4. A larger proportion of oxygen is assigned by Berzelius, viz.

Silver	92.67	100
Oxygen	7.33	7.925
	<hr/>	<hr/>
	100.	107.925

No other oxide of silver has been ascertained to exist.

II. Silver is acted on by sulphuric acid, which, when assisted by heat, oxydizes and partly dissolves it. The sulphate of silver, however, which is very useful as a test, is better prepared by dissolving in sulphuric acid the carbonate of silver, precipitated from the nitrate by carbonate of soda. It forms small brilliant and needle-shaped crystals, which require for solution a large quantity of water.

III. Nitric acid diluted with from two to four parts of water dissolves silver with a disengagement of nitrous gas. If the silver be pure, the solution is colourless, otherwise it has a green hue.* According to Proust, nitrate of silver already saturated, if boiled with powdered silver, dissolves an additional quantity; and a solution is obtained, in which the silver is oxydized at a minimum. The sub-nitrate, he observes, possesses different properties from the common one.†

IV. Muriatic acid does not act on silver; yet this acid takes oxide of silver from others. Thus when muriatic acid is added to nitrate of silver, a white curdy precipitate falls down in great abundance. This precipitate is decomposed by light; for, when exposed to the direct rays of the sun, its colour becomes gradually darker. (See chap. iv. part. v.) If fused by a gentle heat, it forms a semi-transparent mass of the consistence of horn, called *luna cornea*, or *horn silver*.

The composition of muriate of silver has been variously stated. According to Gay Lussac 100 grains of silver combine with 7.60 oxygen and 25.71 acid. Other chemists have given different proportions, as appears from the following Table.

* In dissolving several metals in nitric acid, the solution, during its progress, often assumes a greenish tint; this arises from the absorption of the nitrous gas disengaged; it is however finally expelled, and the solution remains colourless. The same effect is perceived in the action of nitric acid on alcohol. C.

† Nicholson's Journal, xv. 376.

		Acid.	Base.
100 parts, according to Kirwan	16.54	83.46	
Chenevix	17	83	
Zaboada	17.7	82.3	
Proust	18	82	
Dr. Marcet	19.05	80.95	
Gay Lussac	19.28	80.72	
Berthollet	17.5	82.5	
Berzelius	19.035	80.965	

These differences may, perhaps, in part but not entirely, be accounted for, by the different states of dryness of the muriate of silver. A hundred grains, I have found, after being dried during twenty-four hours, at a temperature between 212° and 300° Fahrenheit, lose barely a grain by fusion. On the whole, I should be disposed to consider the determinations of Dr. Marcet and Gay Lussac as most entitled to confidence.

Muriate of silver is decomposed by fusion with desiccated carbonate of soda. Mix one part of the former with three of the latter salt, and let the mixture be fused in a crucible. When cold, the silver will be found reduced at the bottom of the crucible; break the mass, and separate the metal. From 100 grains of the muriate, barely 75 of pure silver are obtained. This is one of the best modes of procuring silver in a state of purity.

V. Silver combines with chlorine, when heated in that gas, and a compound results, which, in every respect, agrees with muriate of silver. According to the new theory of chlorine, it is, in fact, a compound of that body and metallic silver; and it has, therefore, been called by Sir H. Davy, *argentane*, and by Gay Lussac *chlorure of silver*. The former makes the chlorine in this compound amount to 24.5 per cent, and 100 grains should therefore consist of

Silver	75.5	100
Chlorine	24.5	32.5
	<hr/>	<hr/>
	100.	132.5

According to Dr. Marcet's analysis, 100 grains should contain 75 of silver, for this is the quantity of metal in 80.95 grains of the oxide, taking the oxygen at 7.3 to 100 of silver. If this be admitted, 100 of silver will then be saturated by very nearly 33.5 of chlorine. It must be obvious, that, in order to convert the old statement of the composition of horn silver into the new one, it is only necessary, to suppose the oxygen taken from the oxide, and added to the muriatic acid, which gives the quantity of chlorine.

VI. A solution of nitrate of silver stains animal substances a deep black. Hence it has been applied to the staining of human hair; but, when thus employed, it should be very much diluted, and used with extreme caution, on account of its corrosive quality.*

* I have several times tried to colour hair by means of nitrat of silver, of various strength; but from some cause which I cannot explain, I have never succeeded. The fact is so constantly mentioned by writers, that I have no reason to doubt it; I should however be glad to learn on what its success depends. C.

White paper, or white leather, when stained with a solution of nitrate of silver, in the proportion of ten parts of water to one of the salt, undergoes no change in the dark; but when exposed to the light of day, it gradually acquires colour, and passes through a succession of changes to black. The common sun-beams, passing through red glass, have very little effect upon it; yellow and green are more efficacious; but blue and violet produce the most decidedly powerful effects. Hence this property furnishes a method of copying paintings on glass, and transferring them to leather or paper. The process is described by Mr. T. Wedgwood, in Nicholson's Journal, 8vo. iii. 167.

By a similar process, ivory may be covered with silver. Let a slip of ivory be immersed in a dilute solution of pure nitrate of silver, till the ivory has acquired a bright yellow colour. Then remove it into a tumbler filled with distilled water, and expose it to the direct light of the sun. After two or three hours exposure, it will have become black; but on rubbing it a little, the surface will be changed into a bright metallic one, resembling a slip of pure silver. As the solution penetrates deep into the ivory, the bright surface when worn away, is replaced by a succession of others.

VII. The solution of nitrate of silver, when evaporated, forms regular crystals. These crystals fuse when heated; and being poured, in this state, into moulds, form the common *lunar caustic*. Fused nitrate of silver, according to Proust, is composed of

Silver	64	}	70
Oxygen	6		
Nitric acid			30
			<hr/> 100

This statement, however, cannot be correct, as it assigns too large a proportion of oxygen to the oxide, viz. 8.6 to 100 grains of silver.

VIII. Nitrate of silver is decomposed by other metals. Thus the surface of a plate of copper, to which the solution is applied, becomes plated over with silver. The first part of the deposit, Gay Lussac finds, is perfectly pure silver. The latter portions contain an admixture of copper, which may be removed by a fresh solution of nitrate of silver. If a little mercury be poured into a bottle filled with the solution of nitrate of silver, and the bottle be left some time undisturbed, the silver is precipitated in a beautiful form, resembling the branches of a tree, which has been termed *Arbor Dianæ*. The most successful process for obtaining this appearance, Baumé assures us, is the following: Mix together six parts of a solution of silver in nitric acid, and four of a solution of mercury in the same acid, both completely saturated. Add a small quantity of distilled water; and put the mixture into a conical glass, containing six parts of an amalgam, made with seven parts of mercury and one of silver. At the end of some hours, there appears on the surface of the amalgam a precipitate in the form of a vegetation. According to Proust, however, this complicated

process is quite unnecessary; and all that is required is to throw mercury into nitrate of silver very much diluted. A beautiful arborization of reduced silver, he observes, will be produced without difficulty.

IX. The solution of silver is decomposed by charcoal, and by hydrogen gas and its compounds. This may be shown by experiments precisely similar to those already directed to be made with muriate of gold. A stick of clean phosphorus, also, immersed in a dilute solution of nitrate of silver, in the course of a few days becomes beautifully gilt.*

X. Precipitate nitrate of silver by lime-water, and thoroughlyedulcorate and dry the precipitate. Let this be afterward put into a vessel of the purest liquid ammonia. It will then assume the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the celebrated compound termed *fulminating silver*, which detonates with the gentlest heat, and even with the slightest friction. When once prepared, no attempt must be made to enclose it in a bottle, and it must be left undisturbed in the vessel in which it was dried. Great caution is necessary in the preparation of this substance, and in making experiments on it. It even explodes, when moist, on the gentlest friction.

XI. A new detonating compound of silver, formed by a process similar to that employed in making the fulminating mercury of Mr. Howard, has lately been described by Descotils.† It is prepared by adding alcohol, to a heated solution of silver in nitric acid, while the solution is yet going on. Considerable effervescence arises; the liquor presently becomes turbid; and a heavy, white, crystalline powder falls down. This, when washed and dried, is the *detonating silver*. Heat, a slight blow, or long continued friction, causes it to inflame with a brisk detonation. Pressure alone is not sufficient, unless very powerful. It detonates by the electric spark, and is set on fire with an explosion by concentrated sulphuric acid. Both in the preparation of this substance, and in experiments on its detonation, much caution is necessary; and only very small quantities should be employed. This preparation was originally discovered by Mr. E. Howard. In repeating his process, Mr. Cruickshank dissolved 40 grains of silver in two ounces of strong nitric acid, diluted with an equal weight of water. Then by heating the solution with two ounces of alcohol, he obtained 60 grains of a white powder, which detonated violently.

XII. A very useful solvent of silver has been discovered by Mr. Keir of Birmingham. It is formed by dissolving one part of nitre in about eight or ten parts by weight of concentrated sulphuric acid. This compound, (which may be called *nitro sulphuric acid*,) when heated to between 100° and 200° Fahrenheit, dissolves one fifth or one sixth its weight of silver, with an extrication of nitrous gas; and leaves, untouched, any copper, gold, lead, or iron, with

* See Count Rumford's papers, Philosophical Transactions, 1798.

† Nicholson's Journal, xviii. 140.

which the silver may be combined. Hence it is a most useful agent in extracting silver from old plated goods. The silver may be recovered from the solution by adding muriate of soda, which forms muriate of silver; and this may be decomposed by carbonate of soda, in the way which has already been described.

XIII. Silver is acted on by sulphurets of alkalis, and by sulphuretted hydrogen gas. Both these substances blacken silver when exposed to their operation; and the common tarnishing of silver by the atmosphere has been traced to a similar cause. Sulphuret of silver has been analyzed by Berzelius, and found to consist of

Silver	87.032	100.
Sulphur	12.968	14.9
	<hr/>	<hr/>
	100.	114.9

XIV. Silver is capable of being united with most other metals. When alloyed with copper, in the proportion of one part to twelve, it constitutes the *standard silver* of Great Britain. This combination, though its colour differs but little from that of pure silver, is much harder, and better adapted for the purpose of coin, and of domestic implements.

SECTION IV.

Mercury.

I. MERCURY, or quicksilver, is the only one of the metals that retains a fluid form at the ordinary temperature of the atmosphere.

II. When its temperature is reduced to about 39° or 40° below zero of Fahrenheit, it assumes a solid form. This is a degree of cold, however, that occurs only in high northern latitudes: and in this country quicksilver can only be exhibited in a solid state by means of artificial mixtures. By congelation it acquires an increase of its specific gravity; and, therefore, unlike other metals, the congealed portion sinks to the bottom of a fluid mass of mercury. Its specific gravity, at 47° above 0 of Fahrenheit, being 13.545, it was found increased by congelation, in an experiment of Mr. Biddle, to 15.612, or about one seventh.

III. At about 660° of Fahrenheit (656° according to Creighton) mercury boils, and is changed into vapour. Hence it may be driven over by distillation, and may thus be purified, though not accurately, from the admixture of other metals. When its temperature is considerably increased above this point, the vapour acquires great expansive force, and the power of bursting the strongest vessels.

IV. Mercury is not oxydized, when pure, at the ordinary temperature of the atmosphere; but preserves the lustre of its surface unchanged for a considerable time. There are several me-

thods, however, by which it may be brought to combine with oxygen.

(a) Mercury is oxydized by long continued agitation in a bottle half filled with atmospherical air, and is converted into a black powder, to which Boerhaave gave the name of *ethiops per se*. When this oxide (which may be obtained, with less trouble, by decomposing calomel with solution of potash) is distilled in a glass retort, oxygen gas is evolved; or if a moderate heat be long continued, it acquires a reddish colour, and a still farther dose of oxygen. The black oxide consists, according to Fourcroy and Thenard, of 100 parts of metal united with 4 of oxygen.

(b) Another oxide of mercury is obtained by exposing the fluid metal, for several days, to nearly its boiling temperature, in a flat glass vessel, into which air is freely admitted. After a sufficient length of time, small flaky crystals form on its surface, of a brownish red, or flea colour. This red oxide was formerly called *precipitate per se*. When distilled alone in a glass retort, it yields oxygen gas, and returns to a metallic state. It is composed, according to Fourcroy and Thenard, of 100 metal and 8 of oxygen. Sir H. Davy, also, finds its oxygen to be exactly double that of the *protoxide*, which is composed of 190 mercury and 7.5 oxygen, while the peroxide consists of 190 metal and 15 oxygen. Hence the protoxide is composed of

Mercury	96.22	100.
Oxygen	3.78	3.947
	<hr/>	<hr/>
	100.	103.947

And the peroxide of

Mercury	92.69	100.
Oxygen	7.31	7.894
	<hr/>	<hr/>
	100.	107.894

It will be sufficiently near the truth, if we admit, with Dr. Wollaston, the black oxide to consist of 100 metal, united with 4 of oxygen, and the red of 100 mercury + 8 oxygen.

V. Mercury is dissolved by hot and concentrated sulphuric acid. Two parts of sulphuric acid and one of mercury are the proportions generally used; and as strong sulphuric acid acts but little on iron, the combination may be made in an iron vessel. Part of the redundant acid may be expelled by heat; but still the salt retains a considerable excess of acid, and may be called super-sulphate of mercury. It is very difficult of solution, requiring 155 parts of cold or 33 of boiling water. By repeated washings with cold water, the whole excess of acid may be removed, and the salt is rendered much more insoluble.

When the super-sulphate is heated for some time, at a temperature exceeding that of boiling water, it loses still more acid, and is

changed into a hard grey mass. When this is removed from the fire, and boiling water poured upon it, a lemon yellow-coloured powder is formed called *Turbith Mineral*. This substance requires for solution 2000 times its weight of water. One hundred parts consist of 10 sulphuric acid, 76 mercury, 11 oxygen, and 3 water.

VI. The nitric acid dissolves mercury, both with and without the assistance of heat. At the common temperature, but little nitrous gas is evolved by the action of mercury on nitric acid; and the acid becomes slowly saturated. The solution is very ponderous and colourless; and yields, by evaporation, large transparent crystals. The solution does not become milky when mingled with water. Pure fixed alkalis give a yellowish white precipitate; and ammonia a greyish black one.

But if heat be used, a brisk effervescence arises, occasioned by the escape of nitrous gas, and a solution is obtained, in which the metal is more highly oxidated, and the acid is in less proportion. When this solution is poured into cold water, a yellowish white sediment is formed; or, if into boiling water, an orange coloured one. Both precipitates consist of nitric acid, with a great excess of oxide, forming an insoluble *sub-nitrate of mercury*.

If the last-mentioned solution be boiled with a fresh quantity of mercury, the newly added metal is taken up, without any discharge of nitrous gas, the metal becoming oxidized at the expense of that already dissolved.

When the nitrate of mercury is exposed to a heat gradually raised to 600° or upwards, it is deprived of water and most of its acid, and reduced to an oxide, which has the form of brilliant red scales. This substance, commonly called *red precipitate*, is termed more properly the *nitrous oxide of mercury*.

VII. Mercury is the basis of a new fulminating compound discovered by Mr. E. Howard. To prepare this powder, 100 grains (or a greater proportional quantity not exceeding 500) are to be dissolved, with heat, in a measured ounce and half of nitric acid. The solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action and re-action. The precipitate is to be immediately collected on a filter, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water-bath. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid; and while any of that acid adheres to it, it is very subject to be decomposed by the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained.* This powder has the property of detonating loudly in a gentle heat, or by light friction.

VIII. Mercury is not dissolved by muriatic acid, but may be brought into union with this acid by double elective affinity. Thus

* See Philosophical Transactions, 1800, page 214.

when sulphate of mercury and muriate of soda, both well dried, are mixed and exposed to heat, a combination of oxide of mercury and muriatic acid is obtained by sublimation. This compound is the *corrosive sublimate* of the shops. The same components, with a still farther addition of mercury, constitute an insoluble substance called *calomel*.

The corrosive muriate requires 16 or 20 times its weight of water for solution; but is soluble in about $1\frac{1}{8}$ th its weight of alcohol. Its solution in water is decomposed by all the fixed alkalis and alkaline salts, which throw down at first an orange, and afterwards a brick red precipitate.

Calomel, or the sub-muriate, is formed by grinding the muriate with about half its weight of metallic quicksilver, and then repeatedly subliming the mixture. As the new compound is nearly insoluble, it may be freed from any remains of the corrosive muriate by repeatedly washing with water. Fourcroy and Thenard have given the following comparative view of the composition of corrosive sublimate and calomel.

Calomel	{	100. mercury.
		4.16 oxygen.
		13.97 acid.
Corrosive Muriate	{	100. mercury.
		8.21 oxygen.
		27.39 acid.

Mercury unites with chlorine, and, if heated in the gas, burns with a pale red flame. The product is identical with corrosive sublimate, which, according to Sir H. Davy, is a compound, not of muriatic acid and oxide of mercury, but of chlorine and that metal. According to his experiments, calomel consists of 190 mercury, and 33.5 chlorine, or of

Mercury	85	100.
Chlorine	15	17.6
	<hr/>	
	100.	

And corrosive sublimate is composed of

Mercury	74	100.
Chlorine	26	35.2
	<hr/>	
	100.	

IX. The oxides of mercury are all reduced by heat alone, without the addition of any combustible substance, and afford oxygen gas.

X. Mercury dissolves gold, silver, tin, and many other metals; and if these be combined with it in sufficient quantity, the mercury

loses it fluidity, and forms an amalgam. A solid amalgam of lead, and another of bismuth, on admixture together, have the singular property of instantly becoming fluid. The extraordinary powers of the base of ammonia in amalgamating with mercury, have already been described in speaking of that alkali.

By combination with mercury, metals that are not easily oxydized, acquire a facility of entering into union with oxygen. Thus gold and silver, when combined with mercury, are oxydized by agitation in contact with air. This fact furnishes a striking illustration of the effect of overcoming the aggregative affinity of bodies, in promoting chemical union.

XI. By combination with sulphur, mercury affords two distinct compounds. By long continued trituration, these two bodies unite, and form a black sulphuret. When united together by fusion, and afterwards sublimed, they constitute a red sulphuret called cinnabar, which, when powdered, affords the common pigment vermilion. The process used by the Dutch, who have long been celebrated for the preparation of cinnabar, is described in the 4th volume of the *Annales de Chimie*, or in Aikin's Dictionary, vol. ii. This compound also may be obtained by mixing concentrated solutions of muriate of mercury and hydro-sulphuret of ammonia. A brownish muddy precipitate is obtained, which, when left undisturbed, turns yellow in three or four days, then orange, and finally acquires a beautiful cinnabar colour.*

The exact composition of these sulphurets has not yet been determined. But if mercury, like other metals, take twice the quantity of sulphur which it absorbs of oxygen, the proportion of their ingredients will be found by doubling the oxygen of the oxides, and they will be composed as follows :

	Mercury.	Sulphur.
Subsulphuret	100	7.894.
Sulphuret	100	15.788.

SECTION V.

Rhodium and Palladium.

THE discovery of these two metals was made by Dr. Wollaston, who separated them from the ore of platina, by the following process.

I. RHODIUM. When a solution of the ore of platina in nitromuriatic acid has been precipitated, as far as possible, by muriate of ammonia (see sect. 3.) it still retains a considerable degree of colour, varying with the strength and proportion of the acids that have been employed in effecting the solution. Beside iron, and a

* Nicholson's Journal, 8vo. i. 299.

portion of the ammonia-muriate of platina, it contains, also, other metals in very small proportion.

1. Let a cylinder, or thin plate of zinc, or iron, be immersed in the solution. It will separate all the metals that are present in the state of a black powder. Wash the precipitate (without drying it) with very dilute nitric acid, assisted by a gentle heat, which will dissolve the copper and lead. Digest the remainder in dilute nitro-muriatic acid; and to the solution, when completed, add a portion of muriate of soda, equivalent in weight to about one fiftieth the ore of platina employed. Evaporate by a gentle heat. The dry mass contains the soda-muriates of platina, palladium and rhodium; the two former of which may be separated by alcohol, and the salt of rhodium will remain. From its solution the rhodium may be precipitated by zinc, which throws down a black powder, amounting, in weight, to four grains from 4000 of the ore.

2. When exposed to heat, the powder continues black; with borax it acquires a white metallic lustre, but appears infusible by any degree of heat. It is rendered fusible, however, by arsenic, and also by sulphur; both of which may be expelled by a continued heat; but the metallic button, thus obtained, is not malleable.

3. The specific gravity of rhodium, as near as it could be taken, was 11.

4. Rhodium unites readily with all the metals that have been tried, excepting mercury. It does not discolour gold, when alloyed with it.

5. When an alloy of silver or gold with rhodium is digested in nitric or nitro-muriatic acid, the rhodium remains untouched; but when alloyed with three times its weight of bismuth, copper, or lead, each of these alloys may be dissolved completely, in a mixture, by measure, of two parts muriatic acid with one of nitric. The lead appears preferable, as it is reduced, by evaporation, to an insoluble muriate. The muriate of rhodium then exhibits the rose colour, from which the name of the metal has been derived. It is soluble in alcohol.

6. Rhodium is not precipitated from its solution by prussiate of potash, nor by muriate of ammonia, nor by hydro-sulphuret of ammonia. The carbonated alkalis produce no change; but the pure alkalis precipitate a yellow oxide, soluble in all acids that have been tried.

Berzelius has ascertained the existence of three oxides of this metal, composed as follows:

	Metal.		Oxygen.
Protoxide . .	100	+	6.71
Deutoxide . .	100	+	13.42
Peroxide . .	100	+	20.13

II. PALLADIUM. 1. The alcoholic solution (I. 1.) contains the soda-muriates of palladium and platina. The latter metal may be precipitated by muriate of ammonia; and from the remaining li-

quid palladium may be obtained, by the addition of prussiate of potash, which occasions a sediment, at first of a deep orange colour, and changing afterwards to a dirty bottle-green, owing, probably, to the presence of iron. The precipitate is to be ignited, and purified from iron, by cupellation with borax.

2. A more simple method of obtaining palladium has since been announced by its discoverer.* To a solution of the ore of platina in nitro-muriatic acid, neutralized by evaporating the redundant acid, or by adding an alkali, and either before or after the separation of the platina by muriate of ammonia, let prussiate of mercury be added. In a short time the liquid becomes yellow, and a flocculent precipitate is gradually formed of a pale yellowish white colour, which is the prussiate of palladium. This, on being heated, yields the metal in a pure state, in the proportion of four tenths or five tenths of a grain from every hundred grains of the ore.

3. Vauquelin has, also, proposed a method of separating rhodium and palladium from the ore of platina. His process, which is less simple than the second method of Dr. Wollaston, is described at length in the 4th volume of Dr. Thomson's *Annals of Philosophy*.

On examining some ore of platina, brought from the gold mines of Brazil, Dr. Wollaston has lately discovered in it small fragments of *native palladium*, which appear to be free from admixture with every other metal, except a very minute portion of iridium. These fragments differ from the grains of platina, in being formed of fibres, which are in some degree divergent from one extremity. This external character Dr. Wollaston deems sufficient for distinguishing the metal in situations, where recourse cannot be had to experiment.†

Mr. Cloud, assay master of the American mint, has, also, discovered palladium in a native alloy of gold with that metal.‡ The alloy contained no other metal, and was perfectly free from its common ingredients, copper and silver.

Those who may wish to examine palladium, may now procure it in a metallic state at Messrs. Knights', Fosterlane, London.

4. The following are the properties of palladium :

(a) Its colour resembles that of platina, except that it is of a duller white. It is malleable and ductile. Its specific gravity varies from 10.972 to 11.482. Its power of conducting caloric is nearly equal to that of platina, which it rather surpasses in expansion by heat.

(b) Exposed in an open vessel, to a greater degree of heat than is required to melt gold, no oxydizement ensues ; and no degree of fusion takes place. On increasing the fire considerably, a melted button is obtained, and the specific gravity is increased to 11.871. The metal, in this state, has a greyish white colour. Its hardness exceeds that of wrought iron. By the file it acquires the brilliancy of platina ; and is malleable to a great degree.

* *Phil. Mag.* xxii. 272, or *Phil. Trans.* 1805.

† *Philosophical Transactions*, 1809.

‡ 74 *Ann. de Chim.* 99.

Berzelius has shown that 100 parts of palladium unite with 14.209 parts of oxygen. Hence the oxide consists of

Palladium	.	.	87.56
Oxygen	.	.	12.44
			<hr/>
			100.

(c) Palladium readily combines with sulphur. The compound is whiter than the separate metal, and is very brittle. It has been investigated by Berzelius, and shown to be composed as follows :

Palladium	.	.	78.03	.	.	100.
Sulphur	.	.	21.97	.	.	28.15
			<hr/>			<hr/>
			100.			128.15

(d) It unites with potash by fusion, and also with soda, but less remarkably. Ammonia, allowed to stand over it for some days, acquires a bluish tinge, and holds, in solution, a small portion of oxide of palladium.

(e) Sulphuric acid, boiled with palladium, acquires a beautiful blue colour, and dissolves a portion of the metal. The action of this acid, however, is not powerful; and it cannot be considered as a fit solvent for palladium.

(f) Nitric acid acts with much greater violence on palladium. It oxydizes the metal with somewhat more difficulty than silver; and, by dissolving the oxide, forms a very beautiful red solution. During this process no nitrous gas is disengaged. Nitrous acid has even a more rapid action on palladium. From these solutions, potash throws down an orange coloured precipitate, which is probably a hydrate.

(g) Muriatic acid, by being boiled on palladium, acts upon it, and acquires a beautiful red colour.

(h) But the true solvent of palladium is nitro-muriatic acid, which acts upon the metal with great violence, and yields a beautiful red solution.

(i) From all these acid solutions of palladium, a precipitate may be produced by alkalis and earths. These precipitates are mostly of a fine orange colour; are partly dissolved by some of the alkalis; and that occasioned by ammonia, when thus redissolved, has a greenish blue colour. Sulphate, nitrate, and muriate of potash, produce an orange precipitate in the salts of palladium, as in those of platina; but the precipitates from nitrate of palladium have generally a deeper shade of orange. All the metals, except gold, platina, and silver, cause very copious precipitates in solutions of palladium. Recent muriate of tin produces a dark orange or brown precipitate, from neutralized salts of palladium, and is a very delicate test of this metal. Green sulphate of iron precipitates palladium in a metallic state; and, if the experiment succeeds, the pre-

precipitate is about equal in weight to the palladium employed. Prussiate of potash causes an olive-coloured precipitate. The prussiate of palladium, separated by a neutral solution of prussiate of mercury, has the property, when heated to about 500° of Fahrenheit, of detonating, with a noise similar to that occasioned by firing an equal quantity of gunpowder. Hydro-sulphurets, and water impregnated with sulphuretted hydrogen gas, occasion a dark brown sediment from solutions of palladium.

(*k*) Palladium readily combines with other metals. It has the property, in common with platina, of destroying the colour of gold, even when in a very small proportion. Thus one part of platina, or palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed.

Dr. Wollaston has furnished an alloy of gold and palladium for the graduation of the magnificent circular instrument, constructed by Mr. Troughton, for Greenwich observatory. It has the appearance of platina, and a degree of hardness, which peculiarly fits it for receiving the graduations.

SECTION VI.

Iridium and Osmium.

WHEN the ore of platina has been submitted to the action of nitro-muriatic acid, a part remains undissolved, in the form of a black powder, resembling plumbago. In this substance, Mr. Tennant has lately discovered two new metals. The process, which he employed to separate them, was the following:

1. The powder was fused in a silver crucible with pure soda, and the alkali then washed off with water. It had acquired a deep orange or brownish yellow colour, but much of the powder was undissolved. The residue was digested in muriatic acid, and a dark blue solution obtained, which afterwards became of a dusky olive-green; and finally, by continuing the heat, of a deep red colour. By the alternate action of the acid and alkali, the whole of the powder appeared capable of solution.

2. The alkaline solution contained the oxide of a volatile metal not yet described; and also a small portion of another metal. When the solution was kept some weeks, the latter metal separated spontaneously in thin dark-coloured flakes. The acid solution contained both metals also; but principally one, which is not altered by muriate of tin; is precipitated of a dark brown colour by pure alkali; and which exhibits, during solution in muriatic acid, a striking variety of colours, arising from variations in its degree of oxidation. From this property Mr. Tennant terms it **IRIDIUM**. The proportion of oxygen in its oxide still remains to be determined.

3. In order to obtain muriate of iridium, free from the other metal, the acid solution (2) was evaporated, and an imperfectly

crystallized mass obtained; but this, dried on blotting-paper, and again dissolved and evaporated, gave distinct octahedral crystals. The watery solution of these crystals had a deep red colour, inclining to orange. With infusion of galls no precipitation ensued; but the colour almost instantly disappeared. Muriate of tin, carbonate of soda, and prussiate of potash, had the same effect. Pure ammonia precipitated the oxide, but retained a part, and acquired a purple colour. All the metals, except gold and platina, precipitated iridium of a dark colour from the muriate, which had lost its colour.

4. Iridium was obtained pure by heating the muriate, which expelled both the acid and the oxygen. It was of a white colour, and perfectly infusible. It did not combine with sulphur or arsenic. Lead united with it, but was separated by cupellation. Copper, silver, and gold, were severally found to combine with it, and it could not be separated from the two latter by cupellation with lead.—Its other properties remain to be examined.

II. 1. Osmium was procured in the state of an oxide, by simply distilling the alkaline solution, obtained as already described (I. 1.), along with any acid. It was even found to escape, in part, when water was added to the dry alkaline mass remaining in the crucible; and was manifested by a pungent and peculiar smell, somewhat resembling that of chlorine gas, from which property its name has been derived. The watery solution of oxide of osmium is without colour, having a sweetish taste, and the strong smell already alluded to. Another mode of obtaining, still more concentrated, the oxide of osmium, is by distilling the original black powder with nitre. A solution of oxide of osmium in water is found in the receiver, of such strength as to give a stain to the skin that cannot be effaced. The most striking test of this oxide is an infusion of galls, which presently becomes of a purple colour, and afterwards changes to a deep vivid blue. With pure ammonia, the solution becomes somewhat yellow; and slightly so with carbonate of soda. With alcohol, or still more quickly with ether, it acquires a dark colour, and, after some time, separates in the form of black films.

M. Laugier having observed that nitro-muriatic acid, which has been employed to dissolve platina, emits a strong odour of osmium, distilled the liquor, and saturated the product with quicklime; after which, by again distilling the liquid, he obtained a quantity of osmium sufficient to repay the trouble of the process.*

2. The oxide of osmium, the precise composition of which is unknown, gives up its oxygen to all the metals, excepting gold and platina. When its solution in water is shaken with mercury, the solution loses its smell; and the metal, combining with the mercury, forms an amalgam. From this, much of the redundant mercury may be separated by squeezing it through leather, which retains the amalgam of a firmer consistence. The mercury being distilled off, the osmium remains in its metallic form, of a dark

* 89 Ann. de Chim. vol. 191.

grey or blue colour. By exposure to heat, with access of air, it evaporates with its usual smell; but, if oxydation be effectually prevented, it does not seem in any degree volatile. Being subjected to a strong white heat, in a cavity made in a piece of charcoal, it is not melted, nor does it undergo any change. With gold and silver it forms malleable alloys. These are easily dissolved in nitro-muriatic acid; and by distillation give the oxide of osmium with its usual properties.

3. The pure metallic osmium, which had been previously heated, does not seem to be acted upon by acids; at least no effect is produced by boiling it some time in nitro-muriatic acid. By heating it in a silver cup with alkali, it immediately combines with the alkali, and this compound gives with water, a yellow solution, similar to that from which it had been procured. From this solution, acids expel the oxide of osmium, having its usual smell, and possessing the property of changing to a vivid blue the infusion of galls.

Besides the black powder from which osmium is obtained, Dr. Wollaston has discovered a separate ore of these two metals, mixed with the grains of crude platina. The specific gravity of this ore is about 19.5, and therefore exceeds that of crude platina itself, which is only 17.7. The grains are about the size of those of crude platina, but are considerably harder; are not at all malleable; and appear to consist of laminæ, possessing a peculiar lustre.

The discovery of Mr. Tennant, if it had required any confirmation, has lately received it from an elaborate investigation of Vauquelin, whose memoir is published in the 89th volume of the *Annales de Chimie*.

SECTION VII.

Copper.

COPPER, according to Berzelius, as it is found in commerce, is always contaminated with a little charcoal and sulphur, amounting to about one half of a grain in 100 grains. To fit it for purposes of accuracy, it may be dissolved in strong muriatic acid; and, after adding water, may be precipitated from the solution by a polished plate of iron. The metal, thus obtained, should be washed, first with diluted muriatic acid, and then with water, and may either be fused, or kept in a divided form.

Copper is a metal of a beautiful red colour, and admits of a considerable degree of lustre. Its specific gravity varies with the operations to which it has been subjected. Lewis states it at 8.830; Mr. Hatchett found that of the finest granulated Swedish copper to be 8.895; and Cronstedt states the specific gravity of Japan copper at 9.

It has considerable malleability, and may be hammered into very

thin leaves. It is, also, very ductile ; and may be drawn into wire, which has great tenacity.

At 27° Wedgwood, copper fuses, and by a sufficient increase and continuance of the heat, it evaporates in visible fumes.

1. 1. Copper is oxydized by air. This may be shown by heating one end of a polished bar of copper, which will exhibit various shades of colour, according to the force of the heat.

A plate of copper, exposed for some time to heat, becomes covered with an oxide, which breaks off in scales when the copper is hammered. It is composed of 62 of the black oxide and 38 copper. This oxide, when exposed on a muffle, is farther oxydized, and assumes a deep red hue. Copper is also oxydized by long exposure to a humid atmosphere, and assumes a green colour ; but the green oxide holds carbonic acid in combination. These compounds do not return to a metallic state by the mere application of heat ; but require, for their reduction, the admixture of inflammable matter.

2. Copper does not decompose water, which may even be transmitted, in vapour, through a red-hot tube of this metal, without decomposition.

3. Copper is susceptible of only two degrees of oxidizement ; in its lower stage the compound is red ; when oxidated to the maximum, it is black.

The *black* or *feroxide* may be obtained, either by calcining the scales of copper, which have already been alluded to, under a muffle ; or by decomposing sulphate of copper by carbonate of potash, and igniting the precipitate ; or by the simple ignition of the nitrate of copper. It is composed of

Copper	80	100.
Oxygen	20	25.
	<hr/>	
	100.	

To prepare the *protoxide* Mr. Chenevix recommends the following process. Mix together $57\frac{1}{2}$ parts of black oxide of copper, and 50 parts of metallic copper precipitated from the sulphate on an iron plate. Triturate it in a mortar, and put it with 400 parts of muriatic acid into a phial, which is to be well stopped. The copper and its oxide will be dissolved with heat. When potash is poured into this solution, the oxide (or rather hydrated protoxide) of copper is precipitated of an orange colour. This oxide, when deprived of water, becomes red ; but it attracts oxygen so strongly that it can scarcely be dried without absorbing more. It is composed of

Copper	88.89	100.
Oxygen	11.11	12.5
	<hr/>	
	100.	

II. Copper combines with strong sulphuric acid, in a boiling heat, and affords a blue salt, called sulphate of copper. (a) Sulphate of copper is a regularly crystallized salt, easily dissolved by water. (b) The solution is decomposed by pure and carbonated alkalis. The former, however, re-dissolve the precipitate. Thus, on adding pure liquid ammonia to a solution of sulphate of copper, a precipitate appears, which on a farther addition of the alkali, is re-dissolved, and affords a beautiful bright blue solution. (c) The sulphate of copper is decomposed by iron. In a solution of this salt immerse a polished plate of iron. The iron will soon acquire a covering of copper in a metallic state. (d) It gives up its acid on the application of heat, without decomposition; and an oxide of copper remains in the retort. (e) It is composed, according to Proust, of

Copper	25.6	{ forming black oxide }	32
Oxygen	6.4		
Sulphuric acid	. . . . .		32
Water	. . . . .		36
			<hr/> 100

Exclusive of water of crystallization, Berzelius,* from his own analysis, states its composition at

Peroxide of copper	50.90	103.66
Sulphuric acid	. . 49.10	100.
		<hr/> 100.

Proust describes a *subsulphate of copper*, formed by adding solution of potash to a solution of the above sulphate. Berzelius prepared it by the cautious addition of ammonia, and found it, on analysis, to be composed of

Peroxide of copper	. . 80	100
Sulphuric acid	. . . 20	25
		<hr/> 100.

Including its water of composition, the subsulphate consists of

Sulphuric acid	. . . . .	21.28
Peroxide of copper	. . . . .	64.22
Water	. . . . .	14.50
		<hr/> 100.

* 77 Ann. de Chim.

No sulphate of the protoxide is yet known; for when sulphuric acid is brought into contact with the protoxide, one half of the oxide gives up its oxygen to the other half, which thus becomes peroxide and unites with sulphuric acid.

Sulphite of copper may be obtained by transmitting a current of sulphurous acid gas, (which has been first passed through a small quantity of water, in order to deprive it of sulphuric acid) into a vessel containing water and peroxide of copper. A green liquid is formed, which contains sulphite of copper, with a large excess of acid; and sulphite of copper, in very small red crystals, remains at the bottom of the vessel. This salt has been investigated by Chevreul,* and found to consist of

Protoxide of copper	63.84
Sulphurous acid	36.16
	<hr/>
	100.

III. Copper exposed to a damp air rusts, and becomes covered with sub-carbonate of copper. The same compound is still more readily produced by adding carbonated alkalis to the solutions of copper. The nitrate of copper, precipitated by carbonate of lime, affords an apple-green precipitate, called *Verditer*. This substance consists of

Water	3½
Carbonic acid	30
Lime	7
Copper	50
Oxygen	9½
	<hr/>
	100

Berzelius observes that sub-carbonate of copper differs greatly in appearance when precipitated from a cold and from a hot solution. In the latter case, its colour is yellowish green; in the former, it is bluish green, and much more bulky. It is composed of

Peroxide of copper	71.7
Carbonic acid	19.7
Water	8.6
	<hr/>
	100.

IV. Copper dissolves readily in diluted nitric acid; and nitrous gas, holding a little copper in solution, is evolved in great abundance. The salt, resulting from this combination, has the singular property of detonating with tin. When to the solution of this salt,

* 83 Ann. de Chim. 181.

or of any other salt of copper, a solution of potash is added in sufficient quantity, a blue powder is precipitated, consisting of the peroxide of copper combined with water. This substance has been called by Proust, hydrate of copper; but, more properly, by Mr. Chenevix, hydro-oxide of copper. When collected on a filtre, and dried at a heat below that of boiling water, it shrinks somewhat like alumine; but still retains its colour. At a higher temperature it is decomposed, its water being dissipated, and the black oxide only remaining in the proportion of 75 parts from 100. This oxide cannot be brought to combine with water again by merely moistening it.

Nitrate of copper is decomposed, but not entirely, by carbonated alkalis; for, after their full effect, Berzelius found that a precipitate is still occasioned, by adding water impregnated with sulphuretted hydrogen.

This salt is constituted, according to Berzelius, of

Peroxide of copper	67.22
Nitric acid	32.78
	<hr/>
	100.

A sub-nitrate of copper is, also, described by the same chemist.* It may be obtained either by carefully heating the nitrate; or by adding a small proportion of potash or ammonia to its solution.

V. Concentrated and boiling muriatic acid acts on finely divided copper; and a green solution is obtained. In this salt the copper is oxydized to its maximum, and the salt may, therefore, be called, for the sake of brevity, *permuriate of copper*. It is very soluble in water, and generally deliquescent. By careful evaporation and cooling, the salt crystallizes in rhomboidal prismatic parallelipeds, which are readily soluble both in water and alcohol. It is composed, as Proust has stated, of

Black oxide of copper	40
Muriatic acid	24
Water	36
	<hr/>
	100

Exclusive of water, Berzelius states its composition to be

Peroxide of copper	59.8
Muriatic acid	40.2
	<hr/>
	100.

The watery solution of muriate of copper forms a kind of sym-

* 82 Ann. de Chim. 250.

pathetic ink. Characters written with it become yellow by warming, and again disappear when the paper cools.

By digesting a solution of per-muriate of copper with filings of the metal, it is converted into a muriate of protoxide or *pro-muriate*; the fresh portion of copper being oxydized at the expense of what was previously held in solution. The solution of this salt is precipitated by merely pouring it into water. By exposure to air, it acquires oxygen and is converted into the per-muriate. Alkalis throw down an orange precipitate. It consists of

Copper .	65.80	{ forming }	
Oxygen .	8.08	{ sub-oxide }	73.88
Acid			26.12
			<hr/>
			100.

By the combustion of copper in chlorine gas, two compounds are produced at the same time, one of which is a fixed easily fusible substance, resembling common rosin; the other a yellowish sublimate. The first, composed of 60 copper and 33.5 chlorine, and called by Sir H. Davy *cuprane*, is insoluble in water, but becomes green by exposure to the atmosphere. The second, called *cupra-neæ*, dissolves in water, and gives it a greenish colour; and is composed of 60 copper to 67 chlorine. Its solution is identical with per-muriate of copper; for even though it be admitted, according to the view of Sir H. Davy, to be a compound of chlorine and metallic copper, yet during solution it will decompose water, and become a true muriated oxide of copper.

VI. When corroded by long continued exposure to the fumes of vinegar, copper is converted into verdegris.—The verdegris of commerce consists partly of an acetate, soluble in water, and partly of a sub-acetate. By solution in distilled vinegar and evaporation, it forms regular crystals, which are completely soluble in water.—These, distilled alone, yield concentrated acetic acid, and a combination remains in the retort, containing, in 90 parts,

4.50 charcoal
78.66 copper
6.84 oxygen
<hr/>
90.

VII. When the muriate of copper is mixed with a solution of prussiate of potash or of lime, a beautiful reddish brown precipitate of ferro-prussiate of copper is obtained, which has been recommended by Mr. Hatchett as a pigment. Tincture of galls throws down, from all the solutions of copper, a dull yellow precipitate.

VIII. Copper combines with sulphur. When a mixture of three parts of the metal, in the state of fine filings, with one part of sulphur, is melted in a glass tube, at the moment of combination, a

brilliant inflammation ensues, exceeding, in brightness, that produced by the fusion of iron and sulphur.

Copper leaf, Berzelius observes,* burns in gaseous sulphur, as brilliantly as iron wire in oxygen gas. A compound is formed, precisely analogous to the native sulphuret of copper, and composed of

Copper	80.	100.
Sulphur	20.	25.6
	<hr/>	<hr/>
	100.	125.6

This is the only combination of copper and sulphur, that has yet been discovered.

Copper unites, by fusion, with phosphorus. The phosphuret is white, brittle, and of the specific gravity 7.122. The analysis of Pelletier gives 20 per cent. of phosphorus.

IX. Ammonia readily dissolves the oxides and hydro-oxides of copper. Nothing more is necessary than to digest them together in a phial. The solution has a beautiful deep blue colour. By evaporation in a very gentle heat, fine blue silky crystals may be obtained.

X. Copper combines readily with most of the metals, and affords several compounds, which are of great use in the common arts of life. *Tutenag* is a white alloy of copper, zinc, and iron. Copper with about a fourth its weight of lead forms *pot-metal*; with about the same proportion of zinc, it composes *brass*, the most useful of all its alloys. Mixtures of zinc and copper form, also, the various compounds of *Tombac*, *Dutch Gold*, *Similor*, *Prince Rupert's Metal*, *Pinchbeck*, &c. Copper with tin, and sometimes a little zinc, forms *bronze* and *bell-metal*, or *gun-metal*. And when the tin is nearly one third of the alloy, it is beautifully white and takes a high polish. It is then called *speculum-metal*.

SECTION VIII.

Iron.

IRON has a bluish white colour, and admits of a high degree of polish. It is extremely malleable, though it cannot be beat out to the same degree of thinness as gold or silver. It is much more ductile, however, than those metals; for it may be drawn out into wire as fine as a human hair; and its tenacity is such, that a wire only $\frac{78}{10000}$ ths of an inch in diameter is capable of supporting a weight of nearly 550 lb. Its specific gravity varies from 7.6 to 7.8.

* 79 Ann. Ch. 250. See also Vauquelin on the Artificial Sulphuret of Copper, vol. 80, p. 265.

Iron is one of the most infusible of the metals. Its melting point is about 158° of Wedgwood. Its chemical properties are the following :

1. 1. When exposed to the atmosphere, especially when the air is moist, it slowly combines with oxygen, or, in common language, *rusts*. If the temperature of the metal be raised, this change goes on more rapidly ; and, when made intensely hot, takes place with the appearance of actual combustion. Thus the small fragments, which fly from a bar of iron during forging, undergo a vivid combustion in the atmosphere ; and iron filings, projected upon the blaze of a torch, burn with considerable brilliancy. The oxide, obtained in these ways, is of a black colour, and is still attracted by the magnet.

The same change is more rapidly produced, when ignited iron is brought into contact with oxygen gas. A vivid combustion happens, as already described in the chapter on that gas. Lavoisier made many experiments to ascertain the increase of weight, acquired by the iron, and concluded that on an average, 100 parts of iron condense from 32 to 35 parts of oxygen. Dr. Thomson, however, on repeating the experiment several times, did not find that 100 parts of iron absorbed more than 27.5 of oxygen ; but he observes, that it is almost impossible to collect the whole product ; and that minute portions are dissipated in sparks.*

2. By contact with water at the temperature of the atmosphere, iron becomes slowly oxidized, and hydrogen gas is evolved. When the steam of water is brought into contact with red-hot iron, the same change is produced with much greater rapidity ; the iron is converted into the black oxide ; and a large quantity of hydrogen gas is set at liberty, and may be collected by a proper apparatus. The iron is found to have lost all its tensility, and may be crumbled down into a black powder, to which the name of *finery cinder* was given by Dr. Priestley. In composition, it does not appear to differ from the oxide of iron obtained by the action of atmospheric air, and is strongly magnetic. By a careful repetition of the process, Dr. Thomson found that 100 grains of iron, ignited in contact with the vapour of water, acquire 29.1 grains of oxygen.

3. When iron is dissolved in diluted sulphuric acid, the acid is not decomposed ; but the metal is oxidized at the expence of the water, and hydrogen gas is obtained in abundance. Now as water is composed of two volumes of hydrogen and one of oxygen, a quantity of oxygen, equal in volume to half the hydrogen gas obtained, must have combined with the metal ; that is, for every 200 cubic inches of hydrogen, oxygen equal to one hundred cubic inches, or 83.8 grains, must have united with the metal. Dr. Thomson, from an experiment of this kind, calculated that 100 grains of iron, after the action of dilute sulphuric acid, had gained 27.5 of oxygen. It is to be considered, however, that the purity of the iron employed will materially affect the result ; for if the iron contain charcoal, as is always the case, carburetted hydrogen gas will be

* 27 Nich. Journ. 381.

mixed with the hydrogen; and the hydrogen in this gas being in a condensed state, the apparent will be less than the real quantity disengaged.

Iron, by the different processes which have been described, is converted into an oxide, of a black colour, and still retaining the magnetic property. Its composition has been the subject of a series of experiments by Bucholz, who concludes that 100 parts of iron, to become the black oxide, condense 29.88 parts of oxygen; and Dr. Wollaston assumes the oxygen to be 29 parts. Berzelius's determination differs but little from these, viz.

Iron . . .	77.22	. . .	100.
Oxygen . . .	22.78	. . .	29.5
<hr/>			
	100.		

When the oxide of iron, which has just been described, is dissolved in nitric acid; then boiled for some time; and, after being precipitated by ammonia, is washed, dried, and calcined in a low red heat, it is found to be converted into a red oxide. This, according to Bucholz, is composed of 100 parts of iron and 42 of oxygen; or according to Dr. Wollaston of 100 metal and 43.5 oxygen; but Berzelius states its composition as follows:

Iron . . .	69.34	. . .	100.
Oxygen . . .	30.66	. . .	44.25
<hr/>			
	100.		

The existence of these two oxides, and the proportion of their ingredients, is clearly established. But besides these, it has been attempted to be proved that there is another oxide of iron. Thenard contends for a compound, containing less oxygen than the black oxide, viz. 25 parts to 100 metal; a second composed of 37.5 oxygen to 100 metal; and a third of 50 to 100 metal. And Gay Lussac, also, supports the notion of three oxides with proportions differing from those of Thenard. The first is that, which is obtained by dissolving iron in diluted sulphuric or muriatic acid, out of the contact of air. It is precipitated white by alkalis, and by ferroprussiates, and is composed of 100 iron and 28.3 oxygen. The second is obtained when iron is oxidized by the vapour of water or oxygen gas, and consists of 100 iron and 37.8 oxygen. The third is the acknowledged red oxide, which is composed of 100 iron and 42.31 oxygen.* It is probable, however, that the only known oxides are the two, the composition of which has already been stated on the authority of Bucholz, Wollaston, and Berzelius.

There appear to be two hydrates or hydro-oxides, corresponding to these two oxides of iron, which are obtained whenever we pre-

* 80 Ann. de Chim. 163.

precipitate their respective solutions in an acid, by a fixed alkali. The hydrate of the black oxide is white, with a tinge of olive or green; that of the red oxide is orange coloured. The former hydrate passes to the latter, by exposure to the atmosphere. Ochre, it has been shown by Leidenbeck, is a native hydrate of the red oxide, mechanically mixed with earthy ingredients; but exclusively of them, composed of 20.2 to 25 water, with 60 to 62 oxide of iron.* The preparation of a pure hydrate of iron was found by Berzelius to be attended with great difficulty.

It may be remarked, on comparing the composition of the two oxides of iron, that the oxygen of the red is not a multiplication of that of the black oxide by an entire, but by a fractional number; for $29.5 \times 1\frac{1}{2} = 44.25$. This anomaly, as was observed in the account of the principles of the atomic system, is best got over by multiplying by two the numbers (1 and $1\frac{1}{2}$), expressing these proportions, which will make the ratio of 29.5 to 44.25 the same as that of two to three. We are thus, however, led to the supposition, that there is an oxide inferior to the black oxide in its proportion of oxygen; and which, from theory, should consist of 100 iron and 14.75 oxygen. The black oxide contains a quantity of oxygen, which is a multiplication of 14.75 by 2, and the red by 3. And if the supposed protoxide be constituted of an atom of metal and an atom of oxygen, the weight of the atom of iron will be about 50, for as 14.75 to 100 so is 7.5 to little more than 50.

Until this difficulty is cleared up, we may, however, give the name of *protoxide* to the black oxide of iron; and the red compound of iron and oxygen may continue to be called the *ferroxide*.

II. Whenever diluted sulphuric acid is made to act on iron, we obtain a compound of that acid with the protoxide. The solution, by evaporation, yields rhomboidal prismatic crystals, which have a beautiful green colour. They have a strong styptic taste; redden vegetable blue colours; and are soluble in about two parts of cold and three-fourths their weight of boiling water. The solution is precipitated of a greenish white by alkalis, and white by prussiate of potash. The crystals, when distilled, are decomposed, and yield a strong fuming acid, called *glacial sulphuric acid*. The acid, in this salt, is to the oxide, in the proportion of 100 to 88, and it is composed, according to Berzelius, of

Sulphuric acid	28.9
Protoxide of iron	25.7
Water	45.4
	<hr/>
	100.

When a solution of green sulphate of iron is heated with access of air, part of the protoxide passes to the state of peroxide, and combining with a portion of acid, falls down in the form of a yellow powder, which, according to Berzelius, is a sulphate

* 80 An. Ch. 163.

of the peroxide with *excess of base*, or a *subsulphate*. The acid in this compound is to the base, as 100 to 266, and it is therefore composed of

Sulphuric acid	.	.	.	27.33
Peroxide of iron	.	.	.	72.67
				<hr/>
				100.

No sulphate of protoxide with *excess of acid* is yet known.

The farther oxidation of the iron in the green sulphate is effected more expeditiously by boiling its solution with some nitric acid, and evaporating to dryness, care being taken not to raise the heat so as to expel the sulphuric acid. Water added to the residuum, dissolves a salt, which is composed of sulphuric acid and peroxide. The solution has a yellowish colour; does not afford crystals; but when evaporated to dryness, forms a deliquescent mass, which is soluble in alcohol, and may thus be separated from the green sulphate. Its solution affords a blue precipitate with ferro-prussiate of potash. This salt has been called, but not with strict propriety, *oxy-sulphate*. Its legitimate name would be *sulphate of peroxide of iron*; but, as this is inconvenient from its length, it may be called the *red sulphate of iron*. It consists, according to Berzelius, of

Sulphuric acid	.	60.44	100.
Peroxide of iron	.	39.56	65.5
		<hr/>	<hr/>
		100.	165.5

The sulphurous acid, also, unites with iron and forms a sulphite; and the sulphite, taking an additional quantity of sulphur, composes a sulphuretted sulphite. The precise composition of these salts remains to be determined.

III. Nitric acid, in its concentrated state, scarcely acts upon iron, but, when diluted with a small quantity of water, it dissolves iron with great vehemence; and with the extrication of a large quantity of impure nitrous gas. The solution, at first, is a deep green, but when nearly saturated assumes a red colour. It is not crystallizable, but, when evaporated, forms a deliquescent mass.

The nitrate of iron, it was long ago shown by Sir H. Davy, may exist in two different states, the green nitrate in which the oxide is at the minimum of oxidation, and the red, in which it is at the maximum.

To obtain nitrate of iron, in which the oxide is at the minimum, acid of the specific gravity of 1.25 or less must be used; the iron must be added in large pieces, and at distant intervals; and the operation carried on without the access of air. When this solution is made on a large scale for the purposes of the dyer, it is proper to connect the vessel, in which it is prepared, with a large receiver; for, in the latter, a quantity of nitrous acid will be found, which is worth the trouble of collecting. Nitrate of iron, thus prepared,

passes, on exposure to the atmosphere, to the state of that in which the oxide is at the maximum. The composition of these two nitrates has not yet been accurately determined.

IV. Muriatic acid dissolves iron and its oxides with great ease; and affords two distinct salts, differing from each other according to the state of oxidation of the metal. The muriate containing the black oxide is green, and that containing the oxide at the maximum red. Both these salts are deliquescent, and cannot be brought to crystallize.

The green muriate is convertible into the red by simple exposure to the atmosphere. Berzelius describes an interesting experiment founded on this property. If a solution of the green muriate be exposed to the atmosphere, in a tall cylindrical glass jar, for some days, and a few drops of pure ammonia be introduced at different depths by means of a tube, the precipitate formed near the surface will be green; a little lower blue; still lower greyish; then of a dirty white; and at the bottom perfectly white, if time has not been allowed for the atmospheric oxygen to penetrate so low.

When the solution of green muriate is evaporated dry, and the residuum is heated to redness, a compound is obtained which, according to Dr. John Davy's experiments, is composed of iron and chlorine. During ignition, the oxygen of the oxide and the hydrogen of the muriatic acid, are supposed to unite and form water, while the chlorine combines with the metal. The compound is termed by Dr. Davy *ferrane*. It consists of

Chlorine . . .	53.2	100.
Iron . . .	46.8	88.
	<hr/>	<hr/>
	100.	188.

When iron wire is burned in chlorine gas, a substance is formed of a bright yellowish brown colour, and with a high degree of lustre; volatile at a temperature a little above 212° , and crystallizing in small iridescent plates. It acts violently on water, and forms a solution of the red muriate. It is composed of

Chlorine . . .	66.1	100.
Iron . . .	33.9	51.5
	<hr/>	<hr/>
	100.	151.5

V. Iron may be united, in the way of double elective affinity, with the ferro-prussic acid.* Thus, when ferro-prussiate of potash and iron and sulphate of iron, both in solution, are mixed together, the ferro-prussic acid and oxide of iron quit their former combinations and unite together. The beautiful blue precipitate is ferro-prussiate of iron.

* The prussic acid and ferro-prussic acid (or ferruretted chyazic acid of Mr. Porrett) will be described in the chapter on Animal Substances.

- (a) Ferro-prussiate of iron is nearly insoluble in water.
 (b) It is not soluble in acids.
 (c) It is decomposed by a red-heat, the ferro-prussic acid being destroyed, and an oxide of iron remaining.
 (d) It is decomposed by pure alkalis and earths, which abstract the ferro-prussic acid, and leave the iron in the state of peroxide. Thus, when pure potash is digested with ferro-prussiate of iron, its beautiful blue colour disappears, and we obtain a combination of potash and ferro-prussic acid. It has been considered as a triple compound of prussic acid, potash, and iron; but, according to the new views of Mr. Porrett, it is a binary compound of ferro-prussic acid, and peroxide of iron.

Mr. Porrett has ascertained its composition to be as follows:

19.33	Protoxide of iron	} forming ferro-prussic acid . . .	53.38
34.05	Prussic acid		
	Peroxide of iron serving as a base		35.00
	Water of crystallization		11.62
			100.

In Nicholson's Journal (4to. iv. 30. 171), I have given an improved process for preparing the ferro-prussiate of potash. The following, after trying various modes of preparation, I find to afford the purest test.

1. To a solution of potash, deprived of its carbonic acid by quick-lime, and heated nearly to the boiling point, in an iron kettle, add, by degrees, powdered Prussian blue till its colour ceases to be discharged. Filter the liquor, and wash the sediment with water till it ceases to extract any thing; let the washings be all mixed together, and placed in an earthen dish in a sand-heat. When the solution has become hot, add a little diluted sulphuric acid, and continue the heat for about an hour. A copious precipitate will be formed of Prussian blue. Let this be separated by filtration, and assay a small quantity of the filtered liquor in a wine glass, with a little dilute sulphuric acid. If an immediate production of Prussian blue should still take place, fresh sulphuric acid must be added to the whole liquor, which must again, with this addition, be exposed to heat. These filtrations and additions of sulphuric acid must be repeated as long as any considerable quantity of Prussian blue is produced; but when this ceases, the liquor may finally be passed through a filter.

2. Prepare a solution of sulphate of copper in about four or six times its weight of warm water, and into the solution (1) pour this, as long as a reddish brown or copper-coloured sediment continues to appear. Wash this sediment, which is a ferro-prussiate of copper, with repeated affusions of warm water; and, when these come off colourless, lay the precipitate on a linen filter to drain, after which it may be dried on a chalk-stone.

3. Powder the precipitate, when dry, and add it by degrees to a solution of pure potash, prepared as described vol. i. page 206.

The ferro-prussic acid will leave the oxide of copper and pass to the alkali, forming a ferro-prussiate of potash.

4. But as the salt still contains sulphate of potash, a portion of this may be separated by gentle evaporation, the sulphate crystallizing first. To the remaining liquid, add a solution of barytes in warm water (vol. i. page 245) as long as a white precipitate ensues, observing not to add more after its cessation. The solution of prussiate is now free, in a great measure, from iron, and entirely from sulphates; and, by gentle evaporation, will form, on cooling, beautiful crystals. These crystals are perfectly neutral; insoluble in alcohol; are not decomposed by boiling, or by the contact of carbonic acid; and give Prussian blue with solutions of peroxide of iron.

For the vegetable alkali, either soda or ammonia may be substituted in the above process, if they be preferred. If a sufficient quantity of pure barytes cannot be had, the sulphate may be precipitated by acetate of barytes. The acetate of potash, thus formed, not being a crystallizable salt, remains in the mother-liquor.

(e) When the ferro-prussiate of potash is mixed with sulphate of iron, in which the metal is oxydized at the minimum, the ferro-prussiate of iron that is formed is of a white colour, but gradually becomes blue, as the iron, by exposure to air, passes to the state of peroxide.*

(f) The effect of a sympathetic ink may be obtained, by writing with a pen dipped in a very dilute solution of ferro-prussiate of potash. No characters will appear till the paper is moistened with sulphate of iron, when letters of a Prussian blue colour will be apparent. The experiment may be reversed, by writing with sulphate of iron, and rendering the characters legible by prussiate of potash.

(g) The ferro-prussiate of potash decomposes all metallic solutions, excepting those of gold, platina, iridium, osmium, rhodium, tellurium, and antimony.†

VI. When sulphate of iron is mixed with an infusion of galls, we obtain a black solution, which is a new combination of oxide of iron, with the gallic acid and tan. Both the gallate and tannate of iron are, therefore, essential constituents of inks; the other ingredients of which are chiefly added with the view of keeping these insoluble compounds suspended.

In order that the iron may unite with the gallic acid and tan, it must be combined with the sulphuric acid in the state of red oxide; for the less oxydized iron, in the green salt, does not form a black compound with these substances. Iron filings, however, dissolve in an infusion of galls with an extrication of hydrogen gas; but the compound is not black till after exposure to air, which oxydizes the iron still farther. This solution, with a sufficient quantity of gum, forms an excellent ink.

On the same principle may be explained the effect of metallic

* See Proust's memoir, in Nicholson's Journal.

† See Proust, Philosophical Magazine, xxx. 42.

iron in destroying the colour of ink. When ink is digested with iron filings, and frequently shaken, its colour decays; and it also becomes colourless after having a stream of sulphuretted hydrogen gas passed through it. In both these cases the oxide of iron is partly deoxydized. Characters written with ink, after this treatment, are at first illegible, but become black as the iron acquires oxygen from the air.

(a) Write upon paper with an infusion of galls. The characters will not be legible till a solution of sulphate of iron is applied. This experiment may be reversed like the preceding one (V. f.)

(b) The combination of iron, forming ink, is destroyed by pure and carbonated alkalis. Apply a solution of alkali to characters written with common ink, the blackness will disappear, and the characters will become brown, an oxide of iron only remaining on the paper.

Alkalis, added cautiously to liquid ink, precipitate the black combination, but an excess re-dissolves the precipitate.

(c) Characters, which have been thus defaced, may again be rendered legible by an infusion of galls.

(d) Ink is decomposed by most acids, which separate the oxide of iron from the gallic acid in consequence of a stronger affinity. Hence ink stains are removed by dilute muriatic acid, and by some vegetable acids. Hence, also, if to a saturated solution of sulphate of iron there be added an excess of acid, the precipitate no longer appears on adding infusion of galls.

When a mixture of ink is heated with nitric acid, the yellow oxalate of iron is formed, and is precipitated on adding pure ammonia.

(e) Ink is decomposed by age, partly in consequence of the farther oxydation of the iron, and partly, perhaps, in consequence of the destruction of the acid of galls. Hence ink-stains degenerate into iron-moulds, and these last are immediately produced on an inked spot of linen when washed with soap, because the alkali of the soap abstracts the gallic acid, and leaves only an oxide of iron.

(f) Ink is decomposed by oxy-muriatic acid, which destroys the gallic acid, and the resulting muriatic acid dissolves the oxide of iron.

As all writing inks, into the composition of which iron enters, are liable to decay by time, and to be destroyed by various agents, an ink has been proposed by Mr. Close, the basis of which is similar to that of printing ink.—Take oil of lavender 200 grains, gum copal, in powder, 25 grains, and lamp-black from $2\frac{1}{2}$ to 3 grains. With the aid of a gentle heat dissolve the copal in the oil of lavender in a small phial, and then mix the lamp black with the solution, on a marble slab, or other smooth surface. After a repose of some hours, the ink must be shaken before use, or stirred with an iron wire, and if too thick, must be diluted with a little oil of lavender.* This ink I have found extremely useful in writing

* See Nicholson's Journal, 8vo. ii. 145.

labels for bottles which contain acids, or which are exposed to acid fumes in a laboratory.

VII. The phosphoric acid acts with but little energy upon iron; though a native compound of this acid and iron imparts, to some varieties of the metal, the singular property of being very brittle when cold, or, as it is called, *cold-short*.

The phosphate of iron is almost insoluble in water. It is best prepared by mixing the solutions of green sulphate of iron and phosphate of soda. A yellowish white precipitate is formed, which is soluble in many of the acids, and precipitated without change by ammonia.

The *oxy-phosphate* of iron is, also, an insoluble salt. It may be formed by mingling the solutions of phosphate of soda and oxy-sulphate of iron. Its colour is a light blue. Both these preparations have lately derived some importance, from being recommended as remedies of cancer.

VIII. The succinic acid composes with iron a brown mass, insoluble in water. The combination is best effected by double decomposition, and especially by the addition of a solution of succinate of ammonia to the salts of iron. A loose brown red precipitate of succinate of iron falls down. This precipitate Klaproth exposes to heat, first by itself, and afterwards mixed with a small quantity of linseed oil. The first operation destroys the acid, and the second reduces the metal to the state of black oxide. Now as the black oxide contains, in 100 parts, 70.5 of metallic iron, the precipitation of a solution, by succinate of ammonia, affords a ready method of estimating the quantity of iron in any solution of that metal, or in any of its salts.*

IX. The acetic acid, or even common vinegar, acts slowly upon iron, and forms a solution, which is of great use in dyeing and calico printing. The acetite of iron may, also, be obtained by a double decomposition, if we mingle the solutions of acetite of lime or of lead with one of sulphate of iron. It may be formed, also, by boiling acetite of lead with metallic iron, which precipitates the lead in a metallic state.

This combination of iron with acetous acid may exist, like its other salts, in two different states. In the one, the oxide is at the minimum, and in the other at the maximum of oxidation. It is the latter salt only, which is adapted to the use of the dyer and calico printer.

X. Iron is dissolved by water impregnated with carbonic acid. A few iron filings, when added to a bottle of aerated water, and

* "Mr. Peschier, a skilful chemist and practitioner of pharmacy at Geneva, has found that the benzoic acid, and still better the alkaline benzoates, are very good and useful tests of the presence and quantity of iron contained in any solution. They precipitate iron readily and entirely, and, being cheaper and more easily obtained than the saccinates, which are commonly employed for that purpose, are considered by Mr. Peschier as deserving the preference in chemical analysis. Another very valuable property of benzoic acid is, that neither the acid nor its salts exert any action upon manganese." Thomson's Ann. of Philos. Feb. 1817. C.

occasionally shaken up, impregnate the water with this metal. This solution is decomposed by boiling, and in a less degree by exposure to air.

XI. Iron combines with sulphur, and affords compounds, the characters of which vary greatly according to the proportions of their components. (a) A paste of iron filings, sulphur, and water, if insufficient quantity, will burst, after some time, into flame. (b) A mixture of one part of iron filings and three parts of sulphur, accurately mixed, and melted in a glass tube, at the moment of union exhibits a brilliant combustion. The best method, however, of effecting the combination of iron and sulphur is to take a bar of the metal, while of a glowing heat, from a smith's forge, and to rub it with a roll of sulphur. The compound of iron and sulphur falls down in drops, and may be preserved in a phial. Of all the compounds of sulphur, this is best adapted for affording pure sulphuretted hydrogen gas with diluted acids. (c) The sulphuret of iron, when moistened, rapidly decomposes oxygen gas, and passes to the state of sulphate. (d) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphuretted hydrogen gas.

In the sulphuret, made artificially by fusion, as well as in the native sulphuret, iron (it has been shown by Proust and Mr. Hatchett) is in the metallic state. Two compounds, also, have been proved to exist, the one with a larger, the other with a smaller proportion of sulphur. The former may be called the *super-sulphuret*; and the latter, which is distinguished by the property of being magnetic, the *sulphuret*. The super-sulphuret is known only as a natural product; it is not magnetic; is nearly insoluble in diluted sulphuric and muriatic acids; and gives no sulphuretted hydrogen gas with acids. But the sulphuret is readily soluble, obeys the magnet, and gives abundance of sulphuretted hydrogen with dilute acids. It is composed of

Iron	.	.	63.	.	.	100.
Sulphur	.	.	37.	.	.	58.75
<hr/>						
100.						

And the super-sulphuret is composed of

Iron	.	.	53.92	.	.	100
Sulphur	.	.	46.08	.	.	127
<hr/>						
100.						

Though the artificial sulphuret varies in its composition, yet it is probable that these varieties are occasioned by the sulphuret being mechanically mixed with different proportions of iron. The foregoing appear to be the only well ascertained and definite compounds; and the analysis of them by Berzelius, it may be observed, agrees very nearly with that of Proust, and indeed does not differ, in either case, one per cent. If the sulphuret be, as is consist-

ent with all we know at present, that compound in which sulphur exists in the smallest proportion, this would be unfavourable to the notion of any oxide of iron with less oxygen than the black oxide. For in almost every other instance, the protoxide of a metal contains a quantity of oxygen equal to half the sulphur in the pro-sulphuret, a coincidence sufficiently explained by admitting both to be *binary compounds*, in the sense of the word annexed to it by Mr. Dalton, and that the weight of the atom of oxygen is just half the weight of the atom of sulphur. Gay Lussac contends for the existence of three sulphurets corresponding to his supposed three oxides of iron;* but the details of the experiments establishing their existence remain to be published.

XII. Iron combines with carbon in various proportions; and the variety of proportion occasions very different properties in the compound. On these varieties, and the occasional combination of a small proportion of oxygen, depend the qualities of the different kinds of iron used in the arts, as cast iron, steel, &c. &c. The quantity of carbon, in the sub-carburets of iron, may be determined by solution in sulphurous acid, which dissolves the iron and sulphur, and has no action on carbon. An ingenious mode of analysis employed by Mr. Mushet, consists in ascertaining the quantity of litharge, which a given quantity of the iron under examination is capable of reducing, by fusion, to a metallic state.

There can scarcely be a more striking example of essential differences in external and physical characters being produced by slight differences of chemical composition; for steel owes its properties to not more than from $\frac{1}{80}$ to $\frac{1}{140}$ th its weight of carbon.

Cast or crude iron, besides casual impurities, contains oxygen, carbon, and the metal of silex; but its differences depend chiefly on the various proportion of carbon, which is greatest in the black, and least in the white, variety of iron. Berzelius, indeed, denies the presence of oxygen in cast iron, and says that its different kinds are produced by variable proportions of charcoal, manganese, and the metallic bases of magnesia and silex.† By the process of refining, the carbon and oxygen, it has been supposed, unite together, and escape in the form of carbonic oxide; while another part of the oxide of iron unites to the earthy matter, and rises to the surface in the form of a dense slag. After this process, it forms *malleable* or *bar iron*, which may be considered as iron still holding some oxygen and carbon in combination, the latter of which, even in very ductile iron, amounts, according to Berzelius, to about one half per cent. Hassenfratz has suggested that iron, which has been manufactured with wood charcoal, may probably contain potassium, and may owe its superiority to this circumstance; and Berzelius has rendered it probable that even the most ductile iron contains silicium.‡

If bar iron be long and slowly heated, in contact with charcoal, it loses oxygen and acquires carbon, and thus becomes *steel*. A small

* 80 An. de Chim. 170.

† 40 Phil. Mag. 245.

‡ 78. An. Ch. 253.

proportion only of carbon is not capable of depriving it entirely of the properties of malleable iron, for though it becomes a good deal harder, yet it may still be welded. By union with a still farther quantity of carbon, it loses altogether the property of welding; is rendered harder and more compact; and forms the fine *cast steel*. Steel, therefore, though like cast iron it contains carbon, yet differs from it essentially in being destitute of oxygen and earth. The charcoal, which it contains, appears in the form of a black stain, on applying a drop of almost any weak acid to the surface of polished steel.

Another combination of iron and carbon, which is a true carburet of iron, is the substance called *plumbago*, or black-lead, used in fabricating pencils, and in covering iron to prevent rust. By exposure to the combined action of heat and air, the carbon is burned off, and the oxide of iron remains. When mingled also with powdered nitrate of potash, and thrown into a crucible, a deflagration ensues; and an oxide of iron may be obtained by washing off the alkali of the nitre. From recent experiments of Messrs. Allen and Pepys, it appears that pure plumbago, when burnt in oxygen gas, leaves a residue of oxide of iron amounting only to about five per cent.; and that it gives very nearly the same quantity of carbonic acid, by combustion, as the diamond and charcoal. When intensely heated in a Toricellian vacuum by a Voltaic battery, Sir H. Davy found that its characters remained wholly unaltered. Neither could any evidence of its containing oxygen be derived from the action of potassium.* But when exposed to the focus of a powerful lens in oxygen gas, he has lately observed that the gas became clouded during the process, and that there was a deposition of dew on the interior surface of the glass globe; a fact which indicates that plumbago, like charcoal, contains a small proportion of hydrogen.

Iron unites with various other metals. With potassium and sodium, it forms alloys more fusible and whiter than iron, and which effervesce when added to water. Stromeyer† has investigated the alloy of iron and silicium. It is formed by heating together iron, silex, and charcoal. The alloy is dissolved very slowly by acids, for it becomes covered with a coat of silex, which defends it from further action, till it has been removed. Manganese forms a white and brittle alloy with iron. Iron, also, forms an alloy with tin; and iron plates, previously cleaned by a dilute acid, may be covered with tin by dipping them into that metal when melted.

* Philosophical Transactions, 1809.

† 31 An. Ch.

SECTION IX.

Nickel.

1. To obtain nickel in a state of purity, the metal usually sold under that name may be dissolved in diluted nitric acid ; the solution, evaporated to dryness ; and the dry mass be again, for three or four times, alternately dissolved in the acid, and boiled to dryness. After the last evaporation, the mass may be dissolved in a solution of pure ammonia ; which has been proved, by its occasioning no precipitation from muriate of lime, to be free from carbonic acid. The solution is next to be evaporated to dryness ; and, after being well mixed with twice or thrice its weight of black flux, is to be exposed to a violent heat in a crucible for half or three quarters of an hour.

Other processes, for obtaining and purifying nickel, are described by Richter in the 12th volume of Nicholson's Journal ; by Robiquet in the 69th, and by Tupputi in the 78th volumes of the *Annales de Chimie*. The last-mentioned memoir contains an elaborate investigation of the properties and combinations of nickel.

Pure nickel has the following characters :

1. Its colour is white, and intermediate between those of silver and tin. It admits of being finely polished, and has then a lustre between those of steel and platina. When ignited, its colour changes to that of antique bronze, which is increased every time the metal is heated.

2. It is perfectly malleable, and may be forged when hot into bars, and hammered into plates when cold. At 541° Fahrenheit, Tourte found its specific gravity 8.402, and, after being thoroughly hammered, 8.932. It is ductile, and may be drawn into very fine wire. It cannot easily be soldered, on account of the oxide, which forms on its surface when heated. Its power of conducting heat is superior to that either of copper or zinc. Its magnetic property is very remarkable, and is retained when it is alloyed with a little arsenic, and as Lampadius has shown,* with other metals. In difficult fusibility by heat, it appears to equal manganese.

3. Nickel appears to be susceptible of two different states of oxidation. By long exposure to a red heat, with free access of air, it is converted into a dark brown oxide, which is still magnetic. In oxygen gas, it burns vividly, and throws out sparks. When precipitated from its solutions by alkalis, and moderately ignited, it becomes of an ash-grey colour with a slight tinge of blue or green, and in this state contains, according to Klaproth, 66 metal, and 34 oxygen. By farther ignition, it becomes blackish grey, and then consists, as stated by Richter, of 78 metal and 22 oxygen. Tup-

* Thomson's Annals, v. 62.

puti, from 100 grains of nickel dissolved in nitric acid, precipitated by a fixed alkali, and calcined, obtained 127 grains of an ash grey powder, which is to be considered as the *protoxide*. Hence it is composed of

Nickel	.	.	.	.	.	78.8
Oxygen	.	.	.	.	.	21.2
						<hr/>
						100.

Thenard describes a black peroxide of nickel, obtained by passing a current of chlorine gas, through water, in which the hydrate is suspended. Its precise composition is unknown. In a sufficiently high temperature, its oxides are reducible without addition; nor is it more tarnished by a strong heat than gold, silver, or platina. It ranks, therefore, among the noble or perfect metals.

4. The sulphuric and muriatic acids have little action on nickel. Its appropriate solvents are the nitric and nitro-muriatic acids. The nitric solution has a beautiful grass-green colour. Carbonate of potash throws down an apple-green precipitate, which assumes a dark grey colour when heated. The fixed alkalis occasion a greenish white bulky precipitate, which is a hydrate or hydro-oxide of nickel, composed of 76 per cent. of the protoxide and 24 water.

5. When pure ammonia is added to nitrate of nickel, a precipitate is formed, resembling that which is separated by ammonia from a solution of copper, but not of so deep a hue. This colour changes, in an hour or two, to an amethyst red, and to a violet; which colours are converted to apple-green by an acid, and again to blue and violet by ammonia. If the precipitate retain its blue colour, the presence of copper is indicated.* This precipitate, which is a hydrate, is soluble by an excess of ammonia, and by this property the oxide of nickel may be separated, in analyses, from those of almost all other metals.

6. Nickel, when heated in chlorine, affords an olive-coloured compound; and the muriate, when evaporated and strongly heated, gives brilliant white scales, which probably consist of nickel and chlorine. From analogy, the first should contain the largest proportion of chlorine, but the analysis of these compounds has not yet been effected.

7. Solutions of all the salts of nickel are decomposed by alkaline hydro-sulphurets, with which they form black precipitates; but sulphuretted hydrogen has no effect on them. Nickel may, however, be combined directly with sulphur by fusion, and forms a grey compound with a metallic lustre. It contains, according to Mr. E. Davy's experiments, 34 per cent. of sulphur; and the super-sulphuret, which may be formed by heating the protoxide

* See Richter, in Nicholson's Journal, xii.

with sulphur, is stated, by the same chemist, to contain 43.5 per cent. of sulphur.

9. From the solutions of nickel, prussiate of potash throws down a sea-green precipitate. According to Bergman, 250 parts of this contain 100 of metallic nickel. This statement, however, differs considerably from Klaproth's, according to whom 100 grains of nickel, after solution in sulphuric acid, give a precipitate by prussiate of potash, which, after being ignited, weighs 300 grains.

10. Tincture of galls produces no change in these solutions.

11. The solutions of nickel do not deposit the metal either on polished iron or zinc.* All that takes place by the action of zinc, is the separation of a mud-coloured precipitate, consisting, for the most part, of arsenic and iron, with which nickel generally abounds. Hence the green colour of the solution of nickel is greatly improved by the action of zinc.

12. Nickel may be alloyed with most of the metals, but the compounds have no particularly interesting qualities. An alloy of iron and nickel has been found in all the meteoric stones that have hitherto been analysed, however remote from each other the parts of the world in which they have fallen.† In these, it forms from $1\frac{1}{2}$ to 17 per cent. of their weight. It enters, also, into the composition of the large masses of native iron discovered in Siberia and in South America.

SECTION X.

Tin.

THE properties of tin must be examined in the state of grain-tin or block-tin; what is commonly known by the name of tin, being nothing more than iron plates with a thin covering of this metal. Several varieties are met with in commerce, for the discrimination of which, and the means of judging of their purity, Vauquelin has given useful instructions in the 77th volume of the *Annales de Chimie*.

Tin has a silvery white colour, and by exposure to the air acquires a slight superficial tarnish, which does not appear to increase by time. Its specific gravity is about 7.9. It is extremely soft, scarcely if at all, elastic; and when a piece of it is bent backwards and forwards, it gives a peculiar crackling noise. It is very malleable, and may be beaten into leaves, $\frac{1}{1000}$ of an inch thick.

* See Klaproth's *Analytical Essays*, vol. i. page 433.

† In the *An. de Chimie* for January 1816, is an account of a meteoric stone which fell near Langres; which, by the analysis of Vauquelin, yielded neither sulphur nor nickel; the iron being also entirely oxydated, contrary to all former cases of the kind. C.

I. Tin melts on the application of a moderate heat, equal to 442° Fahrenheit, by a long continuance of which it is converted into a grey powder. This powder, which appears to be the first oxide of tin, when mixed with pure glass, forms a white enamel. It may be procured, also, by calcining, in a close vessel, the precipitate from fresh made muriate of tin by carbonate of potash.

The grey oxide, when brought to a full red-heat, takes fire; and, acquiring an increase of oxygen, passes to a pure white colour. This white oxide, when the heat is considerably raised, loses a part of its oxygen and runs into fusion. The white oxide may be obtained at once by projecting tin into a crucible intensely heated, when the oxide rises in the form of flowers somewhat resembling those of zinc. It may, also, be procured, as Berzelius found, by distilling powdered tin with red oxide of mercury.

The oxides of tin have been investigated by Gay Lussac and Berzelius, and their results differ so little, that either of them may be presumed to be correct. Gay Lussac states the composition of the protoxide to be

Tin	.	.	88.10	.	.	100.
Oxygen	.	.	11.90	.	.	13.5
<hr/>						
100.						

And that of the peroxide,

Tin	.	.	79	.	.	100
Oxygen	.	.	21	.	.	27
<hr/>						
100.						

Besides these two oxides, Berzelius suspects the existence of an intermediate one, which is formed when tin is acted on by nitro-muriatic acid. It has a yellow colour, and, from theory, should consist of 100 metal + 20.4 oxygen; but he does not appear fully to have satisfied himself on the subject.

The oxides of tin have, in a certain degree, the properties of acids, so as to render it doubtful whether they should not be arranged in that class of compounds. But their affinities for bases are so extremely feeble, that it seems advisable, on the whole, to retain them in the class of oxides.

The precipitates from solutions of tin by alkalis are *hydrates*, and have a white colour. They are soluble in an excess of fixed alkali; but the oxide is precipitated by the weakest acid, even the carbonic. The hydrates of tin are, also, decomposed by the action of boiling water.

II. Tin is not oxydized at common temperatures by exposure to air with the concurrence of moisture; a property which is the foundation of its use in covering iron.

III. Tin amalgamates readily with mercury; and this compound much used in the silvering of looking-glasses. It is formed by

adding gradually three parts of mercury to twelve of tin melted in an iron ladle, and stirring the mixture.

IV. Tin dissolves in sulphuric acid, which takes up, when concentrated and heated, half its weight. It is dissolved also by this acid, diluted with about a fourth its weight of water, and heated. During both these processes, sulphurous acid is disengaged; and, in the latter, a pellicle of sulphur forms on the surface of the solution, which precipitates on cooling. When saturated, the solution deposits, after a while, needle-shaped crystals of sulphate of tin. If the sulphate be long boiled, a copious white precipitate subsides, which will not again dissolve. It is composed of the white oxide retaining only a small portion of acid, and constituting in fact a *sub-sulphate*.

V. When nitric acid highly concentrated is poured upon tin filings, very little effect is produced; but when a small quantity of water is added, a violent effervescence follows; and the metal is reduced to a bulky powder, which is the white oxide retaining a little acid. If more water be added, an acid liquor is obtained, holding very little tin in solution. Tin, however, is slowly dissolved, without effervescence, in nitric acid greatly diluted. The solution is yellow and deposits oxide of tin by keeping.

VI. Muriatic acid, undiluted, is the proper solvent of tin. To one part of tin, in a tubulated retort, two parts of concentrated muriatic acid are to be added, and heat applied. The solution is complete, with the exception of a small quantity of black powder, which has not been sufficiently examined; and the acid takes up about one fourth of its weight of tin.* The solution has always an excess of acid; is perfectly limpid and colourless; and contains the metal at the minimum of oxidation. It has a tendency, however, to acquire a farther proportion of oxygen, and should, therefore, be carefully preserved from contact with the air. This property of absorbing oxygen is so remarkable, that it may even be applied to eudiometrical purposes. It has, also, the property of reducing, to a minimum of oxidation, those compounds of iron, in which the metal is fully oxydized. For example, it reduces the red sulphate to the green. It is a test also of gold and platina, as already noticed, and blackens the solution of corrosive sublimate. With hydro-sulphurets it gives a black precipitate.

VII. Tin may be brought to combine with the oxymuriatic acid, by first forming it into amalgam with mercury, tritulating this with an equal weight of muriate of mercury, and distilling the mixture. Or the same compound may be formed, according to Proust, by distilling a mixture of eight ounces of powdered tin and twenty-four ounces of corrosive sublimate. The result is a liquid which emits dense white fumes, when exposed to the air, and was formerly termed the fuming liquor of Libavius. It gives no precipitate at all with muriate of gold or muriate of mercury; affords a yellow sediment with hydro-sulphuret of potash; dissolves a further portion

* On the preparation of muriate of tin, see Berard, *Annales de Chimie*, lxxviii. 78; or Nicholson's *Journal*, xxvi.

of the metal without effervescence, and is then changed into the common muriate.

This compound, according to the researches of Adet, is an oxy-muriate of tin, perfectly free from water, and having a strong affinity for that fluid. Hence arises its fuming property; for the white vapours, which exhale when the bottle is unstopped, arise from the union of the salt with the moisture of the air. It may be formed at once, by heating tin in chlorine gas; and it consists, according to Dr. Davy, who calls it *stannanea*, of 55 tin united with 67 chlorine, or of

Tin	.	.	.	45	.	.	100
Chlorine	.	.	.	55	.	.	122
<hr/>							
100							

Another compound of tin and chlorine, called by the same chemist *stannane*, may be obtained by heating together an amalgam of tin and calomel. It dissolves in water, and forms a solution, similar to the muriate of the protoxide, which rapidly absorbs oxygen from the air, and deposits peroxide of tin. It is composed of 55 tin and 33.5 chlorine, or

Tin	.	.	.	62	.	.	100
Chlorine	.	.	.	38	.	.	62
<hr/>							
100							

VIII. The nitro-muriatic acid (formed by mixing two or three parts of muriatic acid and one of nitric) dissolves tin abundantly, with violent effervescence, and with so much heat, that it is necessary to add the metal slowly by successive portions. The solution is apt to congeal into a tremulous gelatinous mass; and if water be added, it is partly decomposed, and some oxide separated. The solution, used by the scarlet dyers, is prepared with that dilute nitric acid called single aqua-fortis, to each pound of which are added from one to two ounces of the muriate of soda or ammonia. This compound acid is capable of taking up about an eighth its weight of tin.

IX. Acetic acid (distilled vinegar) by digestion with tin filings takes up a portion of the metal, and acquires an opalescent or milky appearance. The solution is decomposed by the action of the air, and deposits an insoluble oxide.

Tin dissolves in tartaric acid; and the solution is applied to the useful purpose of *wet-tinning*, the process for which is described in Aikin's Dictionary, ii. 427.

X. Tin unites with sulphur, but requires, for its combination, so high a temperature, that at the moment of union there is too small a quantity of sulphur present, to saturate the tin, and a mechanical mixture results of tin and sulphuret of tin. The only method of obtaining the saturated sulphuret, is to melt the *aurum*

musivum, which will presently be described, in close vessels. This sulphuret is of a bluish colour and lamellated structure. It is composed, according to Dr. John Davy and Berzelius, of

Tin	78.6	100
Sulphur	21.4	27.234
	<hr/>	<hr/>
	100	127.234

The second sulphuret, or super-sulphuret of tin, is formed by heating sulphur with peroxide of tin. It is of a beautiful gold colour, and flaky in its structure. Proust was of opinion that it is a sulphuretted oxide; but Dr. Davy and Berzelius have shown that the tin is in a metallic state. According to the former, it consists of

Tin	64.5	100
Sulphur	35.5	54.5
	<hr/>	<hr/>
	100.	154.5

Berzelius, by redistilling sulphuret of tin with sulphur, obtained a compound of a greyish colour and metallic lustre, which he found to be composed of 100 tin and 40.851 sulphur, or exactly intermediate between the two which have been already described. It is probable, however, that it was merely a mixture of the two sulphurets, and not a distinct compound.

XI. Tin forms useful alloys with many of the metals. *Pewter* is one of these; and the best kind of it is entirely free from lead, being composed chiefly of tin with small proportions of antimony, copper, and bismuth. A mixture of tin and lead, in about equal parts, composes the common *plumbers' solder*. Tin enters, also, into the composition of *bell-metal* and *bronze*; and one of the most useful applications of it is to the tinning of iron plates, which is effected by dipping the plates into tin melted with about $\frac{1}{10}$ th its weight of copper.

SECTION XI.

Lead.

To obtain lead in a state of purity, Berzelius dissolved it in nitric acid, and crystallized the salt several times, till the mother liquor, on adding carbonate of ammonia, gave no traces of copper. The pure nitrate of lead, mixed with charcoal, was strongly heated in a Hessian crucible; and the lead, which separated, was kept some time in a state of fusion, in order to free it entirely from charcoal. The lead, thus obtained, when redissolved in nitric acid, gave no trace of any other metal.

Lead has a bluish white colour; and, when recently cut or

melted, considerable lustre, which soon, however, tarnishes. Its specific gravity is 11.352. Its malleability is sufficient to allow its being beat into very thin leaves; and it may be drawn into wire, which has less tenacity, however, than that of most other metals.

The melting point of lead, according to Morveau, is 590° Fahrenheit; but according to Mr. Crichton of Glasgow, it is 612° . Exposed to a red-heat, with free access of air, it smokes and sublimes, and gives a grey oxide, which collects on surrounding cold bodies. It is slowly oxydized, also, by exposure to the atmosphere at common temperatures; and more rapidly, when exposed alternately to the action of air and water.

Lead appears to be susceptible of forming three distinct oxides. 1. The *yellow oxide* may be obtained by decomposing nitrate of lead with carbonate of soda, and igniting the precipitate, or by heating the nitrate to redness in a close vessel. This oxide is tasteless, insoluble in water, but soluble in potash and in acids. When heated, it forms a yellow semi-transparent glass. Another form of the yellow oxide is that which is known in commerce by the name of *massicot*.

The yellow or *protoxide* of lead has been investigated by Proust, Thomson, and Berzelius, and its composition, as determined by the last-mentioned chemist, is

Lead . . .	92.85	. . .	100	. . .	1298.7
Oxygen . .	7.15	. . .	7.7	. . .	1000.
<hr/>					
	100				

2. The second, or *deutoxide* of lead, may be obtained by exposing the protoxide of lead, or the metal itself, to heat, with a large surface and a free access of air, for some time, till, at length, it is converted into a red oxide, known in commerce by the names of *minium* or *red lead*. This, however, is an impure substance, containing sulphate of lead, muriate of lead with excess of base, oxide of copper, silex, and a portion of the yellow oxide. This, Berzelius found, may be removed by acetic acid, which does not act on the red oxide. Making allowance for the other impurities, he determined the composition of red oxide of lead, which may be considered as the deutoxide, to be

Lead . . .	90	. . .	100
Oxygen . .	10	. . .	11.08
<hr/>			
	100		

When minium is digested with nitric acid, one part of it is reduced to the state of yellow oxide, and is dissolved by the acid; and the remainder is a brown oxide, contaminated (if impure minium has been used) with the substances which have been mentioned. It may be procured, also, by passing a current of oxymu-

riatic acid gas through water, in which the red oxide is kept suspended, and by precipitating with caustic potash, and drying the oxide. It is of a flea or puce colour; very fine and light in its texture; and insoluble in nitric acid. When strongly heated, it gives out 3 or 4 per cent. of oxygen gas, and is converted into yellow oxide. It consists, according to Berzelius, of

Lead	86.51	100
Oxygen	13.49	15.6
	<hr/>	<hr/>
	100.	115.6

On comparing the quantities of oxygen united with 100 parts of lead, in these three oxides, we shall find that the numbers 7.7, 11.08, and 15.6 are very nearly in the proportions of 1, $1\frac{1}{2}$, and 2. If, therefore, we multiply these last numbers by 2, we shall have the oxygen, in the three oxides of lead, represented by 2, 3, and 4; and this view of the subject would render it probable, that there exists an oxide of lead, with less oxygen than any at present known. I have, therefore, till this can be decided, retained the names of the three oxides which are derived from their colour, viz. the *yellow*, the *red*, and the *puce* oxides.

The yellow oxide of lead, when precipitated by pure alkalis from its compounds, forms a white *hydrate*, the composition of which is not exactly known.

The oxides of lead are easily vitrified, and have the property of uniting with all the metals except gold and silver. Hence gold or silver may be purified by melting them with lead. The mixture is to be kept for some time in a state of fusion, in a flat cup made of bone ashes, and called a *cupel* or *test*. The lead becomes vitrified, and sinks into the cupel, carrying along with it all the baser metals, and leaving gold or silver on the surface of the cupel.

The oxides of lead give up their oxygen on the application of heat. When distilled in an earthen retort, they afford oxygen gas; and still more readily when distilled with concentrated sulphuric acid.

To procure oxygen gas, sulphuric acid may be poured on the red oxide of lead, contained in a gas bottle, and a gentle heat applied. The gas, thus obtained, after being agitated with water, is sufficiently pure for common purposes.

The oxides of lead are also reduced, by being ignited with combustible matter. Thus, when a mixture of red oxide of lead and charcoal is ignited in a crucible, a button of metallic lead will be found at the bottom of the vessel.

II. Pure water has no action on lead; but it takes up a small proportion of the oxide of that metal. When left in contact with water, with the access of atmospherical air, lead soon becomes oxidized and dissolved, especially if agitation be used. Hence the danger of leaden pipes and vessels for containing water, which is intended to be drunk. Water appears also to act more readily on

lead, when impregnated with the neutral salts that are occasionally present in spring water.*

III. Sulphuric acid has no action on lead, except when concentrated and at a boiling temperature. It is then decomposed, and sulphurous acid is formed. The insolubility of lead in sulphuric acid occasions its being employed as the material for constructing the chambers, in which that acid is prepared, and even for boiling down the weak acid. Sulphate of lead, however, may be formed, either by adding sulphuric acid, or still better sulphate of soda, to any of the salts of lead. Its insolubility renders its formation of use as a step in mineral analyses, and hence it is necessary to know its exact composition, which is stated by Berzelius as follows:—

Sulphuric acid . . .	26.34	100.
Yellow oxide . . .	73.66	279.
	<hr/>	<hr/>
	100.	379.

If the whole oxygen in the sulphate of lead be supposed to be divided into four parts, one of these, it is remarked, by Berzelius, is combined with the lead, and three with the sulphur. In the sulphite, one third of the oxygen is united with the lead, and two-thirds with the sulphur.

IV. Nitric acid, a little diluted, dissolves lead, with the extrication of nitrous gas. If the acid be in small quantity, a sub-nitrate is formed, which becomes soluble on adding more acid. A small portion remains undissolved, which Dr. Thomson finds to be oxide of antimony with a little silex. The solution is not decomposed when poured into water. By evaporation, it yields large regular crystals, which are soluble in about $7\frac{1}{2}$ parts of boiling water. They contain no water of crystallization, and consist, according to Berzelius, of

Nitric acid . . .	32.78	100
Yellow oxide . . .	67.22	209.5
	<hr/>	<hr/>
	100.	309.5

Chevreul considers this salt as a super-nitrate,† and describes a scaly salt, which is the neutral nitrate, consisting of

Nitric acid . . .	19.86	100
Yellow oxide . . .	80.14	403
	<hr/>	<hr/>
	100.	503

* On the presence of lead in water, consult Dr. Lamb's "Researches respecting Spring Water," (8vo. London. Johnson) and also Guyton, 26 Nich. Journ. 102.

† 1 Thomson's Annals, 101.

By boiling 4 parts of the supernitrate, and 6 of lead, with 350 parts of water, for 14 hours, Chevreul obtained a liquid, which yielded two sorts of crystals; the one, in the form of plates, a *nitrite*; and the other, in the shape of needles, a *sub-nitrite*. The nitrite was little soluble in cold water, and boiling water dissolved only about a tenth of its weight. It was decomposed by all the acids that were tried. Its constituents are

Nitrous acid . . .	18.15	100
Yellow oxide . . .	81.85	450
	<hr/>	
	100.	

The sub-nitrite crystallized in needles, of which 100 parts of boiling water dissolved about three parts, and retained one, when cooled down to 73° Fahrenheit. It consisted of

Nitrous acid . . .	9.9	100
Yellow oxide . . .	90.1	910
	<hr/>	
	100.	

V. When the nitrate, or any other soluble salt of lead, is added to a solution of common salt, a precipitate takes place of muriate of lead. The same compound may, also, be obtained by heating lead in chlorine gas, or by treating the oxides of lead with muriatic acid. When dry, the compound is a dull semi-transparent substance, fusible at a heat below redness, and volatile at an intense heat. It has a sweet taste, and is soluble in 22 parts of cold water. It has successively received the names of *horn-lead*, *muriate of lead*, and *plumbane*. Berzelius states its composition to be

Muriatic acid . .	19.64	100.
Yellow oxide . .	80.36	409.06
	<hr/>	
	100.	

But according to Sir H. Davy, it is composed of

Chlorine . . .	24.62	100
Lead . . .	75.38	306
	<hr/>	
	100.	

When two parts of the red oxide of lead are mixed with one of muriate of soda, and the mixture is made into a paste with water, the common salt is decomposed, and a muriate, or probably a sub-muriate, of lead is formed, which, on fusion, affords the substance called *mineral* or *patent yellow*. The soda is disengaged, and attracts carbonic acid from the atmosphere, but not enough to convert it into a carbonate. In the large way, it is found necessary to sup-

ply carbonic acid to the soda, thus prepared, by burning it with saw-dust.

VI. Carbonic acid may be brought to combine with protoxide of lead, by precipitating the nitrate of lead with carbonate of soda, or by long exposure of thin sheets of lead to the vapour of vinegar. In the latter case, we obtain the carbonate of lead, or common white lead, which Bergman has shown to contain no acetic acid, though made by its intervention. According to Berzelius, it consists of

Carbonic acid	.	.	.	.	16.5
Oxide of lead	.	.	.	.	83.5
					<hr/>
					100.

VII. When carbonate of lead is dissolved in distilled vinegar, and the solution crystallized, we obtain a salt of great utility in the arts, the super-acetate, or more properly acetate, of lead, long known, from its sweet taste, under the name of *sugar of lead*.

It is in the form of small shining needle-shaped crystals, which are nearly equally soluble in hot and in cold water, *viz.* to about one fourth the weight of the fluid. The solution is decomposed by mere exposure to the air, the carbonic acid attracting the lead, and forming an insoluble carbonate. It is decomposed, also, by the carbonates and sulphates of alkali.

Acetate of lead consists of

Acid	.	.	.	.	26	.	.	100
Yellow oxide	.	.	.	.	58	.	.	224
Water	.	.	.	.	16			
					<hr/>			
					100			

By boiling in water a solution of 100 parts of acetate and 150 of finely pulverized litharge, the acetate passes to the state of sub-acetate. The taste of this salt is less sweet; it is less soluble in water; and crystallizes in plates. It is composed, according to Thenard, of

Acid	.	.	.	.	17	.	.	100
Yellow oxide	.	.	.	.	78	.	.	460
Water	.	.	.	.	5			
					<hr/>			
					100			

The oxide in the sub-acetate is, therefore, so nearly double in the acetate, that we may consider the composition of these salts as furnishing an additional example of the law of simple multiples.

All the solutions of lead are decomposed by sulphuretted hydrogen and by alkaline hydro-sulphurets. Hence these compounds are excellent tests of the presence of lead in wine or any other liquor,

discovering it by a dark coloured precipitate. Hence, also, characters traced with solution of acetate of lead, become legible when exposed to sulphuretted hydrogen gas. The same property explains, too, the effect of alkaline hydró-sulphurets in blackening the glass bottles, in which they are kept. The effect is owing to the action of the sulphuretted hydrogen on the oxide of lead, which all white glass contains.

VIII. The yellow oxide of lead unites with phosphoric acid, either directly or by mixing the solutions of a neutral alkaline phosphate and of nitrate or acetate of lead. The compound is insoluble, and is composed, according to Berzelius, of

Phosphoric acid	20.8	.	.	100	.	.	26.2
Yellow oxide	79.2	.	.	380.5	.	.	100.
	<hr/>			<hr/>			<hr/>
	100			480.5			126.2

IX. Lead unites in its metallic state with sulphur; and affords a compound of a blue colour with considerable brilliancy called *galena*. This compound may, also, be formed artificially. It is remarked by Berzelius that the sulphur and lead, which it contains, are in such proportions, that when both are combined with oxygen, and converted, the one into sulphuric acid and the other into yellow oxide of lead, the acid and oxide exactly saturate each other. These proportions he found to be

Sulphur	13.36	.	.	15.42	.	.	100
Lead	86.64	.	.	100.	.	.	643.5
	<hr/>			<hr/>			<hr/>
	100.00			115.42			743.5

SECTION XII.

Zinc.

THE zinc of commerce, known by the name of *speltre*, is never pure, but contains lead and sulphur. To purify it, zinc must be dissolved in diluted sulphuric acid; a plate of zinc is then to be immersed in the solution, to precipitate other metals, which it may contain; the solutions must be decomposed by subcarbonate of potash; and the precipitate ignited with charcoal powder.

Zinc is of a brilliant white colour with a shade of blue. Its specific gravity varies from 6.86 to 7.1, the lightest being the purest. By particular treatment it becomes malleable,* and may be beat into leaves or drawn into wire.

* The discovery of the malleability of zinc is announced by Mr. Silvester in the Philosophical Magazine, vol. xxiii.

I. Zinc is melted by a moderate heat, viz. at about 680° Fahrenheit, and the fused mass, on cooling, forms regular crystals.

II. By exposure to the air at a low temperature, it slowly acquires a coating of grey oxide; but when kept in a degree of heat, barely sufficient for its fusion, zinc becomes covered with a grey oxide. If thrown into a crucible, or deep earthen pot, heated to whiteness, it suddenly inflames; burns with a beautiful white flame; and a white and light oxide sublimes, having a considerable resemblance to carded wool. This oxide, however, when once deposited, is no longer volatile; but, if exposed to a violent heat, runs into glass. It has been examined with much attention by Proust, who found it to consist of 80 parts of zinc and 20 oxygen. Gay Lussac* and Berzelius† have since investigated it, and agree in considering it as composed of

Zinc .	80.39	. .	100
Oxygen .	19.61	. .	24.4
	<hr/>		<hr/>
	100.		124.4

Zinc decomposes water very slowly at common temperatures, but with great rapidity, if the vapour of water be brought into contact with it when ignited. In whatever way it is oxidized, we obtain the compound already described, which is the only known oxide of zinc.

III. Zinc readily dissolves in diluted sulphuric acid, which evolves, during its action on this metal, hydrogen gas; and the gas, when obtained, holds in combination a portion of the metal. A stream of it, burned in Cuthbertson's apparatus (pl. iv. fig. 34), has been found, if recently prepared, to occasion the fusion of the platinum wire, though the pure gas is destitute of this property. This hydrogen gas, holding zinc in solution, may also be obtained by a process of Vauquelin. A mixture of the ore of zinc, called blende, or calamine, with charcoal, is to be put into a porcelain tube, which is to be placed horizontally in a furnace, and, when red-hot, the vapour of water is to be driven over it. The gas that is produced, however, is a mixture of carbonic acid, carburetted hydrogen, and hydro-zincic gas. The zinc is deposited on the surface of the water, by which this gas is confined; but, if burned when recently prepared, the gas exhibits, in consequence of this impregnation, a blue flame.

The solution of zinc in sulphuric acid, when evaporated to a due degree of density, shoots into regular crystals. This salt is soluble in $2\frac{1}{2}$ parts of water; and its solution is not precipitated by any other metal. Its composition is stated by Berzelius and Wollaston as follows:

Acid .	30.96	. :	27.3
Base .	32.69	. .	28.4
Water .	36.45	. .	44.3
	<hr/>		<hr/>
	100.†		100.||

* 80 An. de Chim. 170.

† 81 Ditto.

‡ Berzelius.

|| Wollaston.

IV. Nitric acid, moderately strong, acts on zinc with great violence. The solution, by evaporation, crystallizes, and affords a deliquescent salt.

V. Muriatic acid, a little diluted, acts on zinc, and evolves hydrogen gas of great purity. The solution is clear, but cannot, by evaporation, be brought to crystallize. The dry salt, however, may be sublimed, and passes over in a half solid state, from which circumstance it has been called butter of zinc. When rapidly evaporated, it yields a thick extract, which has somewhat of the viscosity of bird-lime.

Only one compound of zinc and chlorine is known. It may be formed by burning the metal in chlorine gas, or by distilling zinc filings with corrosive sublimate. It fuses at a heat a little above 212° ; is volatile at a temperature below redness; and is identical with the compound, obtained by evaporating muriate of zinc. It consists, according to Dr. John Davy, as nearly as possible, of equal weights of metal and chlorine, or of

Zinc	49.5	100
Chlorine	50.5	102
	<hr/>	
	100.	

VI. Acetate of zinc may be formed either by directly dissolving the metal or the white oxide in vinegar, or by mingling the solutions of super-acetate of lead and sulphate of zinc. An insoluble sulphate of lead is formed, and the acetate of zinc remains in solution. By evaporation it affords a crystallized and permanent salt.

VII. Zinc is oxydized by being boiled with pure alkaline solutions, and a portion of the oxide remains dissolved. A similar compound may be obtained, by projecting a mixture of nitre and zinc filings into a red-hot crucible.

VIII. Zinc, in its metallic state, has very little affinity for sulphur. A mixture of the white oxide of zinc and flowers of sulphur combines, however, into a yellowish brown mass. Water, impregnated with sulphuretted hydrogen, decomposes, after some time, the solutions of zinc, and forms a yellow precipitate, which is probably a hydro-sulphuret. Mr. E. Davy, however, by passing the vapour of sulphur over melted zinc, obtained a white crystalline substance, resembling the natural compound of zinc and sulphur, called *phosphorescent blende*. The native sulphuret has been analyzed by Dr. Thomson, and found to consist of

Zinc . .	67.19	100.	214.40
Sulphur .	32.81	48.84	100.
	<hr/>	<hr/>	<hr/>
	100.	148.84	314.40

IX. Zinc combines with phosphorus. The phosphuret of zinc is of a whitish colour and a metallic lustre not unlike lead. It has some malleability, exhales a phosphoric smell, and, at a high degree of heat, burns like common zinc.

X. Zinc is capable of furnishing alloys with most of the other metals. Of these the most useful, brass, has already been mentioned in the section on copper. It has been lately proposed to apply zinc to the purpose of culinary vessels, pipes for conveying water, sheathing for ships, &c.; but it is rendered unfit for the first, by the facility with which the weakest acids act upon it; and for the rest by its considerable though slow oxidation, when exposed to air and moisture.

SECOND CLASS.

METALS THAT ARE BRITTLE AND EASILY FUSED.

SECTION XIII.

Bismuth.

BISMUTH has a reddish white colour, and is composed of broad brilliant plates adhering to each other. Its specific gravity is 9.822, but is increased by hammering. It breaks, however, under the hammer, and hence cannot be considered as malleable; nor can it be drawn out into wire.

I. Bismuth is one of the most fusible metals, melting at 476° Fahrenheit; and it forms, more readily than most other metals, distinct crystals by slow cooling.

II. When kept melted at a moderate heat, it becomes covered with an oxide of a greenish grey or brown colour. In a more violent heat it is volatile, and may be sublimed in close vessels; but, with the access of air, it emits a blue flame, and its oxide exhales in the form of a yellowish smoke, condensable by cold bodies. This oxide is very fusible; and is convertible, by heat, into a yellow transparent glass. It is the only oxide of bismuth, with which we are acquainted; and consists, according to the recent experiments of Lagerhjelm,* of

Bismuth	. . .	89.863	100.
Oxygen	. . .	10.137	11.28
		<hr/>	
		100.	

* 4 Thomson's Annals, 357.

III. Sulphuric acid acts on bismuth, and sulphurous acid is disengaged. A part of the bismuth is dissolved; and the remainder is changed into an insoluble oxide. The sulphate, on the same authority, is stated to consist of

Oxide of bismuth . . .	66.353	100
———— sulphuric acid . .	33.647	50.71
	<hr/>	
	100.	

Besides the neutral sulphate, Berzelius describes a subsulphate, composed of

Oxide of bismuth . . .	85.5	100.
———— sulphuric acid . .	14.5	17.
	<hr/>	
	100.	

IV. Nitric acid dissolves bismuth with great rapidity. To one part and a half of nitric acid, add, at distant intervals, one of bismuth, broken into small pieces. The solution is crystallizable. It is decomposed when added to water; and a white substance is precipitated, called magistery of bismuth, or pearl-white. It consists of hydrated oxide of bismuth with a small proportion of nitric acid. This pigment is liable to be turned black by sulphuretted hydrogen, and by the vapours of putrefying substances in general.

V. Muriatic acid acts on bismuth. The compound, when deprived of water by evaporation, is capable of being sublimed, and affords a soft salt, which deliquesces into what has been improperly called butter of bismuth. The same compound is obtained by introducing finely divided bismuth into chlorine gas, when the metal takes fire, and burns with a pale blue light. It is the only known combination of bismuth and chlorine, and was found, by Dr. Davy, to contain 66.4 per cent. of the metal, and 33.6 of chlorine.

VI. Bismuth is capable of forming the basis of a sympathetic ink. The acid, employed for this purpose, must be one that does not act on paper, such as the acetic. Characters written with this solution become visible, when exposed to sulphuretted hydrogen.

VII. Bismuth combines with sulphur, and forms a bluish grey sulphuret, having a metallic lustre. Lagerhjelm has analyzed it, and found it to consist of

Bismuth . . .	81.619	100
Sulphur . . .	18.381	22.52
	<hr/>	
	100.	

VIII. Bismuth is capable of being alloyed with most of the metals, and forms with some of them compounds of remarkable fusibility.

One of these is Sir Isaac Newton's *fusible metal*. It consists of eight parts of bismuth, five of lead, and three of tin. When thrown into water, it melts before it is heated to the boiling point. It is from this property of forming fusible alloys, that bismuth enters into the composition of several of the *soft solders*, which, indeed, is its principal use.

Bismuth has the singular property of depriving gold of its ductility; even when combined with it in very minute proportion. This effect is produced by merely keeping gold in fusion, near bismuth raised to the same temperature.

SECTION XIV.

Antimony.

I. ANTIMONY, as it occurs under that name in the shops, is a natural compound of the metal with sulphur in the proportion, as stated by Proust, of 75 antimony and 25 sulphur. To obtain it in a metallic state, the native sulphuret is to be mixed with two thirds its weight of supertartrate of potash (in the state of crude tartar), and one third of nitrate of potash deprived of its water of crystallization. The mixture must be projected, by spoonfuls, into a red-hot crucible; and the detonated mass poured into an iron mould greased with a little fat. The antimony, on account of its specific gravity, will be found at the bottom adhering to the scorixæ, from which it may be separated by a hammer. Or two parts of the sulphuret may be fused in a covered crucible with one of iron filings, and to these, when in fusion, half a part of nitre may be added. The sulphur quits the antimony, and combines with the iron.

In order to obtain antimony in a state of complete purity, the metal, resulting from this operation, must be dissolved in nitromuriatic acid, and the solution must be poured into water. A white powder will precipitate, which must be dried, mixed with twice its weight of crude tartar; and fused in a crucible, when the pure metal will be produced.

II. Antimony in its metallic state (sometimes called *ragulus of antimony*) is of a silvery white colour, very brittle, and of a plated or scaly texture.

III. It is fused by a heat of about 810° Fahrenheit; and crystallizes, on cooling, in the form of pyramids. In close vessels it may be volatilized, and collected unchanged.

IV. It undergoes little change when exposed to the atmosphere at its ordinary temperature; but when fused, with the access of air, it emits white fumes, consisting of an oxide of the metal. This oxide had formerly the name of *argentine flowers of antimony*. The vapour of water, brought into contact with ignited antimony, is decomposed with so much rapidity, as to produce a series of detonations.

V. Antimony, it has been supposed by Thenard, is susceptible of several degrees of oxidation; but these, according to Proust, may be all reduced to two. The first oxide may be obtained by pouring the muriate of antimony into water, and washing the precipitate with water containing a small quantity of potash. When dry, it is of a dirty white colour, without any lustre. It melts at a moderate red-heat, and becomes opake on cooling. It is composed of

Antimony	.	.	.	81.5	.	.	.	100
Oxygen	.	.	.	18.5	.	.	.	22.7
				<hr/>				
				100.				

The oxide at the maximum may be procured by collecting the flowers of antimony already described, or by causing the nitric acid to act on the metal, or by projecting it into melted and red-hot nitre. This oxide is of a white colour, and is much less soluble in water than the protoxide. It is, also, less fusible, and may be volatilized at a lower temperature, forming white prismatic crystals of a silvery lustre. It is composed of

Antimony	.	.	.	77	.	.	.	100.
Oxygen	.	.	.	23	.	.	.	30.
				<hr/>				
				100				

The oxides of antimony have lately been investigated by Berzelius,* who describes four degrees of oxidation in that metal. The first, or *sub-oxide*, is obtained by the long exposure of antimony to a humid atmosphere, or by making that metal the positive conductor in a galvanic arrangement, pure water being employed to complete the circuit. To procure the sub-oxides, the antimony must be reduced to powder, and placed under water in contact with a platina wire, connected with the positive end of the pile. Oxygen gas is disengaged from the point of contact, and the antimony is covered with a bluish grey flocculent powder, which is lighter than the metal, and may be separated by washing with water. It is produced so sparingly, that enough could not be obtained for analysis, and its composition was, therefore, deduced by calculation.

The second oxide (called by Berzelius the *oxidule*) may be obtained from muriate of antimony by an alkali. When the precipitate, which at first is a hydrate, is dried and heated, the oxide assumes a dull white colour, verging on grey. In a red heat, it fuses into a yellowish fluid, which, on cooling, becomes an almost white mass, crystallized something like asbestos.

The *third*, or *white oxide*, was formed by dissolving antimony in nitric acid, and evaporating and igniting the product; or by dissolving in nitro-muriatic acid, decomposing by water, washing the

* 86 Ann. de Ch. 225.

precipitate, and calcining it in a platina crucible. Its colour, when properly prepared, is perfect or snow white.

The *fourth*, or yellow oxide, was obtained by Berzelius in the following manner: Powdered metallic antimony was fused, during an hour, in a silver crucible, with six times its weight of nitre; and the fused mass was washed, first with cold and then with boiling water. The liquid was evaporated to dryness, and digested many hours with nitric acid. The white powder, insoluble in nitric acid, was gently heated in a small platina crucible, and assumed a fine lemon yellow colour. A similar product was obtained by mixing powdered antimony with pure oxide of mercury. An olive substance was produced, which, by long exposure to heat, assumed a straw yellow colour. This oxide, by a strong heat, loses about $6\frac{1}{2}$ per cent of oxygen, and is changed into the white oxide.

The composition of these four oxides is thus stated by Berzelius:

	Metal.	Oxygen.	Metal.	Oxygen.
1. Sub-oxide	96.826	3.174	100	4.65
2. Oxidule	84.317	15.683	100	18.60
3. White oxide . . .	78. 19	21. 81	100	27.90
4. Yellow oxide . . .	72. 85	27. 15	100	37.20

It is probable from the law of definite proportions, that the first or sub-oxide will prove to be a mechanical mixture of metallic antimony with the second or oxidule, which, in that case, will be the true *protoxide*. If this be established, it will afford another example of the general principle, that in protoxides, the oxygen is equal to half the sulphur of the sulphuret.

The white and yellow compounds of oxygen and antimony ought, indeed, to be arranged among acids, rather than among oxides; for each of them combines with salifiable bases, and affords a class of salts. The first may be called the *antimonious acid*, and its compounds *antimonites*; the second the *antimonic acid*, and the salts which it composes *antimoniates*. These names appear to me preferable to those which have been derived, by Berzelius, from the Latin appellation *stibium*, viz. *stibious*, and *stibic acids*. For a detail of the properties of these saline combinations, I refer to the memoir already quoted.

VI. Antimony combines with sulphur, and forms an artificial sulphuret, exactly resembling the native compound, which last may be employed, on account of its cheapness, for exhibiting the properties of sulphuret of antimony. The proportions of its ingredients, as stated by Berzelius, differ from those assigned by Proust, viz.

Antimony	72.86	100	270
Sulphur	27.14	37.25	100

100.

1. When native sulphuret of antimony (frequently called crude antimony) is slowly roasted in a shallow vessel, it gradually loses

its sulphur, the metal attracts oxygen, and is mostly converted into a grey oxide. This, being melted in a strong heat, acquires a reddish colour, and runs into a glassy substance, transparent at its edges, and termed *glass of antimony*. It consists of eight parts of protoxide and one of sulphuret, with ten *per cent.* of silex. The same quantity of oxide and two of sulphuret give an opake compound, of a red colour inclining to yellow; and called *crocus metal-lorum*. With eight parts of oxide and four of sulphur, we obtain an opake mass of a dark red colour, called *liver of antimony*. In all these compounds, the oxide is at its minimum of oxidation; for the peroxide is incapable of dissolving the sulphuret.

2. When fused with potash, a triple compound is formed, composed of alkali, sulphur, and antimony. Or the combination may be effected, in the humid way, by boiling the powdered native sulphuret with pure potash. The solution, on cooling, deposits an hydro-sulphuretted oxide, in which the oxide prevails, called *kermes mineral*. The addition of a dilute acid to the cold solution, precipitates a compound, having the same ingredients, but a larger proportion of sulphur, and called *golden sulphur of antimony*.

3. When the sulphuret of antimony is detonated with twice its weight, or upwards, of powdered nitre, the sulphur is oxygenated by the oxygen of the nitric acid; sulphate of potash is formed, and an oxide of antimony is obtained, varying in its degree of oxidation, with the proportion of nitre which has been employed. The oxide remains, after washing away the sulphate with boiling water. If four times its weight of nitre be employed, the metal gains 32 *per cent.* of oxygen, and acquires somewhat of the character of an acid; since it forms, with potash, a crystallizable compound.

VII. Antimony is dissolved by most of the acids. Sulphuric acid is decomposed by it; sulphurous acid being disengaged, and an oxide formed, of which a small proportion only is dissolved by the remaining acid, constituting a sub-sulphate. Nitric acid dissolves this metal with great vehemence; muriatic acid acts on it by long digestion; but the most convenient solvent is the nitro-muriatic acid, which, with the aid of heat, dissolves it from the native sulphuret. With oxymuriatic acid, it forms a compound of a thick consistence, formerly called butter of antimony. This may be obtained, by exposing black sulphuret of antimony to the fumes of oxymuriatic acid, and by subsequent distillation; or by distilling the powdered metal with twice its weight of corrosive muriate of mercury. It may be formed, also, by the combustion of antimony in chlorine gas, with which, according to Dr. John Davy, it unites in the following proportion:

Antimony	66	.	.	100	.	.	150.
Chlorine	34	.	.	67	.	.	100.
<hr/>							
	100						

On pouring this compound into water, a white hydrate, containing some muriatic acid, falls down, called *powder of algaroth*.

VIII. Antimony enters into combination with most of the metals. It destroys the ductility of gold, even when it composes only $\frac{1}{2000}$ th of the whole mass, or when its fumes alone come into contact with melted gold. The most important of its alloys is that which it forms with lead. In the proportion of one part to sixteen of lead, it composes the metal for printers' types.

SECTION XV.

Tellurium.

I. TELLURIUM was discovered, by Klaproth,* in an ore of gold. His process, for extracting it, consists in the solution of the ore by nitro-muriatic acid, dilution with water, and the addition of pure potash, which throws down all the metals that are present; and, when added in excess, re-dissolves a white precipitate, which it at first occasions. To the alkaline solution, muriatic acid is then added; a precipitate again appears; and this, when dried, and heated with one twelfth its weight of charcoal, or with a small quantity of oil, in a glass retort, yields tellurium, in the form of some small brilliant metallic drops, lining the upper part of the body of the retort. One hundred parts of the ore yield above 90 of tellurium.

II. 1. The colour of this metal is tin-white, verging to lead grey; it has considerable lustre, and a foliated or scaly fracture. It is very brittle; is fusible at a temperature below ignition; and, excepting osmium and quicksilver, is the most volatile of all metals. It is the lightest of the metals, the bases of the alkalis and earths excepted, having the specific gravity of only 6.185.

2. It is oxydized when heated in contact with air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. This smoke, when condensed, and examined in quantity, is found to be white with a tint of yellow. It is fusible by a strong heat, and volatile at a still higher temperature. It not only unites as a base with acids, but also itself possesses the character of an acid, and forms a class of salts, which may be called *tellurates*. It is composed, according to Klaproth, of

Tellurium	.	83	.	.	100
Oxygen	.	17	.	.	20.5
<hr/>					
					100

Berzelius, however, determines the quantity of oxygen, absorbed by one hundred of tellurium, when changed into oxide, to be 27.83.

* Contributions, ii. 1.

3. Tellurium is soluble in nitric and nitro-muriatic acids. The saturated solution is decomposed by the mere addition of water, which throws down a white powder; but this is again dissolved on adding more water. Chlorine unites with tellurium, and forms a white semi-transparent compound, which is decomposed when added to water. It consists, according to Sir H. Davy, of 100 tellurium united with 90.5 chlorine. From its solutions it is precipitated in a metallic form, by iron, zinc, tin, and even by muriate of tin. Carbonated and pure alkalis precipitate the telluric oxide united with water, in the form of a white hydrate; and the oxide is redissolved by an excess of alkali or carbonate. Alkaline sulphurets throw down a dark brown or blackish precipitate. Tincture of galls produces a flocculent yellow precipitate. The solutions of this metal in acids are not decomposed by prussiate of potash; a property which tellurium possesses in common with gold, platina, iridium, osmium, rhodium, and antimony.

Tellurium forms two distinct compounds with hydrogen, the one of which is solid and the other gaseous; 1st. By making tellurium the negative surface in water, in the galvanic circuit, a brown powder is formed, which is a solid *hydruret of tellurium*.

2dly. By acting with dilute sulphuric acid, upon the alloy of tellurium and potassium (which may be obtained by heating a mixture of solid hydrate of potash, tellurium, and charcoal), we obtain a peculiar gas. This gas has a smell resembling that of sulphuretted hydrogen. It is absorbed by water, and a claret-coloured solution results, which, by exposure to the air, becomes brown, and deposits tellurium. After being washed with a small quantity of water, it does not affect vegetable blue colours. It burns with a bluish flame, depositing oxide of tellurium. It unites with alkalis; precipitates most metallic solutions; and is instantly decomposed by chlorine gas. It may be called *telluretted hydrogen gas*. According to Berzelius, it is constituted of 100 parts of tellurium with a little less than two parts of hydrogen.

SECTION XVI.

Arsenic.

I. ARSENIC, as it is to be found in the shops, occurs in the state of a white oxide, from which the metal may be obtained by the following process. Mix two parts of the white oxide with one part of black flux (prepared by detonating, in a crucible, one part of nitre with two of crystals of tartar); and put the mixture into a crucible. Invert over this another crucible; lute the two together, by a mixture of clay and sand; and apply a red-heat to the lower one; keeping the upper one as cool as possible. The arsenic will be reduced; and will be found lining the inside of the upper crucible in a state of metallic brilliancy, not unlike polished steel. Its specific

gravity is 8.31. It is so extremely brittle, that it may be reduced to powder in a mortar.

II. Metallic arsenic is readily fusible, and is volatilized at 356° . In close vessels it may be collected unchanged; but when thrown on a red-hot iron, it burns with a blue flame and a white smoke; and a strong smell of garlic is perceived.

III. All the mineral acids act on arsenic; but not considerably, unless they are heated. In oxy-muriatic acid gas, however, arsenic burns vehemently.

IV. A mixture of oxy-muriate of potash and arsenic furnishes a detonating compound, which takes fire with amazing rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with a knife point. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once, the arsenical mixture burns with the rapidity of lightning, while the other burns with comparatively extreme slowness.

V. Arsenic combines with most of the metals. It has the property of giving a white stain to copper. Let a small bit of metallic arsenic, or a mixture of the white oxide with a little *black flux*, be put between two small plates of copper; bind these closely together with iron-wire; and heat them, barely to redness, in the fire. The inside of the copper plates will be stained white.

VI. Arsenic, by exposure to the air, is tarnished, and becomes converted into a bulky blackish powder. In three months, Berzelius found that 100 parts acquired an increase of 8.475; and he is disposed to consider the product as an oxidule; but it is probably nothing more than a mixture of arsenic and arsenous acid, into both which, indeed, it is resolved by heat. Only two combinations of arsenic and oxygen have hitherto been clearly ascertained; and both are possessed of acid properties.

The white oxide of arsenic has the following properties:

1. It has an acrid taste, and is highly poisonous.
2. It is soluble in water, which, at the ordinary temperature, takes up one eightieth. According to La Grange, it is soluble in one twenty-fourth of cold water, or one fifteenth of hot. Other statements have been given considerably differing from these; and Klaproth was, therefore, induced to examine its degree of solubility with great attention. A thousand grains of cold water, left in contact with the white oxide during 24 hours, and frequently agitated, dissolved only $2\frac{1}{2}$ grains. But 1000 grains of boiling water took up $77\frac{1}{2}$ grains; and, after being left three days to cool, and to deposit the crystals which separated, still retained in solution 30 grains. Bucholz has since published results, which agree, very nearly, with those of Klaproth.

The solution of the white oxide of arsenic has an acrid taste, and reddens vegetable blue colours. When slowly evaporated, the oxide crystallizes in regular tetrahedrons. The oxide is, also, soluble in 70 or 80 times its weight of alcohol, and in oils. At 383°

Fahrenheit it sublimes; or, if suddenly heated out of the contact of air, runs into glass.

3. The composition of the white oxide of arsenic, or *arsenous acid*, has been investigated by several chemists, with the following results. It consists,

	Arsenic.	Oxygen.	Arsenic.	Oxygen.
According to Proust, of . . .	75.2	24.8	100	32.979
————— Thenard, of			100	34.694
————— Berzelius, of . . .	74.48	25.52	100	34.263
————— Do. corrected . . .	69.63	30.37	100	43.616
————— Thomson, of			100	34.930

It has been justly observed, however, by Dr. Thomson,* that the result, which Berzelius considers as the most correct, is probably the least so; not only on account of its want of accordance with other determinations, but on account of the complicated process, by which it was obtained. On the whole, it appears probable, that 100 parts of arsenic, to become the white oxide, combine with between 34 and 35 parts of oxygen.

4. Oxide of arsenic combines with the pure alkalis to saturation; and hence it fulfils one of the principal functions of an acid. It has therefore been called *arsenous acid*, and its compounds *arsenites*. They may be formed by simply boiling the arsenous acid with the respective bases and a sufficient quantity of water; or by double decomposition. Thus arsenite of lead may be prepared, by mixing the solutions of nitrate of lead and arsenite of potash; and the fine green pigment, called *Scheele's green*, by mixing the solutions of arsenite of potash and sulphate of copper.

5. The arsenous acid, or rather the arsenic which it contains, by distillation with sulphur, affords either a yellow substance, called *orpiment*, or a red one, termed *realgar*. The oxygen, uniting with sulphur, escapes in the form of sulphurous acid. Both these compounds are sulphurets of arsenic, varying in the proportion of their components. Orpiment contains three parts of sulphur and four of arsenic; and realgar one part of sulphur and three of arsenic. Hence realgar, by fusion with an additional quantity of sulphur, may be changed into orpiment; and the latter, by an addition of arsenic, becomes realgar.

6. By repeated distillation with nitric acid, arsenous acid is changed into *arsenic acid*. The same change is effected, also, by exposure to the vapour of oxy-muriatic acid, and the subsequent expulsion, by heat, of the common muriatic acid. By both these processes, a white concrete substance is obtained, termed arsenic acid. The process recommended by Bucholz is to mix two parts by weight of muriatic acid of the specific gravity 1.200, twenty-four parts of nitric acid of the specific gravity 1.25, and eight parts of white oxide of arsenic. The whole may be evaporated to dryness, and gently ignited in a crucible.

* Annals, iv. 171.

VII. 1. The arsenic acid has a sour, and at the same time, a metallic taste. It reddens vegetable blues; attracts humidity from the atmosphere; and effervesces strongly with solutions of alkaline carbonates. When evaporated, it assumes the consistence of jelly, and does not crystallize. It is a most active poison. With alkalis, earths, and oxides, the arsenic acid constitutes a class of salts called arsenates. The arsenate of potash may be obtained in a more simple manner, by detonating, in a crucible, a mixture of nitrate of potash with arsenous acid.

The statements of the composition of arsenic acid differ from each other not less than those of the white oxide. It is composed,

	Arsenic.	Oxygen.	Arsenic.	Oxygen.
According to Proust, of . .	65.4 . .	34.6 . .	100 . .	52.905
————— Thenard, of .	64. . .	36. . .	100 . .	56.250
————— Berzelius, of	66.638 . .	33.962 . .	100 . .	51.428
————— Do. corrected	58.366 . .	41.634 . .	100 . .	71.333
————— Thomson, of			100 . .	52 4

In this case, also, Dr. Thomson prefers, and it appears to me with reason, the first determination of Berzelius, as more nearly approaching the truth than the second. Dr. Thomson's result was obtained by the direct acidification of metallic arsenic by nitric acid; and, though not coincident with the analysis by Thenard, yet it agrees with the number, obtained by assuming the proportions, given by that chemist, for the white oxide, and with his assertion that 100 parts of arsenous acid are changed into arsenic acid, by 16 parts of oxygen.

2. When tin is dissolved in arsenic acid, an inflammable gas is disengaged, as was observed by Scheele, consisting of hydrogen gas, holding arsenic in solution. It may be obtained, also, by adding powdered metallic arsenic to a mixture of diluted sulphuric acid and zinc filings.

This gas (to which, perhaps, the name of *arsenuretted hydrogen* is best adapted) has the following properties:

(a) It is a permanently elastic and invisible fluid, of the specific gravity, compared with common air, of 0.5293; but its specific gravity is variable, in consequence of the admixture of different proportions of hydrogen gas.

(b) It has a fetid smell, resembling that of garlic.

(c) It extinguishes burning bodies.

(d) It is not absorbed by water in any notable degree; and has no effect on the blue colours of vegetables.

(e) It burns with a lambent white flame, and a disagreeable odour; and emits, during combustion, fumes of arsenous acid.

(f) When mingled with oxymuriatic acid gas, heat is produced, a diminution ensues, and metallic arsenic is deposited. Soap bubbles, blown with a mixture of this and oxygen gases, burns with a blue flame, a white smoke, and a strong alliaceous smell.

(g) A stream of arsenuretted hydrogen gas, issuing from a bladder fitted with a stop-cock, and set on fire in a large re-

ceiver filled with oxygen, burns with a blue flame of uncommon splendour.

(h) One cubic inch of the gas contains about one fourth of a grain of metallic arsenic.

(i) When 100 measures, in an experiment of Gay Lussac, were acted upon by heated tin, 140 measures of hydrogen were evolved. Hence three volumes of hydrogen are, in this gas, condensed into almost the space of two.

A solid compound of hydrogen and arsenic may be formed, by acting on water with an alloy of potassium and arsenic; and, of course, much less hydrogen gas is evolved, than the same weight of uncombined potassium would liberate from water. It is described, by Gay Lussac, as separating in chesnut brown coloured flocks. There appears, indeed, to be a strong affinity between hydrogen and arsenic; for Berzelius found that the recently prepared metal when distilled along with oxide of tin, gave a drop or two of water.

THIRD CLASS.

BRITTLE AND DIFFICULTLY FUSED.

SECTION XVII.

Cobalt.

I. COBALT may either be obtained from a substance, which may be purchased under the name of Zaffre, by fusing the zaffre with three times its weight of black flux; or it may be purchased, at a moderate price, in a metallic form.

To obtain cobalt in a perfectly pure state, Tromsdorff recommends, that the zaffre should be, three times successively, detonated with one fourth its weight of dry nitre, and one eighth of powdered charcoal. After the last of these operations, the mass is to be mixed with an equal weight of black flux, and the cobalt reduced. The metal is then to be pulverized, and detonated with thrice its weight of dried nitre. This oxydizes the iron to its maximum; and acidifies the arsenic; which last unites with the potash. Wash off the arsenate of potash, and digest the residue in nitric acid. This will take up the oxide of cobalt, and leave the oxide of iron. Evaporate to dryness; re-dissolve in nitric acid; filter the solution; and decompose it by a solution of potash. The oxide of cobalt, now obtained, may be reduced by the black flux, as before directed.

II. Cobalt has a greyish white colour, inclining somewhat to pink. Its specific gravity is 7.7; it is brittle and easily reduced to powder; is not fusible with a less heat than 130° of Wedgwood; and, when slowly cooled, may be obtained crystallized in irregular prisms. It is generally described to be magnetic; but this property Mr. Chenevix imputes to its contamination with a small quantity of iron.

By exposure to the atmosphere cobalt is tarnished, but not oxydized to any extent. In an intense heat it burns with a red flame; but, if pure, it is not easily oxydized by a moderate temperature. Its oxide, formed by long exposure to a strong heat with access of air, is of a deep blue, approaching to black. This, from the experiments of Thenard, appears to be the *protoxide*. It may be obtained, also, by precipitating the nitrate of cobalt with potash. The precipitate, which at first is a bright blue hydrate, when dry becomes of so dark a blue as to appear black. It dissolves readily in muriatic acid, giving a solution which is green when concentrated, and red when diluted. Its solutions in sulphuric and nitric acids are always red.

When this oxide is exposed to the atmosphere, it gradually absorbs an additional quantity of oxygen; and becomes olive green. Treated with muriatic acid, it gives oxymuriatic acid gas, and a red solution is obtained. This olive compound Sir H. Davy suspects to be a mixture of hydrate and oxide of cobalt, and not a peculiar oxide.

When either of the two preceding oxides is heated in the open air, it passes to a flea-brown colour, which gradually becomes black. This is the metal oxidated to its maximum. The peroxide dissolves with effervescence in muriatic acid, and with a copious disengagement of oxymuriatic acid gas. It is insoluble, however, in sulphuric and nitric acids, till it has parted with oxygen enough, to reduce it to the minimum state. It is incapable, also, of being dissolved in pure alkalis, or of tinging vitrifiable mixtures blue.

According to the experiments of Proust, 100 parts of the *protoxide* consist of

Cobalt	83½	100
Oxygen	16½	19.8
	<hr/>	<hr/>
	100	119.8

And 100 of the *peroxide* of

Cobalt	75	100
Oxygen	25	33.25
	<hr/>	
	100*	

* Philosophical Magazine, xxx. 340.

The black or peroxide, heated for half an hour at the bottom of a crucible, loses a part of its oxygen, and is reduced to the state of protoxide.

The oxides of cobalt require, however, farther investigation. Klaproth states that 100 parts of cobalt absorb 18 of oxygen, to be converted into protoxide. But the oxygen of the peroxide does not, either on this or on Proust's data, bear the proportion to the oxygen in the protoxide, which might be expected from the law of definite proportions. If the oxide, described by Klaproth, be really that which is composed of one atom of metal and one of oxygen, the atom of cobalt will weigh 41.5; but if it be, as Sir H. Davy supposes, a deutoxide, or compound of one atom of metal with two of oxygen, the atom of cobalt must weigh 83. On the first supposition, the peroxide should be constituted of 100 metal and 36 oxygen; and, on the second, of 100 metal and 25.8 oxygen; and as the former of these numbers corresponds most nearly with experiment, we may consider the protoxide as the first combination of cobalt and oxygen, and the atom of cobalt to be represented by 41.5.

III. The best solvents of cobalt are the nitric and nitro-muriatic acids; and the solutions have the singular property of forming sympathetic inks. One part of cobalt, or, still better, of zaffre, may be digested, in a sand-heat, for some hours, with four parts of nitric acid. To the solution, add one part of muriate of soda; and dilute with four parts of water. Characters written with this solution are illegible when cold; but when a gentle heat is applied, they assume a beautiful blue or green colour.* This experiment is rendered more amusing, by drawing the trunk and branches of a tree in the ordinary manner, and tracing the leaves with a solution of cobalt. The tree appears leafless, till the paper is heated, when it suddenly becomes covered with beautiful foliage.

IV. Oxide of cobalt is precipitated by carbonated alkalis from the nitric solution, at first of a peach flower colour, and afterwards of a lilac hue. The crystals of nitrate of cobalt, thrown into a flask full of liquid potash, are immediately decomposed. A blue precipitate is formed, which, if the flask be immediately closed, passes to violet, and afterwards to red, by becoming the *hydrate* or *hydro-oxide* of cobalt. This compound is soluble in cold carbonate of potash and tinges it red. The oxide is not soluble in this liquid. The hydrate loses from 20 to 21 *per cent.* of water by heat, and is reduced to protoxide.

V. Oxalic acid throws down, from solutions of cobalt, a rose-coloured precipitate.

VI. Cobalt may be brought to combine with sulphur and with phosphorus; but the compounds have no peculiarly interesting properties. The sulphuret is composed, according to Proust, of

* For some ingenious speculations on the cause of these phenomena, consult Mr. Hatchett's paper on the Carinthian molybdate of lead. (Philosophical Transactions, 1796.)

Cobalt . . .	71.5 . . .	100
Sulphur . . .	28.5 . . .	39.8
<hr/>		100.

This confirms the view, already given, of the atomic constitution of the protoxide, for the oxygen, which it contains, is not far from being equal to half the sulphur in the sulphuret.

VII. It may be alloyed with most of the metals, with the exception of bismuth and zinc.

Cobalt, when oxydized, is the basis of *zaffre*. This is generally prepared by roasting, from the ore, its volatile ingredients; and mixing, with the remainder, three parts of sand, or calcined flints. Zaffre, when fused, forms a blue glass; which, when ground and washed, is the substance termed *smalts*, used as a colouring substance for linen, and for imparting a blue colour to glass.

SECTION XVIII.

Manganese.

I. MANGANESE never occurs in a metallic state; the black substance, known by that name, being a compound of manganese, with a large proportion of oxygen. The metal is obtained, by mixing this oxide, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, one tenth of an inch thick on the sides, and one fourth of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed, for one hour, to the strongest heat that can be raised.

II. This metal is of a dusky white colour, and bright and shining in its fracture. Its specific gravity was found by Dr. John to be 8.013. It is very brittle, and even less fusible than iron, requiring a heat of 160° Wedgwood to melt it. It is not attracted by the magnet; except when contaminated with a small quantity of iron. When exposed to the air it soon crumbles into a blackish brown powder, in consequence of its oxydation, and becomes in succession grey, violet, brown, and finally black.

There is a remarkable want of agreement in different statements of the composition of oxides of manganese, and even of the number of those oxides. Sir H. Davy admits only two, one of a dark olive colour, consisting of 21 oxygen to 79 metal; the other of a dark brown colour, containing almost 10 per cent more of oxygen.* Dr. John, in a memoir published in the 2d and 3d volumes of Dr. Thomson's *Annals*, enumerates three oxides of manganese, the green, the brown, and the black. The *green* is formed by the action of metallic manganese on water, from which it takes oxygen,

* Elements of Chem. Phil. 369.

and disengages hydrogen gas, apparently holding some of the metal in solution. He finds it to be composed of

Manganese	. . .	87	. . .	100
Oxygen	. . .	13	. . .	14.942
		<hr/>		100

The *brown* oxide was formed by exposing the last mentioned one to the air, till it ceased to gain weight, and then drying it quickly. Its colour was pure deep brown, and it was composed of

Manganese	. . .	80	. . .	100.
Oxygen	. . .	20	. . .	25.
		<hr/>		100

The third or *black* oxide was prepared by dissolving manganese in nitric acid, evaporating, and drying by a heat sufficient to expel the nitric acid, but not to decompose the oxide. It consisted of

Manganese	. . .	71.33	. . .	100
Oxygen	. . .	28.67	. . .	40.19
		<hr/>		100.

The brown oxide still continued to absorb oxygen, when exposed to the atmosphere; but the black, when ignited, gave oxygen gas.

Berzelius* admits the composition of the green oxide, as stated by Dr. John, with a slight alteration; but corrects the numbers indicating that of the second and third, and adds, also, two other oxides, the one with less oxygen, and the other with more, than any of those which have been already cited. The first is obtained by exposing metallic manganese in a vessel loosely corked; but there can be little doubt, from its properties, that it is a mixture of the metal and the green oxide. The last of the following oxides, is the native oxide of manganese, which is become important from its use in preparing oxymuriatic acid.

Berzelius's Table of the Composition of Oxides of Manganese.

	Metal.	Oxygen.	Metal.	Oxygen.
1st oxide . .	93.435	. . 6.565	. . 100	. . 7.0266
2d oxide (green)	87.68	. . 12.32	. . 100	. . 14.0533
3d oxide (brown)	78.10	. . 21.90	. . 100	. . 28.1077
4th oxide . .	70.50	. . 29.50	. . 100	. . 42.16
5th oxide . .	64.00	. . 36.00	. . 100	. . 56.215

The numbers in the last column, it may be observed, stand to each other in the proportion of 1, 2, 4, 6, 8. But if the first com-

* 87 Ann. de Chim. 149.

pound, (as appears to me probable,) be not a distinct oxide, the ratio will then be that of 1, 2, 3, 4.

The oxides of manganese may be combined with most of the acids. When the green or protoxide is precipitated from its solution in an acid by a carbonated alkali, we obtain a snow white compound, which is a carbonate of manganese. It is composed, according to Dr. John, of

Protoxide of manganese . . .	55.84
Water	10.
Carbonic acid	34.16
	<hr/>
	100.

Concentrated sulphuric acid has very little action on metallic manganese; but the dilute acid dissolves it with an extrication of hydrogen gas, which has a peculiar smell, resembling assa-fœtida, probably from its holding some of the metal in solution. The solution has a light rose colour, and gives crystals of the same colour.

The pure protoxide, and the carbonate, dissolve in the sulphuric acid in any state of concentration; and a solution is obtained, exactly resembling that which has been described. The first crystals, that shoot from the solution, are of a faint rose red colour. The last are white, and contain a great excess of acid. The red crystals are soluble in $2\frac{1}{2}$ parts water, at 55° Fahrenheit, and are insoluble in alcohol. The alkaline carbonates, prussiates, and phosphates, occasion a white precipitate from the solution, and are almost the only salts that decompose this sulphate. It is composed of

Protoxide of manganese	31.00
Sulphuric acid . . .	33.66
Water	35.34
	<hr/>
	100.

Nitric acid, when moderately concentrated, dissolves metallic manganese with an escape of nitrous gas. The solution is colourless; and by long continued evaporation, the acid is decomposed, and a black oxide is left. The green oxide and white carbonate also dissolve readily in nitric acid, and by particular management crystals may be obtained from the solutions. The crystals deliquesce by exposure to the air; and on the application of heat, melt, and are immediately decomposed. The black oxide does not dissolve in nitric acid, unless a little sugar is added, or some other similar substance.

The action of muriatic acid is most important on the black native oxide. According to the old theory, part of the acid acts on one portion of the oxide; and first reduces it to the state of protoxide, and then dissolves it; affording muriate of manganese. The oxygen, thus liberated, uniting with another portion of muria-

tic acid, composes oxymuriatic acid. But, on the theory of chlorine, the hydrogen of the muriatic acid is attracted by the oxygen of the oxide, and the chlorine is merely set at liberty.

When the muriate of manganese is evaporated to dryness, and strongly heated, it forms brilliant scales, which, according to Dr. John Davy, are identical with the compound obtained by burning manganese in chlorine, and are composed of

Manganese	.	54	.	.	100.
Chlorine	.	.	46	.	85.
<hr/>					
100					

Muriate of manganese is a deliquescent salt ; it is soluble in an equal weight of water, and soluble, also, in alcohol, by which means it may be separated from the sulphate. It may be obtained in large tabular crystals, quite transparent, and of a rose colour. If considered as a compound of muriatic acid and oxide of manganese, it may be stated to consist of

Protoxide of manganese	.	38.50
Muriatic acid	.	20.04
Water	.	41.46
<hr/>		
100.		

Dr. John has investigated, also, several of the combinations of oxide of manganese with vegetable and metallic acids, the details of which are contained in his paper.

The black oxide of manganese has some properties, which render it the subject of amusing experiments.

1. It imparts to borate of soda, when melted with it, a violet colour. When this is effected by the blow-pipe, the colour may be destroyed by the interior flame, and again reproduced by the exterior one, or by a small particle of nitre.*

2. When black oxide of manganese and nitre, both reduced to powder, are mixed together, and thrown into a red-hot crucible, the nitric acid is decomposed, and we obtain a compound of highly oxydized manganese with potash. This compound has the singular property of exhibiting different colours, according to the quantity of water that is added to it. A small quantity gives a green solution ; a farther addition changes it to blue ; more still to purple ; and a still larger quantity to a beautiful deep purple.†

3. The experiment may be varied, by putting equal quantities of this substance into two separate glass vessels, and pouring on the one hot, and on the other cold water. The hot solution has a

* See Klaproth, vol. i. page 243, a.

† This substance may be very conveniently made by adding a small quantity of black oxyd of manganese to the nitre employed to procure oxygen gas : The manganese is left in the retort, combined with the alkali of the decomposed nitre. Two processes may thus be effected at the same time. C.

beautiful green colour, and the cold one is of a deep purple. The same material, with water of different temperatures, assumes various shades of colour, depending on the state of oxydation of the metal. Hence this has been termed the chameleon mineral. This property is destroyed by a very small quantity of sulphuret of potash.

III. Manganese, in its metallic state, cannot be brought to combine with sulphur, though a native compound of these two substances has been examined by Proust. The oxide, however, unites with sulphur by fusion in the proportion of eight of the former to three of the latter; and a compound is obtained of a green colour, which gives out sulphuretted hydrogen gas by the action of acids.

IV. Manganese unites with most of the metals, and composes alloys; none of which are distinguished by important properties.

SECTION XIX.

Chrome.

THIS metal is found in an acidified state, and combined with oxide of lead, in the red-lead ore of Siberia; in the state of an oxide, in the green ore accompanying the red one; and in the emerald, to which it communicates its green colour, and in some meteoric stones. A compound of chromic acid with oxide of iron has, also, been discovered in France and in America,* and is a much more abundant product than the lead ore of Siberia.

I. To separate the chromic acid, the red-lead ore, reduced to powder, is boiled with twice its weight of carbonate of potash. An orange-yellow solution, composed of potash and chromic acid, is thus obtained; and when, to this, a mineral acid is added, and the liquor is evaporated, we obtain, 1. the salt formed by the acid, which has been united with the potash; 2. the acid of chrome, in long ruby-coloured prisms. From this acid the chrome may be obtained by heating it with charcoal, in the manner already often described. In the crucible a metallic mass is found, of a greyish white colour, formed of a number of needles crossing each other.

II. This metal is very brittle, infusible, and fixed. Its specific gravity is 5.9.

III. It is susceptible of three states of oxydizement. The first oxide is green, the second brown, and a farther proportion of oxygen gives the chromic acid. The precise quantity of oxygen in these different compounds has not yet been ascertained.

IV. The nitric acid alone exerts any remarkable action on this metal. Repeated distillation, with this acid, changes chrome into chromic acid, combinable with alkalis. The chromates of alkalis precipitate the salts of lead, of a beautiful yellow colour; which, if

* Thomson's Annals, v. 75.

it could be procured in sufficient quantity, would be highly valuable in painting.* Mercury is thrown down, of a cinnabar-red hue; silver, of a carmine-red; and all its metallic combinations are distinguished by peculiar brilliancy of colour. The emerald derives its colour from the *oxide* of chrome; and the spinelle ruby from the *acid*. This property of imparting colour has suggested its name.

The combinations of the chromic acid with different bases have been fully investigated, and described by Vauquelin, in the 70th volume of the *Annales de Chimie*, and by Dr. John, in the fourth volume of Thomson's *Annals of Philosophy*.

SECTION XX.

Molybdenum.

I. THE most common ore of molybdenum, was long mistaken for plumbago, or carburet of iron, to which it bears, externally a strong resemblance. It is, in fact, a combination of sulphur and the oxide of molybdenum. These two components may be separated, by repeated distillation with nitric acid. To the ore of molybdenum, in a retort, six times its weight of nitric acid are to be added, and the mixture distilled to dryness. This process must be repeated four or five times; and, at its close, both the sulphur and molybdenum will be acidified. The sulphuric acid is expelled by heating the mass in a crucible; and any remaining portions are to be washed off with distilled water. The residue (*molybdic acid*) is a white heavy powder; which has an acid and metallic taste; has the specific gravity 3.4; is soluble in about 1000 parts of water; and forms salts with the alkalis and earths. The acid is reduced by making it into a paste with oil, and exposing it, bedded in charcoal in a crucible, to an intense heat. Or (as Hielm recommends) the ore of molybdenum may be repeatedly roasted in a moderate red-heat, till the whole is reduced to a fine powder, which may be passed through a sieve. The powder is to be dissolved in ammonia, the solution filtered, and evaporated to dryness. The residuum, being moderately heated with a little nitric acid, gives a white powder, which is the pure oxide of molybdenum. This may be metallized by exposure to an intense heat with oil or powdered charcoal.

II. Molybdenum has a whitish yellow colour, but its fracture is a whitish grey. It has not, hitherto, been obtained in any form, but that of small brittle grains. It is almost infusible by any artificial heat. Its specific gravity is 8.611.

* This is accomplished to a considerable extent in the United States, forming the pigment commonly called chromic yellow. From the property possessed by the chromic acid of forming different coloured precipitates with the different metals, it will probably become of considerable use to the analytical chemist. C.

It is readily oxydized when heated in contact with air, and is converted into a white oxide, which is volatilized in small brilliant needle-shaped crystals. This compound has acid properties.

III. The nitric, nitro-muriatic, and oxy-muriatic acids are the only ones that act on molybdenum.

IV. The muriatic, and other acids, act on its oxides, and afford blue solutions.

There appear to be only two well ascertained compounds of molybdenum and oxygen. The first is the molybdic acid already described. It is composed, according to Bucholz, of

Molybdenum	66.7	100.
Oxygen	33.3	50.
	<hr/>	100.

Berzelius states the metal at 65.5, and the oxygen at 34.5 in 100 grains.

When one part of powdered molybdenum, and two parts of molybdic acid, are triturated in boiling water; then filtered; and the solution evaporated at a temperature not exceeding 120° Fahrenheit, we obtain a fine blue powder, which is molybdous acid. This acid is more soluble in water than the molybdic, and its solution reddens vegetable blue colours. It is stated by Bucholz to consist of

Molybdenum	74.5	100.
Oxygen	25.5	34.
	<hr/>	100.

It seems not improbable that there is an oxide, containing a smaller proportion of oxygen than the molybdous acid; and that this acid is constituted of two atoms of oxygen to one of metal. On this supposition the atom of molybdenum must weigh about 44; and, in molybdous acid, it must be combined with two atoms of oxygen, weighing 15; and in molybdic acid with three atoms, weighing 22.5. The oxide, consisting of one atom of metal 44, and one atom of oxygen 7.5, remains to be investigated.

The molybdous and molybdic acids unite with salifiable bases, and form distinct classes of salts. The latter acid is changed into the former by some of those metals, that powerfully attract oxygen. Thus a solution of molybdic acid, in which a small rod of tin or zinc is immersed, becomes blue, in consequence of the partial disoxygenation of the acid; and on the same principle recent muriate of tin throws down, from molybdate of potash, a fine blue precipitate. The molybdic acid decomposes the nitrates of silver, mercury, and lead; and the nitrate and muriate of barytes.

V. Molybdenum unites readily with sulphur, and composes a substance, similar to the one from which the metal was originally obtained. One hundred parts of the metal combine with 67 of sulphur.

SECTION XXI.

Uranium.

I. THIS metal was discovered by Klaproth, in a mineral which contains uranium combined with sulphur. The metal is separated from the sulphur, first by roasting; then dissolving the ore in nitromuriatic acid, and precipitating by an alkali. An orange-coloured precipitate is obtained, which is an oxide of uranium. This may be reduced to a metallic form, in the same manner as the molybdic acid.

II. Uranium is of an iron grey colour; and internally of a reddish brown. It has only been obtained in small grains of considerable hardness and lustre. Its fusion is very difficultly effected. It undergoes no change by exposure to air, unless strongly heated, when it burns, and becomes a black oxide.

III. The metal is soluble only in nitric acid.

IV. Its oxide, when precipitated by potash from nitric acid, is of a yellow colour, and dissolves in acids. It is precipitated by alkalis; and is thrown down, of a reddish brown colour, by prussiates. Sulphuret of ammonia gives a brownish yellow precipitate; and tincture of galls, a chocolate brown one.

V. The yellow oxide of uranium is insoluble in alkalis, which distinguishes it from the oxide of tungsten. It is soluble, however, by alkaline carbonates.

There appear to be two oxides of uranium, the *yellow* one, which retains its colour when heated alone, and becomes the *black* oxide, when heated with a little oil. The first, according to Bucholz, consists of 80 metal and 20 oxygen; but the composition of the black oxide is not yet determined.

SECTION XXII.

Tungsten.

I. TUNGSTEN may be obtained from two different minerals. The one, consisting of the tungstic acid, united with lime, is called simply tungsten. In the other, termed Wolfram, it is united with iron and manganese. Its extraction from the former is the most simple process. One part of the tungstate of lime, and four of carbonate of potash, are fused together, and the mass is dissolved in 12 parts of boiling water. Nitric acid is then added, which unites with the potash, and precipitates tungstic acid. This acid, when reduced in the usual manner, yields tungsten; but the process of its reduction is a very difficult one, and frequently fails of success.

The tungstic acid may, also, be obtained from Wolfram, by fusion with three times its weight of nitrate of potash; or with twice its

weight of carbonate of potash. The fused mass, dissolved in boiling water, and filtered, gives, on the addition of nitric acid, a precipitate of tungstic acid; or Wolfram, reduced to a fine powder, may be boiled with three times its weight of muriatic acid. As soon as the acid becomes hot, a yellow powder appears, and the liquid becomes brown. When cold, decant the clear liquid, and wash the sediment repeatedly with water; then digest it, for some hours, with liquid ammonia, which will take up a part. Repeat these operations, till they cease to act on the substance. Evaporate the ammoniacal solution to dryness, and calcine the salt. The acid of tungsten remains, in the proportion of more than half the weight of Wolfram which has been employed.

II. Tungsten has the following characters:

1. It has a greyish white colour, like that of iron, and a good deal of brilliancy. It is not magnetic. Its specific gravity, according to D'Elhuyarts, is 17.6; or, according to Messrs. Allen and Aikin, 17.22. It is only, therefore, surpassed in density by gold and platina.

2. It is extremely hard and brittle. It requires, for fusion, a temperature of at least 170° Wedgwood.

3. It is oxydized by the action of heat and air. Its first oxide is black. The second is yellow, and is commonly termed tungstic acid.

4. The tungstic acid has no taste; has the specific gravity 6.12; is difficultly fusible; is insoluble in water; but remains suspended in it, and in this state has no action on vegetable colours. Exposed to heat in a platina spoon, it assumes a deep green colour. Calcined with the contact of air, its yellow colour becomes deeper, and passes to a green, and, after some hours, grey. The deficiency of several acid properties induced Vauquelin to withdraw it from the class of acids, and to arrange it among the oxides.

The tungstic acid is composed, as appears from the experiments of Bucholz, of 20 parts oxygen and 80 metal; and the tungstate of lime was shown by Klaproth, to contain per cent. 77.75 parts of acid, and 22.25 of lime.

FOURTH CLASS.

REFRACTORY METALS.

SECTION XXIII.

Titanium.

I. TITANIUM is obtained from a mineral found in Hungary, &c. called red schorl, or titanite; and, also, in a substance from Cornwall, termed menachanite. It was in the latter substance that it

was originally discovered by Mr. Gregor of Cornwall; and its characters have since been more fully investigated by Klaproth, Vauquelin and Hecht, Lovitz, and Lampadius. To separate it from the first compound, the mineral is to be reduced to powder, and fused with twice its weight of potash. When the fused mass, after cooling, is dissolved in water, a white oxide of titanium remains. To free it from iron, Laugier dissolved it in muriatic acid, and added oxalic acid, which separates a white flocculent precipitate of oxalate of titanium.* The oxalic acid in this may be destroyed by calcination.

Menachanite is to be first fused with potash in a similar manner; and to the alkaline solution, muriatic acid is to be added. This dissolves the oxide of iron, and precipitates the white oxide of titanium, still, however, contaminated by some iron.

II. The oxide of titanium is reduced, by exposure to an intense heat, moistened with oil, and surrounded by powdered charcoal. A blackish blistered substance is obtained, some points of which have a reddish colour. Lampadius states its colour to be that of copper, but deeper; and its lustre to be considerable. It is brittle, but when in thin plates, has considerable elasticity. When this is boiled with nitric acid, no remarkable effect ensues, but the bright spots disappear, and are succeeded by a white compound. Nitromuriatic acid forms, also, a white powder, which remains suspended in it. Sulphuric acid exhibits a similar appearance; sulphurous acid is disengaged; and the titanium is partly changed to a white oxide, and partly dissolved. Muriatic acid dissolves titanium, but not its oxide.

III. The solution of titanium gives a white precipitate with carbonates of alkali; a grass green, mixed with brown, with prussiate of potash; and a dirty dark green, with hydro-sulphurets. Infusion of galls precipitates a reddish brown substance, which, if the solution be concentrated, has the appearance of coagulated blood. A rod of tin, immersed in the solution, imparts to the liquid around it a fine red colour; and a rod of zinc a deep blue one.

IV. Titanium tarnishes by exposure to the atmosphere, and is oxydized when heated with access of air. It is susceptible of three stages of oxydizement. The first oxide is blue or purple, the second red, and the third white. The white oxide is the only one, with the composition of which we are accurately acquainted. It has been shown, by Vauquelin and Hecht, to consist of 89 parts of the red oxide and 11 parts of oxygen.

V. Titanium appears to be incapable of uniting with sulphur; but Mr. Chenevix has succeeded in combining it with phosphorus.

The only alloy of any consequence, which it forms, is with iron. It is of a grey colour, interspersed with brilliant particles, and is quite infusible.

* 89 Ann. de Chim. 306.

SECTION XXIV.

Columbium and Tantalum.

COLUMBIUM was discovered by Mr. Hatchett, in a mineral belonging to the cabinet of the British Museum, supposed to be brought from Massachusetts, in North America. By alternate fusion with potash, and digestion with muriatic acid, the mineral was decomposed; the acid combining with oxide of iron, and the alkali with a peculiar metallic acid, separable by the addition of diluted nitric acid, which threw down a copious white sediment.

This acid has not yet been reduced; but from its properties, there can be little doubt that it has a metallic base. It is insoluble in nitric acid; but when fresh precipitated, it combines both with the sulphuric and muriatic. It unites also with alkalis: and both solutions are colourless. Prussiate of potash gives an olive-coloured precipitate; tincture of galls, a deep orange; and hydro-sulphuret of ammonia, one of a chocolate colour.

Tantalum.

This metal was discovered by Mr. Ekeberg, an eminent Swedish chemist, in two different fossils, called Tantalite and Ytthro-tantalite, both of which are found in Finland. In the one it occurs combined with iron and manganese; in the other, with the earth called yttria.* From these ores it is obtained, by treating them alternately with caustic fixed alkali, and muriatic or nitro-muriatic acid. The alkaline solution, being supersaturated with an acid, lets fall a white powder which is oxide of tantalum. The following are the characteristic properties of tantalum, as enumerated by Mr. Ekeberg:

1. It is not soluble in any acid, even the nitro muriatic, in whatsoever state the mineral is taken, and whatever means are employed.

2. Fixed alkalis attack it when fused with it in considerable excess, and dissolve a considerable quantity, which may afterwards be precipitated by acids, even by the carbonic.

3. The oxide of this metal is white, and does not acquire any colour, by exposure to a high temperature with access of air. Its specific gravity, after being made red-hot, is 6.500.

4. It melts with phosphate of soda, and with borax, but does not impart to them any colour.

5. The oxide of tantalum, ignited with charcoal, melts and agglutinates. It then presents a metallic lustre, and a shining fracture of a greyish black colour. Acids change it again into a white oxide.

Though the oxides of tin and of tungsten are equally soluble with that of tantalum in fixed alkalis, yet the former is easily re-

* See *Annales de Chimie*, xliii. 281.

duced, furnishing a ductile metal; and the oxide of tungsten dissolves in ammonia, is changed to a yellow colour by acids, and communicates colour to phosphate of soda and borax. The oxide of titanium differs from this, in being soluble by acids, and in tinging borax and phosphoric salts, when fused with them.

Considerable doubts had been entertained by several chemists, whether any essential difference exists between columbium and tantalum; and their identity appears now to be sufficiently established by the experiments of Dr. Wollaston.* Having procured specimens of the tantalite and ytthro-tantalite, from which tantalum may be separated, he compared its properties with those of oxide of columbium, furnished by Mr. Hatchett, and obtained from a specimen in the British Museum.

The external characters of the mineral, which yields columbium, closely accord with those of tantalite. Both, also, yield a white oxide, combined with iron and manganese, and as nearly as possible in the same proportion. The white oxide, though not absolutely insoluble in sulphuric, nitric and muriatic acids, is (from which ever mineral it has been obtained) very nearly so. Its appropriate solvent is potash, which does not require to be absolutely free from carbonic acid. The whole of the oxide, thus dissolved, may be precipitated by an acid, and it is not re-dissolved by an excess of acid. The oxides from both minerals agree, also, in being soluble, when fresh precipitated, by oxalic, tartaric and citric acids. Ekeberg, however, we are informed by Berzelius,† discovered in a sample of the mineral from the British Museum, a considerable quantity of tungstic acid, to which it owes its acid properties, and its other constituent he found, with Dr. Wollaston, to be oxide of tantalum.

Infusion of galls, prussiate of potash, and hydro-sulphuret of potash, occasion no precipitation from the alkaline solution of either of these oxides; and, when a sufficient quantity of acid has been added to neutralize the redundant alkali, infusion of galls only throws down a precipitate which, in both cases, is of an orange colour. From these coincidences, there can be little room to doubt of the identity of tantalum with the characteristic ingredient of columbium.

SECTION XXV.

Cerium.

I. CERIUM was discovered, by Messrs. Berzelius and Hisinger of Stockholm, in a mineral from Bastnas, in Sweden, which had

* "Mr. Freysmuth has discovered columbium in Bohemia. He extracted it from a mineral which had been hitherto regarded as a native sulphuret of zinc, and also for *nigrin*, which it resembles. The author thinks that tantalum and columbium are very different metals, notwithstanding the resemblances which Wollaston found between them." *Tilloch's Philos. Mag.* vol. xlvii. 157. C.

† Thomson's *Annals*, iv. 467.

been supposed to be an ore of tungsten. This discovery has been since confirmed by Vauquelin; who after a careful examination of the mineral, concurs in opinion, that it contains the oxide of an unknown metal. From the planet Ceres, discovered about the same period, it has been called Cerium; and the mineral that contains it is termed Cerite.*

II. To obtain the oxide of this new metal, the cerite is dissolved in nitro-muriatic acid, after being calcined and pulverized. The solution is filtered, neutralized with pure potash, and then precipitated by tartrate of potash; or, as Laugier recommends, by oxalic acid. This precipitate, well washed, and afterwards calcined, is the oxide of cerium. The white oxide has been recently determined by Hisinger,† to consist of

Cerium	85.088	100
Oxygen	14.912	17.41
		<hr/>
		100.

And the red or peroxide is composed of

Cerium	79.29	100
	20.71	26.115
		<hr/>
		100.

III. Cerium appears to be susceptible of two stages of oxydization; the first oxide being white, and the second of a fallow red. The white oxide, by calcination, becomes red.

IV. Sulphuric acid, diluted with four times its weight of water, dissolves the red oxide. The solution, on being evaporated, yields crystals, some of which are orange, and others have a lemon-yellow colour. The sulphate is soluble only by an excess of acid. Its taste is saccharine mixed with acid.

V. Sulphuric acid readily unites with the white oxide; the solution is nearly colourless, but has a slight rosy tinge. It has a saccharine taste, unmixed with acidity, and yields white crystals.

VI. Nitric acid unites most easily with the white oxide. The solution is very sweet, and is not crystallizable. When decomposed by heat, it leaves a brick-coloured oxide.

VII. Muriatic acid dissolves the red oxide; and the solution crystallizes confusedly. The salt is deliquescent; soluble in an equal weight of water; and in three or four parts of alcohol. When this solution is concentrated, it burns with a yellow sparkling flame. The dry salt consists of 100 parts of muriatic acid united with 197.5 of oxide of cerium.

An infusion of galls produces, in muriate of cerium, a yellowish precipitate not very abundant. A few drops of ammonia throw down a very voluminous one of a brown colour, which becomes black and brilliant, by desiccation. By the action of heat, it assumes a brick-red colour.

* See Nicholson's Journal, xii.

† Thomson's Annals, iv. 357.

VIII. Oxide of cerium unites readily with carbonic acid. This union is best effected, by precipitating a solution of the oxide with carbonate of potash. An effervescence ensues; and a white and light precipitate is formed, which assumes, on drying, a silvery appearance. It contains per cent 57.9 parts of protoxide, 19.1 of water, and 23 of carbonic acid.

IX. Sulphuretted hydrogen does not unite with cerium.

X. The attempts of Vauquelin to reduce the oxide of cerium, produced only a small metallic globule, not larger than a pin's head. This globule was not acted upon by any of the simple acids; but it was dissolved, though slowly, by nitro-muriatic acid. The solution was reddish, and gave traces of iron; but it also gave evident marks of cerium, by the white precipitate which tartrate of potash and oxalate of ammonia threw down. The metallic globule, also, was harder, whiter, and much more brittle, and more scaly in its fracture, than pure cast iron.

XI. Hence cerium appears to be a volatile metal, unless it is volatilized in the state of an oxide, which remains to be ascertained by future experiments.

CHAPTER XX.

VEGETABLE SUBSTANCES.

VEGETABLE substances, though they are all distinguished from each other by peculiar characters, present several circumstances of agreement in chemical properties. Oxygen, hydrogen, and carbon are their principal ingredients, to which a certain proportion of nitrogen is occasionally added; and variations in the proportions, and mode of combination, of these elements, cause the great diversity, which subsists among the products of the vegetable kingdom. They are all susceptible of decomposition by heat alone; but we cannot, as in bodies of the mineral kingdom, proceed from a knowledge of their components to the actual formation of the substances themselves. It is not probable, indeed, that we shall ever attain the power of imitating nature in these operations. For in the functions of a living plant, a directing principle is concerned, peculiar to animated bodies, and superior to, and differing from, the cause which has been termed chemical affinity.

The distinction (as has been well observed by Berzelius*) between inorganic and organic compounds appears to be this. The former are composed either of combustible or of oxidized bodies; and, when of the latter, each combustible base is united with a portion of oxygen, which belongs exclusively to it, and which accompanies it, when it is detached from combination. Organic compounds, also, contain oxygen; but in these, we have several combustible bases, united to one portion of oxygen, which cannot be

* 80 Ann. de Chim. 37.

said to belong more to the one, than to the other; and which would not suffice to bring any one of those bases to its maximum of oxidation.

The productions, of which I am about to offer the chemical history, may be regarded as the *immediate* or *proximate* principles of vegetables; for we may presume, generally speaking, that they exist in the living plant in a state identical with that, under which chemical processes exhibit them. It is not so when we proceed to the *ultimate* analysis of vegetables; for, in that case, we obtain compounds, which formed no part of the vegetable structure, and which result from a new arrangement of the elements composing it. Acetic and carbonic acids, for example, are obtained by the destructive distillation of several vegetable substances, in which neither of these acids existed ready formed, but only their elements.

The destructive distillation of vegetables was, till lately, the only method employed to determine the proportion of their ultimate elements; but more refined and perfect modes of analysis have lately been practised by Gay Lussac and Thenard, which have afforded results, much more deserving of confidence. Their process consists in effecting the combustion of vegetable substances, in close vessels of a peculiar construction, by means of hyper-oxy-muriate of potash.

The following general laws, respecting the composition of vegetable bodies, have been deduced, by those philosophers, from a general review of their experiments.

I. A vegetable substance is always acid, when the oxygen, which it contains, is to the hydrogen, in a proportion greater than is necessary to compose water.

II. A vegetable substance is always resinous, or oily, or alcoholic, &c., when the oxygen, contained in it, is to the hydrogen, in a less proportion than in water.

III. A vegetable substance is neither acid nor resinous, but in a state analogous to sugar, gum, starch, lignin, &c., whenever oxygen and hydrogen enter into its composition in the same proportion as in water.

Without supposing then, that oxygen and hydrogen exist, as water, in vegetables, we may, for the sake of illustration, consider vegetable acids, as constituted of carbon, water, and oxygen;—the resins, alcohol, ether, &c., as composed of carbon, water, and hydrogen;—and bodies of the third class, as composed of carbon and water only.

The products of the vegetable economy are either situated in particular organs or vessels, or are distributed throughout the whole plant. Sometimes they reside in the root or stalk; at others in the bark or leaves; at others they are peculiar to the fruit, the flowers, the seeds, or even to particular parts of these organs. When thus insulated, they may readily be procured in a separate state; and, in several instances, nothing more is required than the labour of collecting them. Thus gum exudes from some trees, and manna issues from the branches of others. Sometimes, how-

ever, we are presented with a variety of substances mingled together, and requiring separation by processes which are sufficiently simple, and which consist in repose, filtration, pressure, washing, distillation at a gentle heat, solution by water and alcohol, and similar operations, that do not alter the nature of the bodies submitted to them.

The number of principles, which have thus been extracted from vegetables, has of late years been greatly enlarged, and amounts at present to between thirty and forty. Of these, the greater part are certainly entitled, by a train of properties sufficiently characteristic, to rank as distinct compounds. But others seem to be so nearly allied to substances, with which we have long been acquainted, that it can serve no useful purpose to assign them a different place in the system. The unnecessary multiplication, indeed, of vegetable principles, contributes rather to retard than to advance the progress of this difficult part of chemistry; and it is only in cases of decided and unequivocal differences of qualities, that we should proceed to the establishment of new species.

SECTION I.

Vegetable Extract.

THE term Vegetable Extract is not to be understood in the sense which is generally annexed to it, as comprehending all those parts of vegetables which may be dissolved in water, and obtained in a solid form by evaporating the solution; but is now limited to a distinct and peculiar substance. This substance may be obtained by evaporating, at a temperature below 212° , an infusion of saffron, prepared with boiling distilled water. Extract, thus procured, has the following properties:

1. It is cohesive, of a brownish colour, and generally of a bitterish taste, varying with the plant, from which it has been obtained.

2. It is soluble in cold water, but more copiously in hot; and the solution is always coloured. Hence the decoctions of certain substances (Peruvian bark for example) become turbid on cooling. The solution, exposed for a long time to the air, acquires a mouldy pellicle, and undergoes a sort of putrefaction.

3. When a solution of extract is slowly evaporated, it affords a semi-transparent mass; but rapid evaporation renders it perfectly opaque. By repeated solutions in water, and evaporations, it acquires a deeper colour, and loses its property of being soluble in water, apparently in consequence of absorbing oxygen from the air.

4. Extract exposed to the atmosphere, slowly imbibes moisture; or is imperfectly deliquescent.

5. It is soluble in alcohol and in liquid alkalis, but neither in ether nor in acids, which last even precipitate it from its solution in water.

6. Oxy-muriatic acid, poured into a solution of extract, precipitates a dark yellow powder, which is no longer soluble in water, but dissolves in hot alcohol.

7. Extract has an affinity for alumine. When the sulphate or muriate of this earth is poured into one of extract, a precipitate appears, especially if the mixture be boiled. When linen or woollen thread, previously impregnated with a solution of alum, is boiled with a solution of extract, the thread is dyed a fawn colour, and the extract disappears in great part from the liquor.

8. Muriate of tin, and several other metallic salts, also precipitate extract, their oxides forming with it insoluble compounds.

9. Extract is not precipitated by a solution of tan.

These are the properties of extract, in the purest form under which we have yet procured it. As commonly obtained, however, it is combined with one or more, and frequently with a great number of other principles. In the sap of plants, it exists united with mucilage, gallic acid, tan, acetate of potash, and other neutral salts. Of the substance called *catechu*, it forms, according to the experiments of Sir H. Davy, a considerable part; and being not easily dissolved by cold water, may be obtained by washing off the more soluble parts. The infusions, also, of most vegetable substances, hold extract in solution united with other principles.

From a recent series of experiments, Dr. Bostock is disposed to doubt whether there be any distinct principle, to which the title of *extract* can with propriety be given. The re-agents, he finds, which have been pointed out as tests of extract, act also upon tan; and the processes, for separating extract from the other parts of vegetable infusions, appear to him to be founded upon incorrect assumptions. He has not, however, examined the extract from saffron.*

SECTION II.

Mucilage, or Gum.

THIS substance, termed mucilage when fluid, is, in a solid state, generally known by the name of gum. Gum arabic may be taken as an example. It appears, however, from Dr. Bostock's experiments, that there is a considerable variety in the chemical properties of different mucilages.

1. Gum is dry, brittle, and insipid, and undergoes no change by exposure to the atmosphere, except that the action of light destroys the yellow colour, which it frequently exhibits. Its specific gravity varies from 1300 to 1490.

2. It is readily soluble in water, and forms a viscid solution, which may be kept a long time without undergoing any change; but finally becomes sour.

* See Nicholson's Journal, xxiv. 204.

3. It is insoluble in alcohol and in ether, the former of which precipitates it from water.

4. It is separated from water, in a thick curdy form, by acetate of lead; and is thrown down by the red sulphate of iron, in the state of a brown semi-transparent jelly. Several other salts, also, have a similar effect. According to Dr. Thomson's experiments, the salts, containing mercury and iron at the maximum of oxydation, are the most efficient in precipitating gum. The oxides of copper, antimony, and bismuth, are, also, acted upon by it; for it prevents water from precipitating them in the state of sub-salts. The effects of re-agents on a solution of gum have been lately investigated, also, by Dr. Bostock;* and have been found to vary considerably in the different species of gum; for example, in gum arabic, cherry-tree gum, and linseed mucilage.

5. Gum is soluble in pure alkalis, and in lime-water, and is precipitated unchanged by acids. Of the earths, silex seems to have the strongest affinity for it; a solution of silicated alkali decomposing a very dilute solution of gum. (Thomson.) Dr. Duncan, jun. however, informs me, that this precipitate is produced only by solutions of the lighter coloured specimens of gum, which have different properties from those of darker colour. The precipitation, when it does occur, Dr. Bostock suspects to take place, only in consequence of the lime which gum contains. Hence oxalic acid, also, produces a precipitate from the solution of gum arabic.

6. Diluted acids dissolve gum unchanged, and the concentrated ones decompose it. Strong sulphuric acid converts it into water, acetous acid, and charcoal; the last of which amounts to rather more than one fourth the weight of the gum, and exhibits slight traces of artificial tan. Nitric acid dissolves gum with a disengagement of nitrous gas; and the solution, on cooling, deposits a little saccholactic or mucous acid. The production of *mucous* acid appears to be the characteristic property of mucilage; and Vauquelin even obtained this acid from the mucilage of linseed. Some malic acid is also formed; and by continuing the heat, the gum is changed by the nitric acid into oxalic acid, which bears the proportion of nearly one half of the weight of the gum. Oxy-muriatic acid transmitted through a solution of gum, changes it into citric acid.

7. Gum and sugar readily combine; and by gentle evaporation of their mixed solutions, a transparent substance is obtained. From this, alcohol separates a part of the sugar, but the remainder continues in combination, and forms a substance, resembling that of which the nests of wasps are composed.

8. Gum, when submitted to destructive distillation in a retort, yields an acid, formerly called the pyro-mucous, but now ascertained to be merely the acetic, holding in solution a portion of essential oil, and some ammonia. Carburetted hydrogen and carbonic acid gases are also disengaged; and in the retort there remains charcoal, mixed with lime and phosphate of lime. Gum, there-

* See Nicholson's Journal, xviii. 28.

fore, is composed of oxygen, hydrogen, carbon, and (as may be deduced from its yielding ammonia) a little nitrogen. It appears to differ from sugar, not only in containing a less proportion of oxygen, but also by its combination with lime and nitrogen.*

Respecting the varieties of vegetable mucilage, which appear to be pretty numerous and well marked, much valuable information may be obtained from the paper of Dr. Bostock, which has been already referred to.

Gum Arabic has been analysed by Gay Lussac and Thenard, and by Berzelius, and found to consist of

Carbon	42.23	41.906
Oxygen	50.84	51.306
Hydrogen . . .	6.93	6.788
	<hr/>	<hr/>
	100. †	100. ‡

SECTION III.

Vegetable Jelly.

VEGETABLE jelly may be obtained from the recently expressed juices of certain fruits, such as the currant and gooseberry. When the expressed juice of these fruits is allowed to remain, for some time, in a state of rest, it partly coagulates into a tremulous soft substance, well known by the name of jelly. The coagulum, washed with a very small quantity of water, is jelly nearly in a state of purity.

Vegetable jelly, unless when tinged by the colour of the fruit, is nearly colourless; has a pleasant taste, and a tremulous consistency. It is soluble in cold water; but more copiously in hot, and the solution, if strong enough, again gelatinates on cooling. By long boiling it loses this last property, and is changed into a substance analagous to mucilage. When dried it is transparent. It combines readily with alkalis. Nitric acid converts it into oxalic acid, without disengaging any azotic gas. Its solution in water is precipitated by infusion of galls.

* Cruickshank, Nicholson's Journal, 4to. ii. 409.

† Gay Lussac.

‡ Berzelius.

SECTION IV.

*Sugar and Oxalic Acid.*ART. 1.—*Sugar.*

ALMOST all the sugar, which is applied to the common purposes of life, is derived from a plant, the growth of hot climates, called *Arundo Saccharifera*. This plant produces strong canes, inclosing a soft pithy substance, which yield, by the compression of powerful machinery, a large proportion of sweet juice. The juice is evaporated in copper vessels, with the addition of a small quantity of slaked lime. During evaporation, a thick scum is formed, which is continually removed. The juice passes successively from larger to smaller boilers, till at length, in the last of these, it becomes thick and tenacious. When this happens, it is emptied into shallow wooden coolers, where the syrup forms a mass of small irregular crystals, enveloped in a treacly fluid. The whole mass is drained in hogsheads, in the bottoms of which holes are bored. The fluid, which separates, is called *melasses* or *treacle*; and the dried crystals are exported to this country under the name of *raw* or *muscovado sugar*.

The subsequent process, which sugar undergoes, with the view of bringing it to the white and beautiful form of *loaf-sugar*, consists in its being redissolved in lime-water, and in being boiled with a quantity of some coagulable substance, such as the whites of eggs or bullock's blood. These substances coagulate into a thick scum, which rises to the surface, carrying along with it the principal part of the impurities of the sugar. The solution, after being evaporated to a due consistence, is let out into large conical earthen pots, with a hole at the apex of the cone, and each supported by an earthen jar. When the syrup has concreted into a solid mass, the plug is removed from the point of the cone, to allow the adhering liquid to drain off; and a mixture of pipe-clay and water is poured on the surface of the mould, and suffered to continue there four or five days. The moisture from this, slowly descending through the sugar, carries with it the remains of the darker coloured syrup; and the whole loaf, after being dried in a stove, is obtained of the proper degree of whiteness.

Besides the juice of the cane, sugar may be extracted, also, from several other vegetables. The juice which flows spontaneously from incisions made in the American maple-tree, affords a quantity sufficient to render it a process worth following. Ripe fruits contain sugar in considerable quantity, and by long keeping after they have been dried, it appears, in a granular state, on their surface. The juice of the carrot, and still more remarkably of the beet (*beta vulgaris*, Linn.) yield a considerable proportion of sugar. To obtain it from the latter vegetable, the roots, softened in water, are

to be sliced, and the juice expressed. It is then to be boiled down with the addition of a little lime till about two thirds remain, and afterwards strained. These boilings and strainings are repeated alternately, till the liquid attains the consistence of syrup, when it is left to cool. The sugar thus extracted, retains somewhat of the taste of the root; but it may be purified by the operation already described as used for the refining of West India sugar, and it then loses its peculiar flavour. The quantity obtained varies considerably; but in general it may be stated at between four and five pounds from 100 pounds of the root, beside a proportion of uncrystallizable syrup. In Germany, the expence has been calculated at about three pence *per* pound; but this estimate is probably underrated.

From the experiments of Proust,* it appears that a coarse sugar may be produced from grapes (of which many thousand tons are annually wasted in Spain,) at the expence of about eight pence *per* pound; or, under favourable circumstances, even for five pence. In apples and pears, in the juice of liquorice, and in some other vegetable juices, sugar exists, but in a state of combination, which prevents it from assuming a crystallized form.

Sugar is produced also in the process of malting, which consists in the conversion of starch into sugar.

The following are its chemical properties:

1. Sugar is soluble in an equal weight of cold water, and almost to an unlimited amount in hot water. The latter solution affords a liquid called syrup; from which, by long repose, transparent crystals of sugar separate, called *candied sugar*. Their form is that of prisms with four or six sides, bevelled at each extremity, or sometimes acuminated by three planes.

2. Alcohol dissolves, when heated, about one fourth its weight of sugar. The solution, by keeping, deposits large crystals of sugar.

3. Lime-water renders sugar more soluble. Alkalis unite with it, and destroy its taste. It may be recovered, however, unchanged, by adding sulphuric acid, and precipitating the alkaline sulphate by alcohol, which retains the sugar in solution. It unites, also, with the alkaline earths; and with barytes so strongly, that it appears to undergo a kind of decomposition.

4. Sugar has the property of rendering oils miscible with water.

5. The sulphurets, hydro-sulphurets, and phosphurets appear to have the property of converting sugar into a substance not unlike gum.†

6. It is converted, by destructive distillation, into acetic acid, carburetted hydrogen, and carbonic acid gas, and charcoal. According to Lavoisier, it is composed of 64 oxygen, 28 carbon, and eight hydrogen: Gay Lussac, Thenard, and Berzelius, have analyzed it

* Nicholson's Journal, xxi. 356.

† Thomson's Chemistry, iv. 214.

by combustion with hyper-oxymuriate of potash, and find it to consist of

Carbon	. . . 42.47	. . . 44.200
Oxygen	. . . 50.63	. . . 49.015
Hydrogen	. . . 6.90	. . . 6.785
	<hr/> 100.*	<hr/> 100.†
Or of carbon	. . . . . 42.47	
Oxygen and hydrogen in the same proportion as in water	} 57.53	
	<hr/> 100.	

It is remarkable that these are as nearly as possible the proportions of the ingredients of gum arabic.

Beside pure sugar, there are other saccharine substances that bear a considerable resemblance to it. Manna is the inspissated juice which flows spontaneously from incisions in the bark of a species of ash (the *fraxinus ornus*). Sugar has been discovered, also, by Fourcroy and Vauquelin, to enter largely into the composition of the juice obtained by pressure from the onion. Besides sugar, it appears, also, to contain a portion of mucilage and extract, to which its taste and other peculiar properties are owing.

The same may perhaps be said of honey. When treated with nitric acid it was found, however, by Mr. Cruickshank, to give very little less oxalic acid, than was obtained from an equal weight of pure sugar. Proust has considered honey itself as of two distinct species. Common yellow honey is of an uniform consistence and viscid; but, besides this, there is a granulated white kind, which has a tendency to become solid. From the latter he obtained by alcohol a white saccharine powder, which he considers as agreeing more nearly with the sugar of the grape than with common sugar.

ART. 2.—*Oxalic Acid.*

Sugar is acidified by distillation with nitric acid. To six ounces of strong nitric acid, in a stoppered retort, to which a large receiver is luted, add, by degrees, one ounce of lump-sugar, coarsely powdered. A gentle heat may be applied during the solution. Nitrous gas will be disengaged in great abundance. When the whole of the sugar is dissolved, distil off a part of the acid. The remaining liquor will form regular crystals (amounting to 58 parts from 100 of sugar), which must be again dissolved in water and crystallized. Lay this second crop of crystals on blotting paper to dry.

* Gay Lussac.

† Berzelius.

Oxalic acid may be procured, also, by a similar treatment of gum, and of various other vegetable, and even of some animal products.

The crystals of oxalic acid have the following characters :

1. They have a strong acid taste, and act powerfully on vegetable blue colours.

2. They dissolve in twice their weight of cold, and in an equal weight of hot water. They are soluble, also, in boiling alcohol, which takes up about half its weight; and, though sparingly, in ether.

3. They effloresce in the air, and become converted with a white powder.

4. A red-heat entirely decomposes them, and leaves only charcoal. During distillation, a considerable quantity of inflammable gas is obtained; and a portion of the acid is sublimed, unaltered, into the neck of the retort. The constitution of oxalic acid, has been investigated with much skill and attention by Dr. Thomson.* The crystals, in their perfect state, he has proved to consist of

Real acid	. . .	77
Water	. . .	23
		<hr/>
		100

And from an elaborate examination of the gases, obtained by destructive distillation, he concludes that 100 parts of real oxalic acid consist of

Oxygen	. . .	64
Carbon	. . .	32
Hydrogen	. . .	4
		<hr/>
		100

Oxalic acid has since been analysed by Gay Lussac and Thénard,† and by Berzelius.‡ The first mentioned chemist decomposed oxalate of lime of known composition by oxymuriate of potash, and obtained the following results :

Carbon	. . .	26.566
Oxygen	. . .	70.689
Hydrogen	. . .	2.745
		<hr/>
		100.
		<hr/>

* Philosophical Transactions, 1808.

† Recherches, vol. ii.

‡ 81 Ann. de Chim. and Thomson's Ann. iv. 232.

Or the analysis may be thus stated :

Carbon	26.566
Oxygen and hydrogen in the } same proportions as in water }	22.872
Excess of oxygen	50.562
	<hr/> 100

Berzelius, some time ago, ascertained that of the water, which enters into crystallized oxalic acid, only 28 per cent. can be driven off by heat, but that a farther quantity may be detached, by uniting the acid with oxide of lead. Taking the latter portion into account, the crystals consist of 58 acid and 42 water; and the real acid is thus constituted, according to his experiments:

Oxygen	66.211	. . .	= 6 atoms.
Carbon	33.021	. . .	= 4 atoms.
Hydrogen	0.728	. . .	= 1 atom.

OXALATE OF POTASH forms flat rhomboidal crystals, terminated by dihedral summits. Its taste is cooling and bitter. At 60° Fahrenheit, it requires three times its weight of water for solution. There is, also, a salt formed of the same base and acid, but with a considerable excess of the latter, called SUPER-OXALATE or BINOXALATE OF POTASH. It forms beautiful four-sided prisms. The acid, which it contains, is double that in the oxalate; or if we suppose 100 parts of potash, and denote the quantity necessary to convert it into oxalate by x , then $2x$ will convert it into super oxalate.

According to Berzelius 100 parts of potash are united, in the oxalate, with 97.3 parts of oxalic acid, and in the binoxalate, with 192.4. Exclusively of water, which, in the crystals of the oxalate, amounts to 17.31 per cent., they are composed as follows :

	Acid.	Base.
Oxalate of potash	49.32 . . .	50.68
Binoxalate of do.	65.80 . . .	34.20

QUADROXALATE OF POTASH may be composed in several methods.* It was formed by Dr. Wollaston, by digesting the super-oxalate in nitric or muriatic acid. The alkali is divided into two parts, one of which unites with the mineral acid; and the other half remains in combination with the oxalic acid. Hence the quadroxalate contains four times the acid that exists in the neutral oxalate, and twice as much acid as the super-oxalate: or its acid may be denoted by $4x$.

* See Berard, 73 Ann. de Chim. 271.

Berzelius determined that, in this salt, 100 parts of potash are combined with 330 parts of oxalic acid, or it consists of

Potash	.	.	18.95
Acid	.	.	72.05
Water	.	.	9.
			<hr/>
			100

Salt of sorrel was found by Berard to be a true quadroxalate of potash.

OXALATE OF SODA readily crystallizes, and has a taste nearly resembling that of oxalate of potash. When heated, it falls to powder, and loses the whole of its water of crystallization. Soda is said to form, also, with oxalic acid a *binoxalate*, but no *quadroxalate*. In the oxalate, 100 parts of soda are combined with 143.5 parts of acid; in the binoxalate with 284.7 according to the analysis of Berzelius.

OXALATE OF AMMONIA crystallizes in long transparent prisms, rhomboidal, and terminated by dihedral summits, which, according to Berard, contain 13 per cent. of water. Its taste is bitter and unpleasant. At the temperature of 60°, 1000 grains of water dissolve only 45 grains of the salt. The solution is of great use as a re-agent; for it precipitates lime from all its soluble combinations, and discovers it even when in very minute quantities. Hence it is a most important instrument of analysis.

In oxalate of ammonia, 100 parts of real alkali are united with 261 parts of acid. A super-oxalate or *binoxalate* of ammonia, also, exists, which is less soluble in water than the oxalate. In this, 100 parts of base are united with 523 of acid.

OXALATE OF LIME is an extremely insoluble salt. It may be formed, either by dropping oxalic acid into lime-water, or by mingling the solutions of a salt with base of lime and of any of the soluble oxalates. When very slowly dried at the temperature of about 60° Fahrenheit, it is tolerably uniform as to its composition; and consists, according to Dr. Thomson, of

Acid	.	.	59.2
Lime	.	.	35.5
Water	.	.	5.3
			<hr/>
			100.

When rapidly dried, it is apt to concrete into hard lumps, which contain not less than 10 per cent. of water. It is soluble in nitric and muriatic acid; and hence, in the use of oxalate of ammonia or oxalic acid as a precipitant, it is necessary first to neutralize any excess of acid.

OXALATES OF BARYTES AND STRONTITES are white tasteless powders of very sparing solubility; but these earths are said, with an excess of acid, to form soluble super-oxalates.

One hundred parts of strontites take 83.62 of oxalic acid for saturation. No super-oxalate exists with this base. The oxalate of barytes is more soluble than the strontitic salt. It consists of 100 parts of base, united with 60.84 acid. A super-oxalate may be formed, by heating muriate of barytes with oxalic acid. This salt, which shoots into crystals, has its elements so feebly combined, that it is decomposed by mere solution in water. It is constituted of 100 parts of base and 123 oxalic acid.

OXALATE OF MAGNESIA is a soft white powder, bearing a considerable resemblance to oxalate of lime. It is tasteless, and not sensibly soluble in water. Yet when oxalate of ammonia is mixed with sulphate of magnesia, no precipitate falls. It is composed of 100 parts of base and 265 of acid.

According to Dr. Thomson, 100 parts of oxalic acid saturate the following quantities of the several bases :

Ammonia . . .	34.12
Magnesia . . .	35.71
Soda . . .	57.14
Lime . . .	60
Potash . . .	122.86
Strontian . . .	151.51
Barytes . . .	142.86

And the composition of the different oxalates is shown by the following Table.

One hundred parts of	Consist <i>per Thomson of</i>		Consist <i>per Berard of</i>	
	Acid.	Base.	Acid.	Base.
Oxalate of ammonia	74.45	25.55	*62.34	27.66
— magnesia . .	73.68	26.32	71.65	27.35
— soda . . .	63.63	36.37	58.92	41.08
— lime . . .	62.50	37.50	62.00	38.00
— potash . . .	44.87	55.13	49.32	50.68
— strontian . .	39.77	60.23	45.54	54.46
— barytes . . .	41.16	58.84	37.83	62.17
— lead . . .	25.20	74.80		

The above table is to be understood as applicable to the salts in their state of ordinary dryness. With the exception indeed of oxalate of potash, and perhaps of soda, Dr. Thomson is of opinion that, when slowly and carefully dried, the proportion of water is so small, that it may be overlooked.

* This number should probably be 72.34; for, as it stands in the Table, the acid and base do not make up 100.

SECTION V.

Native Vegetable Acids.

NATIVE vegetable acids are such as are found, ready formed, in plants or their fruits, and require only pressure, and other simple processes, for their extraction. The following are the principal ones hitherto discovered :

- | | |
|--------------|----------------|
| 1. Citric. | 6. Benzoic. |
| 2. Gallic. | 7. Acetic. |
| 3. Malic. | 8. Prussic. |
| 4. Tartaric. | 9. Phosphoric. |
| 5. Oxalic. | |

ART. 1.—*Citric Acid.*

Citric acid exists in the expressed juice of the lime and lemon, along with a quantity of extractive matter and mucilage. The process, for obtaining it in a separate state, we owe to the ingenuity of Scheele. To the expressed juice of the lime or lemon, contained in a vessel of earthen ware, or white wood, add, very gradually, finely powdered carbonate of lime (chalk or whiting), and stir the mixture well after each addition. An effervescence will ensue; and as long as this arises, on adding fresh portions of chalk, more chalk will be required. The exact proportion it is impossible to assign, on account of the variable strength of the acid juice. In general, from six to eight ounces of chalk are sufficient to saturate a wine-gallon of lime-juice. When it ceases to excite effervescence, and the liquor has lost its sour taste, allow the mixture to settle; decant the liquid, and add a quantity of water. Let the powder subside; the liquor be again decanted, and thrown away; and these operations repeated, till the water comes off nearly colourless. The insoluble precipitate consists of citric acid, united with lime; add to it a quantity of sulphuric acid, of the density 1.8 equal to about three fourths the weight of the chalk which has been employed, and previously diluted with 20 parts of water.—Let the acid and precipitate remain together 24 hours; during which time they must be frequently stirred. Then let the white sediment, which consists of sulphate of lime, subside; decant the clear liquor; add more water till it comes off tasteless; and mix all the liquors together. The solution, containing citric and sulphuric acids, and some mucilage, is to be evaporated in shallow earthen dishes, placed in a sand-heat. Reduce the liquid to about one fourth of its bulk by evaporation; separate the sulphate of lime, which will be deposited, and again waste the liquor, by a heat not above 212° , to the consistence of syrup.—Dark brown crystals will form on cooling, which must be set to drain; and the remaining liquor, when again evaporated re-

peatedly, will continue to yield fresh crystals. To purify these, let them be dissolved in water; and the solution be again evaporated. After the second crystallization, their colour will be improved; but it will require three or four crystallizations to obtain them perfectly white and well formed. In this state, they are the pure citric acid.

The proportions, which I have recommended for the preparation of citric acid, differ a little from those, which have been deduced by Proust from his experiments. Four ounces of chalk, saturated, he found, 94 ounces of lemon juice; the citrate of lime weighed seven ounces four drachms. But the four ounces of chalk, or 32 drachms, contained only $17\frac{1}{4}$ drachms of lime; and, from the analysis of citrate of lime, it appears to contain 70 parts of citric acid in 100. Hence the seven ounces four drachms contained $41\frac{1}{4}$ drachms of citric acid. But to expel the carbonic acid completely from four ounces of chalk, five ounces of sulphuric acid of commerce were found necessary. This proportion, therefore, he employed in decomposing the citrate of lime. Six ounces of the citrate, by two crystallizations, gave $3\frac{1}{2}$ ounces, or 28 drachms, of pretty large crystals; from whence it follows that the whole $7\frac{1}{2}$ ounces would have given 4 ounces 3 drachms of citric acid.*

The citric acid, which is made for sale, is generally prepared from lime-juice. The quantity of solid citric acid, in a gallon of this juice, varies considerably; but about six or eight ounces to the wine gallon is a fair general average. The only method of ascertaining its proportion consists in adding, to a quantity of the juice, solution of pure potash till saturation is produced; having previously determined, by direct experiments, how much of the alkaline solution is required to neutralize an ounce of crystallized citric acid.

Pure citric acid forms beautiful transparent crystals, consisting of two four-sided pyramids joined base to base, or sometimes of rhomboidal prisms. An ounce of distilled water, at 60° Fahrenheit, dissolves an ounce and a quarter of these crystals, or at the boiling temperature twice its weight. The crystals do not attract moisture from the atmosphere. They contain per cent. according to Berzelius,

Real acid	. . .	79
Water	. . .	21
		<hr/>
		100

Only a small part of this water, viz. about 7 per cent. can be driven off by a degree of heat, just below what is sufficient to decompose the acid. The real proportion of water can only be determined, by uniting the acid with some basis, oxide of lead for example.

Citric acid is decomposed at a high temperature, and yields

* Philosophical Magazine, x.

products, which are constituted of carbon, hydrogen, and oxygen in uncertain proportions. A better method of effecting its analysis is that practised by Gay Lussac and Thenard, viz. combustion with hyper-oxymuriate of potash. By this process, they determined it to consist of

Carbon . . .	33.811
Oxygen . . .	59.859
Hydrogen . . .	6.330
	<hr/>
	100.

Berzelius obtained results, differing considerably from these; owing, he believes, to the want of due allowance, by Gay Lussac and Thenard, for the quantity of water of crystallization. His proportions are

Carbon . . .	41.37
Oxygen . . .	54.83
Hydrogen . . .	3.80
	<hr/>
	100.

When treated with about three times its weight of nitric acid, the citric acid is converted partly into the oxalic, of which it gives half its weight. As the proportion of nitric acid is increased, that of the oxalic is diminished, till at length it disappears altogether, and acetic acid appears to be formed.

Citric acid readily unites with alkalis, earths, and metallic oxides.

CITRATE OF POTASH.—According to Vauquelin, 36 parts of crystallized citric acid, dissolved in water, require for saturation 61 of crystallized carbonate of potash: and the result is an extremely soluble and even deliquescent salt, composed of $55\frac{1}{2}$ acid and $44\frac{1}{2}$ alkali.

CITRATE OF SODA is a very soluble salt. Thirty-six parts of citric acid neutralize 42 of dry sub-carbonate of soda; and hence 100 parts of the citrate consist of 60.7 acid and 39.3 base.

CITRATE OF AMMONIA.—The same quantity of citric acid saturates 44 parts of sub-carbonate of ammonia; and affords a soluble and difficultly crystallizable salt, composed, in 100 parts, of 62 acid and 38 base.

CITRATE OF BARYTES consists of equal weights of acid and base. It is an insoluble salt of little importance.

CITRATE OF MAGNESIA.—Thirty six parts of crystallized acid neutralize 40 parts of sub-carbonate of magnesia. Hence 100 parts of the salt contain 33.34 base and 66.66 acid. The salt is soluble, but not crystallizable.

CITRATE OF LIME.—Crystallized citric acid, dissolved in water, requires an equal weight of chalk for saturation. The compound, when neutral, is insoluble; but with an access of acid it becomes

readily soluble. It was found by Gay Lussac and Thenard to consist of

Acid . . .	68.83
Lime . . .	31.17
	<hr/>
	100.

The METALLIC CITRATES have been but little examined. The compounds of this acid with the oxides of iron are of the most importance; from the use which is made of it as a discharger in calico-printing.

ART. 2.—*Gallic Acid.*

The acid exists in the gall-nut, along with tan and other substances. In Sir H. Davy's experiments, 400 grains of a saturated infusion of galls, gave fifty-three of solid matter, composed of nine tenths tan and one tenth gallic acid. The acid may be obtained by exposing an infusion of galls in water to the air. A mouldy pelticle will form on the surface of the infusion; and, after some months' exposure, small yellow crystals will appear on the inside of the vessel. These crystals must be dissolved in alcohol, to separate them from other substances, and the solution evaporated to dryness.

It may also be procured by sublimation. Pounded galls are to be put into a retort, and heat applied. The gallic acid will rise, and be condensed in the neck of the retort in a solid form. This process is recommended by Deyeux as preferable to any other.*

The gallic acid may be separated from the infusion of galls, by adding muriate of tin till the precipitate ceases to appear. This precipitate may be reserved for the experiments detailed under the article *Tan*. From the remaining solution the superabundant oxide of tin must be precipitated by sulphuretted hydrogen gas, and the clear liquor, on evaporation, yields crystals of gallic acid.

From one ounce of galls, according to Haussman, about three drachms of gallic acid may be obtained.

In Nicholson's 8vo. Journal, vol. i. page 226, a very simple process for obtaining gallic acid is proposed by M. Fiedler. Boil an ounce of powdered galls, in sixteen ounces of water down to eight, and strain the decoction. Precipitate also two ounces of alum, dissolved in water, with a sufficient quantity of carbonate of potash,

* The best method to obtain this acid, is, in conformity to my experiments, to evaporate to dryness a watery infusion of galls. To the mass obtained, add alcohol, which takes up the gallic acid, and may then be filtered from the insoluble residue. The alcoholic solution is next to be evaporated to dryness; the solid matter having a crystalline appearance, somewhat resembling muscovado sugar. This mass is to be mixed with clean dry sand in a glass subliming vessel, surmounted by a paper cone or cap, as in procuring benzoic acid, and exposed to a gentle sand-heat; a portion of moisture is first expelled, after which the gallic acid sublimes in delicate brilliant, white, needle-form crystals. C.

and, after having washed the precipitate extremely well, add to it the decoction, and digest the mixture for 24 hours, shaking frequently. The alumine combines with, and carries down, both the tan and extract; and the filtered solution yields, by gentle evaporation, crystals of gallic acid.

By none of these processes, however, can gallic acid be obtained perfectly pure; for it still, according to Sir H. Davy, is contaminated with a small portion of extract. To purify it, Deyeux advises its sublimation. Over a glass capsule, containing the impure acid, and placed in a sand-heat, another capsule is to be inverted, and kept cool. On the impression of the heat, the acid rises into the upper one, in the form of white needle-shaped crystals.

The pure acid has the following characters:

1. Its crystals have the form of transparent plates or octohedrons. They have an acid and somewhat astringent taste.
2. Gallic acid burns with flame, when placed on a red-hot iron, and emits an aromatic smell.
3. It is soluble in 24 parts of cold, or three of boiling water. Alcohol, when cold, dissolves one fourth, or an equal weight when heated.
4. The solution reddens blue vegetable colours, and effervesces with alkaline carbonates.
5. Nitric acid converts the gallic into oxalic acid.
6. It unites with alkaline solutions without producing any deposit; but from watery solutions of lime, barytes, and strontites, it occasions a bluish precipitate. Of the combinations of earths with acids, it decomposes those only with base of glucine, yttria, and zircon.
7. It precipitates most metals from their solutions; gold, silver, and copper, of a brown colour; lead, white; mercury, orange; bismuth, yellow; and iron, deep black.* The precipitate from solutions of iron is soluble in an excess of acid. It forms the basis of ink, which, according to Deyeux, consists of carburetted oxide of iron, and gallate of iron.
8. By a moderate heat, it is sublimed without alteration, but a strong heat decomposes it; and aëriiform products are formed, which show it to consist of hydrogen, oxygen, and carbon, in proportions not yet exactly determined.

A full and valuable history of the gallic acid, and the process for obtaining it, by Bouillon La Grange, may be consulted in Nicholson's Journal, xvii. 58†. This chemist has lately, however, expressed a doubt of the claim of the gallic acid to be considered as a distinct acid, and suspects that it is only a modification of the acetic. Its properties, he remarks, differ according to the method in which it has been prepared.‡

* Pure gallic acid does not appear to precipitate the salts of iron black, as commonly asserted. We much want a series of experiments on this subject. C.

† The reader will find, also, much important matter on this subject in Messrs. Aikins' Dictionary of Chemistry, article Gall Nut, and in Dr. Bostock's papers in Nicholson's Journal, vol. xxiv.

‡ Annales de Chimie, lx. 156.

ART. 3.—*Malic Acid.*

This acid exists in the juice of apples, gooseberries, and of some other fruits, and is found mixed with the citric, and occasionally with other acids. It may be obtained by evaporating the juice nearly to dryness, and then adding alcohol, which dissolves the acids, and leaves the mucilage. To this solution of citric and malic acids in alcohol, chalk is to be added to saturation, and the precipitate to be washed with boiling water, which takes up the malate of lime, and leaves the citrate. The solution of the malate of lime may then be decomposed by sulphuric acid.

Or the juice of apples may be saturated with carbonate of potash, and mixed with a solution of acetate of lead, till the precipitate ceases. This precipitate is to be washed with water, and dilute sulphuric acid is to be added, till the liquor acquires an acid taste, unmixed with any sweetness. The liquor is to be filtered, to separate the sulphate of lead, and evaporated. It yields no crystals, but a thick liquor of a cherry-red colour.

Vauquelin has shown that the malic acid may be obtained advantageously from the juice of house-leek (*sempervivum tectorum*) by adding acetate of lead, and decomposing the insoluble malate with sulphuric acid. It is formed, also, by the action of nitric acid on sugar. Equal weights of the two are to be distilled together, till the mixture assumes a brown colour. The oxalic acid may be separated by adding lime water; after which, the remaining liquor is to be saturated with lime and filtered. On the addition of alcohol a coagulum of malate of lime is formed, which may be dissolved in water, and decomposed, as before directed, by acetate of lead; and afterwards by sulphuric acid.

The malic acid is liquid, and incapable of being crystallized; for, when evaporated, it becomes thick and viscid, like syrup. It is very soluble in water. By keeping, it undergoes a kind of decomposition. Nitric acid converts it into oxalic acid. It unites with alkalis and earths. With lime it forms a salt which is almost insoluble in cold water, but readily soluble by hot; and in consequence of this last property, it may be easily separated from the oxalic, citric, and tartaric acids. It precipitates mercury, lead, and silver from nitric acid; and decomposes, also, the solution of gold.

ART. 4.—*Tartaric Acid, and its Combinations.*

The tartaric acid is generally obtained from the supertartrate of potash (common cream of tartar) by the following process:

Let 100 parts of finely powdered cream of tartar be intimately mixed with about thirty parts of pulverized chalk. This is best done by grinding them together in a mortar, and passing the mixture through a sieve. Let the mixture be thrown, by spoonfuls, into eight or ten times its weight of boiling water; waiting for the cessation of the violent effervescence, which is produced by each addition, before any more is thrown in. This method I find preferable to the entire solution of the cream of tartar in the first in-

stance, which requires a very large quantity of water. If it should appear, from the effect of the liquor on litmus paper, that the chalk has not been added in sufficient quantity, more may be gradually used, till the colour of the litmus is no longer reddened.

By this operation, a quantity of insoluble tartrate of lime will be formed, which is to be allowed to subside, and washed, three or four times, with cold water. To the tartrate of lime, diffused through a sufficient quantity of water, concentrated sulphuric acid may be added, equal in weight to the chalk which has been employed. The mixture may be allowed to stand for 24 hours, during which it should be frequently agitated. Assay a little of the clear liquor, by pouring into it some solution of acetate of lead. A copious precipitate will be formed, which may either consist of tartrate of lead, or of a mixture of tartrate with sulphate of lead. To determine this, add diluted nitric acid, which dissolves the tartrate but not the sulphate. A small proportion of the latter is desirable, because the tartrate of lime cannot be wholly decomposed without an excess of sulphuric acid; but a large excess of that acid is injurious, from its re-acting on the tartaric acid, when heat is applied in the subsequent part of the process. The deficiency of sulphuric acid should be supplied by adding more; or a great redundancy of it removed by the addition of a little chalk. The evaporation of the solution may now be carried on, in a manner precisely similar to that directed for the citric acid; and the crystals purified by a second solution and evaporation.

The liquor remaining after the addition of chalk, consists of the neutral tartrate of potash. It may be decomposed by adding muriate of lime, till no farther precipitation ensues. An insoluble tartrate of lime falls down, which may be decomposed by sulphuric acid in the way already directed. Or the tartrate of potash may be evaporated to dryness, and reserved for other purposes. If the tartrate of lime be formed by the first operation only, the product of crystallized acid amounts to between one fourth and one fifth the weight of the cream of tartar. But the decomposition by muriate of lime doubles the quantity of acid produced.

Quicklime has been recommended as a substitute for chalk in this process; but I have never found that it could be employed with any advantage; for a quantity of caustic potash is set at liberty by its action, which dissolves the tartrate of lime, and prevents it from precipitating. When chalk is employed for saturation, that part of the acid only is neutralized, which constitutes the *super-salt*; but with quicklime the operation is carried still farther, and the neutral tartrate, also, abandons its acid.

The tartaric acid forms regular crystals, the shape of which varies considerably according to the circumstances of their preparation. They require for solution five or six parts of water at 60° Fahrenheit; but are much more soluble in boiling water. The solution, like that of most other vegetable acids, acquires a mouldy pellicle by keeping. The crystals were found by Berzelius to consist of

Real acid	88.75
Water	11.25
	<hr/>
	100.

Bergman exposed tartaric acid to distillation with nitric acid, in the manner of obtaining oxalic acid, but without being able to produce the latter acid. Hermstadt, however, by using a very concentrated nitric acid, succeeded in converting the tartaric into the oxalic acid, and from six drachms of the former obtained four drachms and two scruples of the latter. Westrumb, also, was successful in the same attempt, and adds that the tartaric acid may be changed into the acetic by digestion with water and alcohol.

When distilled alone in a strong heat, the tartaric acid is decomposed; it yields a quantity of dark-coloured acid liquor, which has erroneously been supposed to be acetic acid; and a large quantity of combustible gas is obtained.

From the experiments of Fourcroy and Vauquelin, it appears that the pyro-tartaric acid is a peculiar species. From the acetic, it differs in being less volatile and less odorous; in being crystallizable by evaporation; and in affording, with potash, a salt which precipitates acetate of lead. It is distinguished from the tartaric acid, in not occasioning any precipitate from the acetates of lime, of barytes, or of lead; and in not forming, with potash, an insoluble salt when the acid is in excess. Influenced by the results of these experiments, the same chemists submitted the pyro-mucous and pyro-lignous acids to a fresh and rigid examination, which terminated in the conviction that they both consist of acetic acid, holding in combination a quantity of empyreumatic oil.*

Tartaric acid has been recently analyzed by Gay Lussac and Thenard, and by Berzelius; and their results are contained in the following Table. One hundred parts consist,

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac, of . . .	24.050	69.321	6.629
—————Berzelius, of	35.98	60.28	3.74

The disagreement of these results arises, probably, from the omission of part of the water of crystallization in the estimate of the two first mentioned chemists.

Tartaric acid unites with alkaline and earthy bases, and affords a distinct class of salts called tartrates.

TARTRATE OF POTASH may be obtained by adding sub-carbonate of potash either to cream of tartar, or to the solution of the crystallized acid, till all effervescence ceases. According to Von Packen 120 grains of sub-carbonate require for saturation 112 of pure tartaric acid. Mr. R. Phillips finds that 100 parts of cream of tartar require for neutralization $43\frac{1}{2}$ of subcarbonate of potash.

* *Annales de Chimie*, lxiv. 42; or *Nicholson's Journal*, xxvi. 44.

The resulting salt is very soluble, and even deliquescent. It is composed, according to Berzelius, of

Acid	. . . .	58.69	. . . .	100
Base	. . . .	41.31	. . . .	70.4
<hr/>				
100.				

SUPER-TARTRATE OF POTASH.—If into a solution of the neutral tartrate, we pour a solution of tartaric acid, a white powder falls down in great abundance, which is a compound of the neutral salt, and an additional quantity of acid. This is an example of the diminution of solubility, by an increased proportion of the acid ingredient of a salt. The tartaric acid, in this proportion, has even so strong an affinity for potash, that it separates this alkali from the mineral acids. Thus by adding tartaric acid to the muriate of potash, we obtain a precipitate of super-tartrate of potash.

The substance which is known in commerce under the name of *tartar*, is an impure variety of this salt. When purified, it affords white crystals, which, by being reduced into powder, form the *cream of tartar* of the shops.

Super-tartrate of potash requires for its solution a very large quantity of water, not less than 120 parts of water at 60° Fahrenheit, or 30 at 212°. Hence its solution deposits the salt on cooling in such quantity as amounts almost to precipitation.

From the experiments of Berzelius, its composition may be stated at

Acid	. . . .	70.45	. . . .	100
Potash	. . . .	24.80	. . . .	35.2
Water	. . . .	4.75		
<hr/>				
100.				

This small portion of water appears to be essential to the salt; for it cannot be separated by heat, without decomposing the acid. When 100 grains of the salt are incinerated, so as to destroy the acid, the alkali obtained is exactly sufficient to neutralize 100 grains of the supertartrate; a proof that the potash in the acidulous salt is combined with twice as much acid as in the neutral compound.

By the destructive distillation of super-tartrate of potash, Fourcroy and Vauquelin obtained, exclusively of acid and charcoal,* of

Pure dry sub-carbonate of potash	. . . .	350
Tartrate of lime	. . . .	6
Silex	. . . .	1.2
Alumine	. . . .	0.25
Iron and manganese	. . . .	0.75

TARTRATE OF POTASH AND SODA may be formed by neutral-

* Annales de Chimie, lxiy. 48.

izing 24 parts of cream of tartar with 18 parts of sub-carbonate of soda. The resulting salt is well known, from its being employed in medicine under the name of *Rochelle Salt*. It requires, for solution, about five parts of cold water, but much less at the boiling temperature. From the experiments of Vauquelin it appears to be composed of 54 parts of tartrate of potash, and 46 parts of tartrate of soda.

The EARTHY TARTRATES have no particularly interesting properties. With the exception of those of magnesia and alumine, they are insoluble. Tartrate of lime consists of $77\frac{1}{2}$ acid and $22\frac{1}{2}$ base; and tartrate of lead of $37\frac{1}{2}$ acid and $62\frac{1}{2}$ oxide.

ART. 5.—*Benzoic Acid.*

This may be obtained from a substance termed gum benzöin or benjamin. The process consists in pulverizing a pound and a half of gum benzöin with four ounces of quicklime, and then boiling them for half an hour in a gallon of water, constantly stirring. When cold, the clear liquor is poured off; and what remains is boiled, a second time, in four pints of water, the liquor being poured off as before. The mixed liquids, after being boiled to one half, are filtered through paper; and muriatic acid is gradually added, until it ceases to produce a precipitate. Finally, after having decanted the liquid, the powder is dried in a gentle heat, and sublimed from a proper vessel, placed in a sand-bath, into cones of writing paper.*

Benzoic acid has a peculiar and not disagreeable odour. Its crystals are soft, and cannot be reduced to powder. It is volatilized, in white fumes, by a moderate heat. It requires for solution about 24 times its weight of boiling water, which, as it cools, lets fall $\frac{19}{20}$ ths of what it had dissolved. It is soluble in alcohol.

The composition of this acid has been ascertained by Berzelius, as follows:

Carbon	74.41
Oxygen	20.43
Hydrogen	5.16
	<hr/>
	100.

The compounds, which it forms with alkaline and earthy bases, called BENZOATES, are fully described by Hisinger in the 40th volume of the *Philosophical Magazine*.

ART. 6.—*The Oxalic Acid*

Is also found native in the juice of sorrel, forming a quadroxalate, and as appears from the experiments of Vauquelin, in the *Rheum Palmatum*.

* For the purpose of merely obtaining the acid as an experiment, a small quantity of the benzöin may be thrown on a hot brick, and covered with an ale glass or tumbler; the salt sublimes very quickly, and may be brushed out with a feather. C.

ART. 7.—*Moroxylie Acid.*

Mr. Klaproth has lately discovered a new acid, combined with lime and extract, in a saline mass, which exudes from the trunk of the white mulberry, *morus alba*, L. It was collected, by Dr. Thomson, from trees in the botanic garden at Palermo; and seems peculiar to those individuals that grow in hot climates. Its characters have not been fully ascertained. From its origin, it has been called, by Klaproth, MOROXYLIC ACID, and its compounds MOROXYLATES.*

ART. 8.—*The Laccic Acid*

(Which, in strictness, should be classed among animal acids) is obtained from the white lac of Madras, from which, when liquefied, it oozes out in drops. It is in the form of a reddish liquor, having a slightly bitter saltish taste; but, on evaporation, it shoots into acicular crystals. It may be raised in distillation. It combines with carbonate of lime and soda, and excites effervescence. It precipitates barytic salts; assumes a green colour with lime-water, and a purplish one with sulphate of iron. A full account of its properties, and of those of the substance that affords it, may be found in Dr. Pearson's paper in the Philosophical Transactions, 1794.

ART. 9.—*Phosphoric acid*

Exists in almost all vegetable substances, and particularly in all the varieties of grain, not however in a free state, but in combination chiefly with potash and lime. Hence the coal of almost all kinds of seeds affords phosphorus by distillation, a fact originally observed by Margraaf, and confirmed by the recent experiments of Saussure.†

ART. 10.—*The Prussic Acid*

Has been discovered in water distilled from bitter almonds, from the leaves of the laurel, and from peach blossoms, and in the bark of the *prunus padus*. When the distilled liquid is neutralized with potash, a crystallizable salt is obtained, the solution of which throws down Prussian blue from the salts of iron. Vauquelin, also, obtained prussic acid by distilling water, with a very gentle heat, from the kernels of apricots.‡ The properties of the prussic acid will be described in the chapter on animal products.

ART. 11.—*Boletic Acid.*

This acid was first obtained by Braconnot, from the juice of the *boletus pseudo-ignarius*.§ The juice was boiled, filtered, and evaporated cautiously, to the consistence of syrup. This was repeatedly digested in alcohol; the insoluble portion was dissolved in wa-

* See Nicholson's Journal, 8vo. vii. 129.

† Annales de Chimie, xlv. 206.

‡ Nicholson's Journal, xxv. 279.

§ Thomson's Annals, ii. 469.

ter, and precipitated by nitrate of lead. The white precipitate, thus obtained, was mixed with water, and decomposed by sulphuretted hydrogen gas. The liquid being evaporated, yielded crystals of *boletic acid*.

The crystals, when purified by solution in alcohol, and re-crystallization, are white, and have the shape of irregular four sided prisms. They require 180 parts of water at 68° to dissolve them, and 45 parts of alcohol. The aqueous solution reddens vegetable blues, precipitates nitrate of lead; and throws down the peroxide, but not the protoxide of iron, from its solutions. Nitrates of silver and mercury afford with it a white precipitate.

With the alkalis and earths, it unites, and forms a class of salts, which may be called *boletates*.

ART. 12.—*New Acid discovered by Braconnot.*

A new acid has been discovered, by Braconnot, in vegetable substances,* which have undergone the acetous fermentation. He first procured it from rice, which had been left, mixed with water, at a gentle heat, till it had become sour. When drained in a woollen bag, a liquid passed through, which gave acetous acid by distillation. Continuing the evaporation, almost to dryness, a gummy substance was left, having a decidedly acid taste. This was digested in alcohol, and the solution, evaporated to the consistence of syrup, became a granular crystalline mass with a strongly acid taste. It still, however, contained a salt with base of lime. The excess of acid was, therefore, neutralized by oxide of zinc; the salt obtained was decomposed by barytes; and the barytes precipitated by sulphuric acid. The liquor, being now carefully evaporated to a syrup, left an uncrystallizable, almost colourless, acid, nearly as strong to the taste as the oxalic.

With potash and soda, this acid gave deliquescent salts, soluble in alcohol; and, with ammonia, a crystallizable salt. It formed, with lime, a salt, which required 21 times its weight of water for solution; with strontites, a salt soluble in 8 parts of water; with barytes a gummy substance; and, with magnesia, small granular crystals, which were not soluble in less than 25 parts of water.

SECTION VI.

Fixed Oils.

1. THESE oils are obtained, by pressure, from certain vegetables; as the olive, the almond, linseed, poppy-seed, rape-seed, &c.

2. As thus obtained they are generally found combined with mucilage, to the spontaneous decomposition of which is chiefly owing the change that oils undergo by keeping, called *rancidity*.

* 86 Ann. de Chim. 84.

3. They are usually coloured, but may be deprived of colour by digestion with charcoal.

4. Their specific gravity is commonly between that of alcohol and water. Hence they sink in the former, and float on the surface of the latter fluid. They cannot, by strong agitation, be brought to combine with water, but always separate on standing. When the seeds, however, which contain them, are rubbed with water, especially if a little sugar be added, an imperfect solution is obtained called an *emulsion*. On adding an acid to this, the oil is detached, and floats on the surface.

5. The expressed oils of linseed and of olives, Mr. Brande finds, are very sparingly soluble in alcohol of specific gravity .820. Four ounce measures of alcohol dissolve a drachm of linseed oil. Castor oil is perfectly soluble in every proportion in alcohol of .820, but not in weaker alcohol.*

6. Four ounce measures of sulphuric ether of specific gravity .7563 are capable of dissolving a fluid ounce and quarter of oil of almonds; a fluid ounce and half of olive oil; and almost any proportion of castor oil. (Brande.)

7. Some of the fixed oils congeal, or become solid, by a very moderate reduction of their temperature; and others, as palm oil, are permanently thick, or form a soft solid like butter, at the temperature of the atmosphere.

8. They unite with alkalis, and form soap. The soap, however, which is commonly manufactured in this country, is made by combining the fixed alkalis with tallow. Of the processes followed in the preparation of soap, both from vegetable and animal oils, an excellent description is given in Messrs. Aikins' Chemical Dictionary. A memoir of Chevreul on the Combination of Alkalis with Fat may, also, be consulted in the 88th volume of the *Annales de Chimie*.

Soap is readily soluble in water. The solution is decomposed by acids, and by neutral salts with earthy bases. Hence hard waters, which contain earthy salts, curdle soap; their acid uniting with the alkali of the soap, and setting the oil at liberty. When a strong solution of soap is mixed with one of a metallic salt, a substance is formed termed a metallic soap. The alkali unites with the acid of the salt, and the oil with the metallic oxide.

9. Fixed oils dissolve sulphur, and form a kind of balsam. They act also on phosphorus.

10. Their properties are changed by boiling with metallic oxides, those of lead for example. The mucilage unites with the oxide, which probably gives up a portion of its oxygen to the oil, and the oil is rendered drying, and fit for the use of the painter. If the oxide be added in larger proportion, the mass, when cold, composes a plaster.

11. Fixed oils, when distilled with a gentle heat, yield olefiant and carburetted hydrogen gases. A portion of the oil passes over, also, without decomposition. Hence they cannot be considered as

* Phil. Trans. 1811, p. 265.

absolutely fixed, but have received this name chiefly from a comparison with the essential or volatile oils. By repeated distillations the whole of any fixed oil may finally be changed into gaseous matter.

12. Fixed oils are extremely combustible; and when burned in an apparatus, adapted for collecting the products of their combustion, they afford carbonic acid and water. It may be inferred, therefore, that they are composed of carbon and hydrogen, the proportions of which, according to the experiments of Lavoisier, are 79 of the former and 21 of the latter. From this statement, however, oxygen is excluded, which it is probable all fixed oils contain. Its presence indeed is almost demonstrated by Sir H. Davy's experiments. When a globule of potassium, he observes, is introduced into any of the fixed oils made hot, the first product is pure hydrogen, which arises from the decomposition of the water absorbed by the crust of potash during exposure to the atmosphere. If the globule be previously freed from this crust, carburetted hydrogen is disengaged, coaly matter deposited, and a soap is formed. To generate the alkali, however, which this soap contains, oxygen must necessarily have been supplied by the decomposition of the oil. Sir H. Davy has also found, in the products of their destructive distillation by heat, a proportion of water, to the production of which oxygen is essential.* But decisive proof of the presence of oxygen in oil has lately been supplied by Gay Lussac and Thenard's analysis of olive oil, which they find to be composed of

Carbon	. .	77.213
Oxygen	. .	9.427
Hydrogen	. .	13.360
		<hr/>
		100.

The analysis may also be stated as follows :

Carbon	. . . . .	77.213
Oxygen and hydrogen in the	} 10.712	
proportions to form water		
Excess of hydrogen	. . .	12.075
		<hr/>
		100.

13. Nitric acts with great energy on the fixed oils. In a small proportion, its chief effect is to render them thicker. When distilled together with a larger proportion of acid the oil is decomposed, and nitrous gas disengaged; oxalic acid remaining in the retort. Red and smoking nitric acid, when suddenly mixed with a fixed oil, especially with the addition of a little sulphuric acid, occasions a violent combustion. Oxymuriatic acid gas, pass-

* Phil. Trans. 1808.

ed through them, thickens them, and renders them tenacious like wax.

14. The fixed oils have a singular property, which has led sometimes to serious accidents. When mixed with lamp black, or with any light kind of charcoal, and even with several vegetable substances, as cotton, wool, or flax, the mixture, after some time, heats spontaneously, and at length bursts into flame. This combustion has sometimes been observed to take place in the waste cotton, employed to wipe the oil from machinery; and has probably occasioned many of the dreadful fires, which have happened in cotton-mills, and for which no adequate cause could be assigned.*

SECTION VII.

Volatile or Essential Oils.

WITH the exception of the oil from the rinds of the lemon and the orange, which are obtained by expression, the essential oils are procured, by distilling the vegetables that afford them, with a proper proportion of water. The oil either sinks to the bottom, or swims on the surface of the water, according to its specific gravity; but if the distilled water be long kept, Bucholz finds that the oil is converted into mucilage.

1. These oils have a penetrating smell, and an acrid taste.
2. They are volatilized by a gentle heat. Hence the spot, which they leave on paper, may be removed by holding it at a small distance from the fire; but the stains from expressed oils are permanent.
3. They can, with difficulty, be brought to unite with alkalis.
4. They are soluble in alcohol.
5. They do not unite with water. With the intervention of a little sugar, however, they are combinable, in small proportion, with water.
6. When nitric acid is poured upon these oils, especially if it has been previously mixed with one fifth or one sixth of sulphuric acid, the mixture bursts into a violent flame. This experiment requires caution, as the inflamed oil is apt to be scattered about.
7. Several of them detonate, when rubbed with hyper-oxygenized muriate of potash, and take fire when poured into oxymuriatic acid gas.
8. Essential oils are thickened by long exposure to air. This is owing, as Dr. Priestley first proved, to their absorbing oxygen, a fact which accounts, in some degree, for the injurious effects of fresh painted rooms.
9. Potassium decomposes the volatile oils when heated. Al-

* For a variety of cases of spontaneous combustion, both in the animal and vegetable kingdom, see the *Emporium of Arts and Sciences*, vol. 1. C.

kali is formed; a small quantity of gas is evolved; and charcoal is deposited.

CAMPBOR resembles the essential oils in many properties, but is not inflamed by nitric acid, which converts it into an acid, distinguished by peculiar properties,* and termed the *camphoric acid*.

For this purpose, camphor is repeatedly distilled with four times its weight of nitric acid, till about 20 parts of acid have been employed. At each operation, the portion of camphor, which sublimes and escapes decomposition, is to be returned into the retort. The acid is susceptible of crystallization; the crystals effloresce in the air, and are soluble in 100 times their weight of cold, or in 11 times their weight of boiling water; they are combustible; and burn with a dense, aromatic smoke; they melt and sublime with a gentle heat, and dissolve in the mineral acids. They dissolve also in about six times their weight of cold alcohol, or to any amount in boiling alcohol; and are not precipitated by water. With alkalis and earths they compose a class of salts called camphorates. Fifty grains of the acid are saturated by 28 of carbonate of lime, ≈ 15.7 pure lime.

A singular substance, very much resembling camphor in its sensible and chemical properties, may be obtained by passing muriatic acid gas through essential oil of turpentine, which absorbs about a third of its weight. The oil of turpentine becomes thick, from an abundance of a white crystalline substance which forms in it. This may be separated by draining off the liquid; and is found rather to exceed the weight of the essential oil submitted to experiment.† It is white, crystalline, granular, volatile in a moderate heat, and has very much the smell of camphor. By exposure to the air, it soon loses its property of reddening vegetable blue colours. As to the theory of its production, Thenard is of opinion that no decomposition of the oil of turpentine takes place; but that the muriatic acid unites to it entire. Ordinary camphor of commerce, he supposes from analogy, to be a compound of an essential oil and a vegetable acid.

SECTION VIII.

Resins.

RESINS are the inspissated juices of certain plants, and are generally obtained by wounding their bark. Copal, or lac, may be taken as an example. Dragon's blood, guaiacum, sandarach, labdanum, common resin, and turpentine, are also varieties of this substance.

1. They have generally a yellow colour, and are imperfectly transparent. In specific gravity they exceed water.

* Bucholz, 84, Ann. de Chim. 301.

† Thenard, Mémoires d'Arcueil, ii.

2. They are dry, brittle, and extremely inflammable.

3. They dissolve in alcohol, ether, and essential oils; but not at all in water, which even precipitates them from the foregoing solvents.

4. Both acids and alkalis act on them; the pure alkalis most remarkably. The alkaline solution is clear, and may be diluted with water without decomposition; but acids immediately precipitate the resin. By mixing it with a solution of a metallic salt, the oxide is precipitated in combination with resin.

5. By long continued and repeated digestion with nitric acid, the resins afford a deep yellow solution, which has the property of precipitating animal gelatine, and agrees, therefore, with tannin. No oxalic acid is obtained by this process, a circumstance which distinguishes the resins from all other vegetable substances.

6. Concentrated sulphuric acid dissolves the powdered resins. If the solution be digested in a moderate heat, sulphurous acid is first evolved; in a few days this ceases; and a black porous coal remains, equal to between a fifth and a third the weight of the resin which has been employed; whereas, by incineration in close vessels, scarcely $\frac{1}{100}$ th part their weight of coal is obtained.

Acetic acid dissolves resins, which are precipitated from it by the addition of water.

7. Resins are the basis of varnishes, and are much used in medicine.

Balsams are liquid resins holding in combination a proportion of benzoic acid.*

Gum-Resins, along with resin, have an admixture of extractive matter. They dissolve partly in water, and partly in alcohol. They are almost solely used in medicine. Assafoetida, gum-ammoniac, aloes, gamboge, myrrh, opium, &c., are varieties of gum-resin.†

Guaiacum was observed by Mr. Hatchett to differ from other resins in giving oxalic acid by the action of nitric acid, and very little tannin. In other respects, also, it has been since shown, by Mr. Brande, to possess properties that do not agree with those of resins in general.‡

Amber is a resin possessed of peculiar properties. By distillation it yields a distinct acid, called the *succinic*.—To prepare this acid, let a glass retort be half filled with powdered amber, and the remainder with fine dry sand. Lute a receiver, and apply a gentle heat. A portion of water first comes over, which is succeeded by a weak acetic acid. The succinic acid then sublimes; but is contaminated by a mixture of oil. It may be purified by solution and crystallization; and it then forms transparent white shining crystals, having the form of triangular prisms. They are so-

* See 69 Ann. de Chim. 293.

† The reader, who may wish for further information respecting the gum-resins, may consult Braconnot's Memoir in the 28th vol. of Nicholson's Journal; and Pelletier's in the 80th vol. of Annales de Chimie.

‡ Philosophical Transactions, 1806.

luble in 24 times their weight of water, and in boiling alcohol. The solution reddens the blue colour of turnsole, but not that of violets, and has an acid taste. It combines with alkalis, &c., and forms succinates, the most important of which is the succinate of ammonia. This salt decomposes all the solutions of iron; and affords an insoluble precipitate, composed of succinate of iron. Hence it is highly useful in the analysis of mineral waters.

SECTION IX.

Farina, Starch, or Fecula.

STARCH may be obtained from the flour of most varieties of grain, from the roots of the potato, and from almost every part of vegetables, by a very simple process. The grain in the state of fine powder, or the root well rasped, is to be washed with a quantity of *cold* water which becomes turbid, and if the fecula is white, milky. The fecula, however, is not dissolved, but merely suspended mechanically; and, after separating the fibrous and grosser parts by a sieve, it subsides to the bottom of the vessel. The liquid, which contains the soluble parts of the vegetable, is to be decanted, and the farina to be washed by repeated affusions of cold water. It may, afterwards, be dried in a gentle heat.

From the analysis of Dr. Pearson,* we learn that 100 parts of the fresh potato root, deprived of skin, afford

Water	. . .	68 to 72
Meal	. . .	32 to 28
		<hr/>
		100 100

The meal is composed of three distinct substances; *viz.*

Fecula	. . . . .	15 to 17
Fibrous matter	. . .	8 to 9
Extract or mucilage	. . .	5 to 6
		<hr/>
		28 32

Some useful information respecting the quantity of fecula in different varieties of the potato, and the methods of separating it, has been given by Mr. Skrimshire in the 21st volume of Nicholson's Journal.

Common starch may be taken as an example of fecula. It will be found to have the following qualities:

1. It is not soluble in water, unless when heated to 160°; and if

* Repertory of Arts, iii. 383. The analysis of several varieties of the potato by Lampadius may be seen in Thomson's Annals, v. 39.

the temperature be raised to 180° , the solution coagulates into a thick tenacious transparent jelly. By evaporation at a low heat, this jelly shrinks, and at length forms a transparent brittle substance closely resembling gum. The solution of starch in a large quantity of water is precipitated by Goulard's extract of lead; but not by any other metallic salt.

2. Farina is insoluble in alcohol, and in ether.

3. Pure liquid alkalis act on starch, and convert it into a transparent jelly. The compound is soluble in alcohol.

4. Sulphuric acid dissolves it slowly; sulphurous acid is evolved; and so much charcoal is disengaged, that the vessel may be inverted, without spilling its contents.

5. Nitric acid, at the temperature of the atmosphere, acts on starch, and dissolves it; but no oxalic acid appears subsequently, unless heat be applied. Hot nitric acid is decomposed by starch, and oxalic acid is generated.

6. Starch, as it exists in grain, is spontaneously convertible into sugar. On this property is founded the process of malting.

Another method of converting starch into sugar was discovered, three or four years ago, by M. Kirchoff of St. Petersburg. The change is effected by the action of sulphuric acid, which is boiled, for many hours, with starch and water. The process has been successfully repeated by several persons, and among the rest by M. Vogel,* and by Dr. Tuthill of London.† The latter digested a pound and a half of potato starch (obtained from $8\frac{1}{2}$ pound of potatoes) six pints of distilled water, and a quarter of an ounce by weight of sulphuric acid, in an earthen vessel, at a boiling heat; the mixture being frequently stirred, and kept at an uniform degree of fluidity by the supply of fresh water. In 24 hours there was an evident sweetness, which increased till the close of the process; at the end of 34 hours, an ounce of finely powdered charcoal was added, and the boiling kept up two hours longer. The acid was then carefully saturated by recently burned lime; and the boiling continued for half an hour, after which the liquor was passed through calico, and the substance, remaining on the drainer, washed repeatedly with warm water. This, when dry, weighed seven eighths of an ounce, and consisted of charcoal and sulphate of lime. The clear liquor, being evaporated to the consistence of syrup, and set aside, was in eight days converted into a crystalline mass, resembling common brown sugar with a mixture of treacle. The saccharine matter, which Dr. Tuthill judged to be intermediate between cane sugar and grape sugar, weighed one pound and a quarter. By fermenting one pound of this substance in the usual manner, and distilling and rectifying the product, fourteen drachms by measure of proof spirit were obtained.

The theory of this process is not clearly understood. It has been ascertained, by Vogel and Bouillon la Grange, that the sulphuric acid is not decomposed; and its agency (which appears essential to the change) can only, therefore, consist in producing a slight al-

* Ann. de Chim. 1. 82.

† Nich. Journ. vol. 33.

teration in the arrangement, and probably in the proportion, of the elements of the starch.

7. Starch is said by Dr. Thomson to be capable of entering into chemical union with tan.* Of the existence of such a combination, however, Dr. Bostock has found reason to doubt.†

8. Starch has been analyzed by Gay Lussac and Thenard, and by Berzelius, and the near coincidence of their results, obtained by different methods, is a strong presumption in favour of their accuracy. It consists,

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac, of	43.55	49.68	6.77
———— Berzelius, of	43.481	48.455	7.064

9. When strongly heated, starch becomes first yellow, and afterwards a reddish brown; it softens, swells, and exhales a penetrating smell. If the process be stopped, a substance is the result, which is employed by calico-printers under the name of *British gum*. This substance, however, Vauquelin finds, is not a true mucilage; for with nitric acid it gives only oxalic acid, and no mucous acid.‡

10. When starch is distilled in close vessels, it yields an acid, which has been called the pyromucous, but which, in fact, is nothing more than vinegar, with an admixture of empyreumatic oil.

11. When starch and iodine are triturated together, both in a dry state, the starch assumes a violet tint, which passes to blue or to black, according to the proportions that are employed. The colour of this *ioduret of starch* is reddish, if the starch be in excess; a beautiful blue, when the two bodies are in due proportion; and black, when the iodine prevails.§ This compound is soluble in diluted sulphuric acid, and the liquor is of a fine blue colour. Concentrated sulphuric acid, also, dissolves it, and the solution is brown, but passes to a beautiful blue on the addition of water. There is also a *sub-ioduret* of starch, which is white, but becomes blue by the action of almost any acid.||

SECTION X.

Gluten.

GLUTEN may be obtained from wheat-flour, by a very simple process. The flour is first to be formed, by the gradual addition of a small quantity of water, into a soft and ductile paste. This is to be

* Nicholson's Journal, 8vo. ix. 74.

† Ditto, xviii. 33.

‡ 80 Ann. de Chim. 317. See also Thomson's Annals, v. xxxviii. and Ann. de Chim. xc. 29.

§ A single grain of iodine will sensibly colour 3 or 4 oz. of starch, by long continued trituration. C.

|| Colin and Gaultier de Claubry. 90 Ann. de Chim. 100.

washed by a very slender stream of water, and, at the same time, to be constantly worked between the fingers. The water carries off the starch, and for some time is rendered milky. When it passes off transparent, the washing may be discontinued; and the pure gluten remains in the hands.

The following are the properties of gluten :

1. It is of a grey colour, and has so much elasticity, that, when drawn out, it recovers itself like elastic gum. It has scarcely any taste, and does not melt or lose its tenacity in the mouth.

2. When exposed to a gentle heat, it dries very slowly, and becomes hard, brittle, semi-transparent, of a dark brown colour, and somewhat like glue. When broken it has the fracture of glass. In this state it is insoluble in water.

3. When kept moist, it ferments and undergoes a sort of putrefaction, emitting a very offensive odour. At the same time a portion of acid is developed, which is perceivable by its smell, and which considerably retards the putrefaction of the gluten. In this circumstance, chiefly, it differs from animal gluten.

4. When suddenly heated, it first shrinks; then melts, blackens, and emits a smell like that of burning horn. By distillation in close vessels, it yields a portion of water impregnated with carbonate of ammonia; a considerable quantity of brown fetid thick oil; solid sub-carbonate of ammonia; and carburetted hydrogen gas. These products resemble, very closely, those of animal substances.

5. It is generally described to be insoluble in water, in alcohol, and in ether. After fermentation, it is partially soluble in alcohol, and the solution may be applied to the purposes of varnish. From the recent experiments of Dr. Bostock, gluten appears, however, by long digestion, to be partly soluble in water. The solution is precipitated by acetate and super-acetate of lead, by muriate of tin, and by other re-agents.*

6. All acids dissolve it, and alkalis precipitate it, but considerably changed, and deprived of its elasticity. It undergoes a similar change when dissolved in pure alkalis, and precipitated by acids.

7. It exists most abundantly in wheat-flour, of which it constitutes about one fourth, and is essential to its soundness; but it is found, also, in various vegetable juices.†

SECTION XI.

Caoutchouc, or Elastic Gum.

CAOUTCHOUC is chiefly the product of two trees, which are the growth of Brazil; the *Hoevea Caoutchouc* and *Jatropha Elastica*. When the bark of these trees is wounded, a white milky juice flows

* Nicholson's Journal, xviii. 34.

† See Proust on the Green Fecula of Vegetables, Nicholson's Journal, 8vo. iv. 273.

out, which speedily concretes in the air into an elastic substance; and, when the juice is applied in successive coats, upon clay moulds, it forms the globular bottles, which are brought to this country. By an immediate and careful seclusion from air, the juice may be preserved some time from concreting, and has occasionally been brought to Europe in a liquid state. But even, when thus preserved, a part of it, in the course of time, passes to a solid form. If it could easily be imported in a fluid state, it would be invaluable, from its application to the rendering cloth, leather, and other substances impervious to water.

1. Caoutchouc is inflammable, burning with a bright flame in atmospheric air, and with still greater brilliancy in oxygen gas, or in oxymuriatic gas.

2. It is insoluble in water and in alcohol. If long slips of caoutchouc, however, are tied spirally round a glass or metal rod, and boiled for an hour or two, the edges cohere, and a hollow tube is formed.

3. Caoutchouc is soluble in ether; not, however, in the ordinary state of this fluid as it is found in the shops. To render ether a fit solvent of this substance, it should be purified by washing it with water, in the manner to be hereafter described. The solution may be applied to the purpose of forming tubes or vessels of any shape. The principal difficulty in using it arises from the great volatility of the ether, in consequence of which the brushes, or other instruments, by which it is applied, are soon clogged up, and rendered useless.

4. Caoutchouc is soluble in volatile oils; but when they have evaporated, they leave it in a glutinous state, and deprived of much of its elasticity. Petroleum dissolves it, and, when evaporated, leaves it unchanged. One of the most useful solvents, however, of caoutchouc, appears to be the *cajeput oil*, a substance lately admitted into the Pharmacopœia of the London College of Physicians. A thick and glutinous solution is obtained, from which alcohol detaches the essential oil. The caoutchouc floats on the surface in a semi-fluid state, but soon hardens, and regains its elastic powers on exposure to the atmosphere. To this process, the chief objection is the expensiveness of the solvent.*

5. Caoutchouc is acted on by alkalis; and when steeped in them for some time, loses its elasticity.

6. The sulphuric acid is decomposed by it; sulphurous acid is disengaged; and charcoal remains. Nitric acid acts on it with the assistance of heat, nitrous gas is formed; and oxalic acid crystallizes from the residuum.

7. When distilled it gives ammonia, and hence may be inferred to contain azote. A large quantity of olefiant gas and of very dense carburetted hydrogen, which burns with a remarkably bright flame, are at the same time evolved.

* The solutions of caoutchouc in cajeput oil which I have tried, have all possessed the same clamminess and disposition to adhere, that is perceptible in the other volatile oils. C.

SECTION XII.

The Woody Fibre.

AFTER removing all the soluble parts of wood, first by long boiling in water, and then by digestion in alcohol, a fibrous substance is obtained, to which, by some chemists, the name of *Lignin* has been given. From whatever variety of wood it may have been procured, its properties appear to be uniformly the same.

1. It is perfectly destitute of taste, smell, and colour. In specific gravity, it is generally inferior to water.

2. It is insoluble in water at all temperatures.

3. The pure fixed alkalis act on the woody fibre, and render it soft, and of a brown colour.

4. Concentrated sulphuric acid immediately blackens it, and, after sufficient digestion, converts it into charcoal.

5. Nitric acid decomposes it with the assistance of heat; and oxalic, malic, and acetic acids, are formed.

6. When exposed to heat, it affords an acid called the *pyroligneous*, which has been lately proved to be identical with the acetic. This acid holds in combination a quantity of essential oil, from which it can with great difficulty be freed, and also, a small proportion of ammonia. From the last mentioned product, it follows that the woody fibre must contain nitrogen. The charcoal, which remains in the retort, is greatly superior to that procured by the ordinary process; and hence distillation in iron cylinders has been, for some time past, practised as the best method of obtaining charcoal for the manufacture of gunpowder.

7. The woody fibre, by exposure to the atmosphere in a perfectly dry state, does not undergo any change. The action of the air upon it, however, when moistened, converts it, through various shades of colour, to a black mould. If the process be carried on in a confined portion of oxygen gas, carbonic acid is formed. When excluded from the air, even moist wood shows very little tendency to decomposition.

Gay Lussac and Thenard have analyzed, by their new process, the wood of oak and beech. The wood was taken from the most compact part of a log, reduced to fine powder by a file, then sifted and washed in succession with water and alcohol; and finally dried, before its admixture with oxymuriate of potash.

	Carbon.	Oxygen.	Hydrogen.
100 parts of Oak contain	52.53	41.78	5.69
————— Beech ———	51.45	42.73	5.82

In both the oxygen and hydrogen are in the proportions required to form water, and there is no excess of oxygen to acidify any part of the carbon.

SECTION XIII.

Colouring Matter.

I. THE colouring matter of vegetables presents a considerable variety in its relation to chemical agents, depending on the diversity of the basis, or sub-stratum, in which it resides. Chaptal has arranged the varieties of the colouring principle under four heads. 1st, As it is attached to extractive matter: 2d, As it resides in gum; in both which cases it is soluble in water: 3d, As it exists in farina, or fecula; and in this instance it dissolves most readily in sulphuric acid: 4th, The colouring principle is occasionally inherent in resin, and then it requires alcohol, an oil, or an alkali, for solution.

II. The extraction of colouring matter from the various substances that afford it, and its fixation on wool, silk, or cotton, constitute the art of DYEING; the details of which would be foreign to the purpose of this work. In this place I shall state only a few general principles; and refer for more minute information to a paper by Mr. Henry in the third volume of the *Manchester Memoirs*; to the works of Berthollet and Bancroft; and to a memoir of Thenard and Roard, in the 74th volume of *Annales de Chimie*.

III. Of the various colouring substances, used in the art of dyeing, some may be permanently attached to the dyed fabric, and fully communicate their colour to it, without the intervention of any other substance; while others leave a mere stain, removable by washing with water. The latter class, however, may be durably attached by the mediation of what was formerly called a *mordant*, but has since been more properly termed, by Mr. Henry, a *basis*. The colours which are of themselves permanent, have been termed, by Dr. Bancroft, *substantive* colours; while those that require a basis, have been denominated *adjective* colours.

IV. The most important bases, by the mediation of which colouring matter is united with wool or cotton, are alumine, the oxide of iron, and the oxide of tin. Alumine and oxide of iron are applied in combination with sulphuric, or acetic acids; and the oxide of tin, united with nitro-muriatic, muriatic, acetic, or tartaric acids. In dyeing, the most common method is to pass the substance to be dyed through a decoction of the colouring matter, and afterwards through a solution of the basis. The colouring principle thus becomes permanently fixed on the cloth, sometimes considerably changed by its union with the basis. In calico-printing, the basis, thickened with gum or flour-paste, is applied to the cloth by wooden blocks, or copper cylinders. The cloth is then dried, and passed through a decoction of the colouring ingredient, which adheres only to that part of the cloth where the basis has been applied. From

the rest of the cloth it may be removed by simple washing with water.

V. The variety of colours, observed in dyed substances, are reducible to four simple ones, *viz.* blue, red, yellow, and black.

1. Indigo is the only substance used in dyeing blue, which it does without the intervention of a basis. It is the production, chiefly, of several varieties of the plant called *Indigofera*, a native of America and of the East and West Indies. The plant, after being cut a little while before the time of flowering, is steeped with water in large vats, where it undergoes fermentation. During this process, a fine pulverulent pulp separates, which is at first green, but becomes blue by exposure to the atmosphere. The operations, by which indigo is separated and collected, are rather complicated, and cannot be described without considerable minuteness. A good account of them may be seen in Messrs. Aikins' Chemical Dictionary.

Indigo has been supposed to be a variety of fecula, but it differs from that principle in several important particulars. It is volatile, and may be sublimed at a temperature a little below that, which is required for its decomposition.* Water, by being boiled on it, dissolves only about a ninth or a twelfth the weight of the indigo. The colouring matter, however, remains untouched; and the solution, which appears to consist chiefly of extract, has a reddish brown hue. It is insoluble in alcohol, ether, and in fixed and volatile oils. Its appropriate solvent appears to be sulphuric acid. When thus dissolved, it is sometimes applied directly, in a diluted state, to the fabric, and dyes what is termed a Saxon blue. But, by the abstraction of part of its oxygen, indigo becomes soluble in water; and its colour changes from blue to green. It recovers the former colour, however, on exposure to the air, by again absorbing oxygen. Its de-oxydizement is effected by allowing it to ferment, along with bran, or other vegetable matter; or by decomposing, in contact with it, the green sulphate of iron. Substances dyed by indigo, thus deprived of oxygen, are green when taken out of the vat, and acquire a blue colour by exposure to the atmosphere. By this revival, the indigo again becomes insoluble, and fitted, therefore, for affording a permanent dye.

There appears, however, to be a certain stage of oxygenizement in indigo, which is essential to the existence of its blue colour, and that any proportion, either exceeding or falling short of this, is equally destructive of its colour. Thus diluted nitric acid dissolves indigo, but the solution is yellow, and the indigo is decomposed. A thin layer of resinous matter appears, floating in the solution. If this be removed, and the solution, after evaporation to the consistence of honey, be re-dissolved in hot water, filtered, and mixed with a solution of potash, yellow crystals appear, which consist of the bitter principle united with potash. These crystals, being wrapped in paper and struck with a hammer, detonate and emit a purple light. If to a drachm or two of finely powdered indigo, we add an ounce measure of fuming nitrous acid, the mixture presently becomes

* Gay Lussac, 74 Ann. de Chim. 191.

hot, nitrous gas is evolved, a stream of sparks arises from it, and finally the whole bursts into flame.

Muriatic acid has no action on indigo, but oxymuriatic acid destroys its colour. Hence a solution of indigo in sulphuric acid has been recommended for measuring the strength of watery solutions of oxymuriatic acid gas; in order to regulate their application to the process of bleaching.

Alkalis do not act on indigo, unless it be previously reduced to that state of partial dis-oxygenation at which its green colour reappears. And the solution exists no longer, if oxygen be absorbed, and the blue colour restored.

The analysis of indigo by destructive distillation affords but little information respecting its nature. The products, usually obtained from vegetable substances, are evolved, along with a portion of ammonia.

2. The substances, chiefly employed for affording red colours, are cochineal (an insect which has been supposed to derive colour from its food, the leaves of the *cactus opuntia*, L.,) archil, madder, brazil-wood, and saf-flower. The first four are soluble in water; the last not without the intervention of an alkali. They are all adjective colours. Cochineal, though its colour is naturally crimson, is used for dyeing scarlet; and to evolve the scarlet hue, it is necessary to employ the supertartrate of potash. The basis, by which it is attached to cloth, is the oxide of tin. This may be exhibited experimentally. A decoction of cochineal will leave only a fugitive stain on a piece of cloth; but if, in the decoction, some supertartrate of potash has been dissolved, and a portion of nitro-muriate of tin afterwards been added, it will impart a permanent scarlet colour.

3. The yellow dyes are wild American hiccory, sumach, turmeric, fustick, and quercitron bark; which afford various colours, accordingly as they are combined with the cloth, by the intervention of alumine, or of oxide of iron, or tin. Thus, with the aluminous base, the quercitron bark yields a bright yellow; with oxide of tin, all the shades, from pale lemon colour to a deep orange; and with oxide of iron, a drab colour. With the addition of indigo, it gives a green.

4. A combination of red oxide of iron, with the gallic acid and tan, is the principal black colour, which has therefore the same basis as common writing-ink. In calico-printing, white spots, or figures, on a black ground, are produced, by previously printing on the cloth a protecting paste of citric acid, thickened with gum or flour. The parts to which this paste is applied do not receive the black dye, but remain perfectly white.

VI. The colouring matter of vegetables, besides being capable of fixation on cloth, may be obtained in a dry form, in combination with a base only. Thus if to a decoction, or infusion, of madder in water, a solution of sulphate of alumine be added, the colouring matter is precipitated in combination with the alumine, forming what is termed a *lake*. For obtaining this, the following process is given by Sir H. Englefield. Put two ounces of Dutch crop-madder into a calico bag, capable of holding three or four times that quan-

tity. Pour on it a pint of distilled water, and triturate, in a mortar, as much as can be done, without destroying the bag. The water becomes loaded with colouring matter, and is opaque and muddy. Pour off this portion, and repeat the operation till no more colour is obtained, which will generally happen after the fifth or sixth affusion. Pour these several washings into an earthen or well-tinned copper pan; and apply heat till the liquor boils. Let it then be poured into a basin; and one ounce of alum, dissolved in a pint of water, be added, and mixed by stirring. Add an ounce and a half of saturated solution of sub-carbonate of potash; a violent effervescence will ensue, and the colouring matter will be precipitated. Stir the mixture till cold, and wash repeatedly with boiling water. About half an ounce of lake will be obtained, containing two fifths its weight of alumine.

Other lakes may be obtained, of different colours, by the substitution of different dyeing woods; and from the infusion of cochineal, the beautiful pigment called Carmine is precipitated by means of a solution of tin.

SECTION XIV.

Tan, Tannin, or the Tanning Principle.

TAN exists abundantly in the bark of the oak, the willow, &c., and in the gall-nut. The interior bark next to the wood, contains the largest proportion; the middle and coloured part, the next; and in this it is accompanied with more extract. The epidermis affords very little.

I. Tan may be obtained by any of the following processes; but, according to Sir H. Davy, it is difficult to procure it in a state of perfect purity. Indeed it has been doubted by several chemists, and especially by Chevreul and Pelletier,* whether tan has ever been obtained sufficiently pure, to entitle it to be considered as a distinct vegetable principle.

1. Into a strong infusion of nut-galls, pour the muriate of tin, till the yellowish precipitate, which at first falls down abundantly, ceases to appear. Wash the precipitate with a small quantity of distilled water, and afterwards add a sufficient quantity of warm water for its solution. From this solution, the oxide of tin is precipitated by a stream of sulphuretted hydrogen gas; and the tannin, which remains dissolved, may be procured by evaporation. There is reason, however, Dr. Bostock informs me, to believe that, by this process, tan is so much altered as to be scarcely entitled to retain the appellation; and the same remark applies, though perhaps not in an equal degree, to the following operations.

2. Into a saturated infusion of galls, pour a saturated solution of carbonate of potash. The yellowish white precipitate, after being washed with a small quantity of water, affords the tan. When

* See 87 Ann. de Chim. 103.

thus prepared, Sir H. Davy observes that tan is not perfectly pure, but contains a minute proportion of gallic acid, and alkali.

3. Into a similar infusion, pour sulphuric or muriatic acid. A precipitate will form, which must be re-dissolved in water, and the excess of sulphuric acid saturated by carbonate of potash. When a farther addition is made of the alkali, the tan falls down, and must be purified by washing with a small quantity of water.

It has been discovered by Sir H. Davy, that the *terra japonica*, or catechu (which is to be met with under this name in the druggists' shops,) is composed of about one half tan, the remainder being a mixture of extract, mucilage, and earthy impurities. The purest kind of tan, we learn from the same authority, may be procured by the action of a small quantity of cold water on bruised grape seeds. A substance lately introduced into medicine under the name of Extract of Rhatania, Dr. Bostock is of opinion, consists of tan in a purer form than catechu.

Tan procured from galls, has been analyzed by Berzelius, and found to consist of

Carbon	51.16
Oxygen	44.654
Hydrogen	4.186

100.

II. Tan has the following properties :

1. When evaporated to dryness, it forms a brown friable mass, which has much resemblance in its fracture to aloes, a sharp bitter taste, and is soluble in water, but still more readily in alcohol.

2. From this watery solution all acids precipitate tan.

3. The alkaline carbonates have a similar effect.

4. The watery solution, poured into one of glue (inspissated animal jelly,) converts it immediately into a coagulum, insoluble by boiling water, which has the elastic properties of the gluten of wheat.

The solution of gelatine or jelly, may be prepared, for the purpose of precipitating tan, by dissolving isinglass in water, in the proportion of ten grains to two ounces. The precipitate consists of 54 jelly and 46 tan.* An excess of the solution partly re-dissolves it. It is this property, of forming with gelatine an insoluble compound, not liable to putrefaction, that fits tan for the purpose of converting skins into leather.

Dr. Duncan, jun. who has made numerous experiments on tan, informs me, that the proportion of ingredients in this precipitate varies very considerably, according to the mode in which it is

* From some experiments I have made on this subject, I am disposed to think the precipitate thus produced by gelatin and tannin, used in its soft state, may be usefully employed to cover catheters, bougies, and other elastic tubes, &c. The coating dries readily, and is a firm tenacious covering of eather. I have no doubt it may be equally employed for numerous other purposes, as for making waiters, boxes, &c. &c. C.

effected; and that insolubility in water is by no means one of its constant characters. In ammonia it dissolves readily. Dr. Bostock, also, has found that tan and jelly do not unite in any constant proportion, and that the compound is not, in all cases, insoluble in water.*

In this country a preference is universally given to oak bark for the purpose of tanning, but various other substances afford it, as appears from the following Table, drawn up by Sir H. Davy, from his own experiments.

Table of Numbers, exhibiting the Quantity of Tan afforded by 480 lbs. of different Barks, which express nearly their relative Values :

	<i>lb.</i>
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 ditto	8
White internal cortical layers of Oak Bark	72

The inner cortical layers of all barks Sir H. Davy found to contain the greatest proportion of tan. The quantity, also, is greatest at the time the buds begin to open, and smallest in winter, and after a cold spring.

As a general average, four or five pounds of good oak bark are required to form a pound of leather. The operation is most perfect when performed slowly; for, if too rapidly effected, the outer surface of the skin is covered with a coat of leather, which defends the interior from change.† In general, skins, by being completely tanned, increase in weight about one third, the skin and the leather being each supposed dry.

5. Tan forms, with fecula, or starch, a precipitate which is sparingly soluble in cold water, and very copiously in hot water.

6. With gluten it gives an insoluble precipitate.

* See his paper on the union of Tan and Jelly, Nicholson's Journal, xxiv. 1.

† This observation is highly important, and ought to be attended to by our Tanners; The speed with which hides are now made to undergo the process is such, that many are merely changed into leather, externally, the interior parts being almost entirely raw. We want some regulations in this country on this point, quite as much, or even more, than is found to be necessary in Europe. C.

7. It is precipitated by salts with earthy bases, such as the nitrates of barytes, lime, &c.

8. It is separated also by salts with metallic bases, such as acetate of lead, muriate of tin, muriate of gold, sulphate of iron, tartarized antimony, and muriate of platina.

Green sulphate of iron effects no change in the solution of tan, but the red sulphate occasions a dark bluish precipitate. This precipitate differs from gallate of iron, in being decomposed by acids, the tan being thus separated. An excess of the red sulphate re-dissolves the precipitate, and affords a black or dark blue liquor. By union with tan, the red sulphate is de-oxydized, the salt becoming the green sulphate, and the oxygen passing to the tan. Tan may also be oxygenized, by passing streams of oxymuriatic acid through its solution in water.

Until within the last ten years, tan had been known only as a production of nature; and the processes of chemistry had effected nothing more, than its separation from the various substances, with which it occurs combined. An important discovery, however, has been made by Mr. Hatchett, of the artificial formation of tan, from substances which unquestionably do not contain it, but only furnish its elements. The processes for its factitious production are very numerous; but they are arranged, by their author, under three heads. 1st, The synthesis of tan may be effected by the action of nitric acid on animal or vegetable charcoal; 2dly, By distilling nitric acid from common resin, indigo, dragon's blood, and various other resinous substances; 3dly, By the action of sulphuric acid on common resin, elemi, assafœtida, camphor, &c. Of these various processes, I shall select the most simple, referring to Mr. Hatchett's very interesting paper for a fuller detail of the experiments.*

To 100 grains of powdered charcoal, contained in a matrass, add an ounce of nitric acid (specific gr. 1.4) diluted with two ounces of water; place the vessel in a sand-heat, and continue the digestion till the charcoal appears to be dissolved. A copious discharge of nitrous gas will take place. At the end of the second day, it may be necessary to add another ounce, and sometimes even a third, of nitric acid; and to continue the digestion during five or six days. A reddish brown solution will be obtained, which must be evaporated to dryness in a glass vessel; taking care in the latter part of the process, so to regulate the temperature, that the acid may be expelled, without decomposing the residuum. A brown glossy substance will be obtained, having a resinous fracture, and amounting, in weight, to 116 or 120 grains. This substance has the following properties:

1. It is speedily dissolved by cold water and by alcohol. 2. It has an astringent flavour. 3. Exposed to heat, it smokes but little, swells much, and affords a bulky coal. 4. Its solution in water reddens litmus paper. 5. The solution copiously precipitates metallic salts, especially muriate of tin, acetate of lead, and red sulphate of iron.

* See Philosophical Transactions for 1805 and 1806.

These precipitates, for the most part, are brown, inclining to chocolate, excepting that of tin, which is blackish grey. 6. Gold is precipitated from its solution in a metallic state. 7. The earthy salts are precipitated by it. 8. Gelatine is instantly precipitated from water, in the state of coagulum, insoluble both in cold and in boiling water.

The identity of this substance with tan can, therefore, be scarcely doubted, since the two bodies agree in having the same characteristic properties. The only essential circumstance of discrimination is, that the natural tan is destroyed, while the artificial is produced, by the agency of nitric acid; and that the artificial substance, even when formed, powerfully resists the decomposing action of this acid, which readily destroys natural tan. Even, however, among the different varieties of the natural substance, Mr. Hatchett found essential differences in the facility of destruction by nitric acid. Those of oak bark and catechu are less destructible; and, in general, the varieties of tan seem to be less permanent, in proportion to the quantity of mucilage which they contain. Infusions of factitious tan differ, also, it has been said, from those of the natural kind, in not becoming mouldy by keeping. This character, however, is not confirmed by Dr. Bostock, who has observed the artificial tan to mould.

The artificial substance is a purer variety of tan than the natural one; inasmuch as it is perfectly free from gallic acid, and from extract, both of which are always present in the latter. The properties of the factitious compound vary a little, according to the mode of its preparation, principally in the colour of the precipitates, which it separates from metallic solutions. Those effected by tan, formed by processes of the first class, are always brown, and by the second, pale or deep yellow.

SECTION XV.

Wax.

It was long supposed that bees' wax is merely the dust of the stamina of plants, unchanged by any process in the economy of that animal. This opinion, however, has been lately shown by Huber* to be erroneous; for bees, he has proved, continue to form wax, when supplied with only raw sugar or honey. Little doubt, therefore, can exist that sugar contains all the principles of wax; and that wax is the result of a new combination of those principles, effected by the animal.

At the same time, it is equally well established, that wax is also a product of vegetation. It forms the varnish, which is conspicuous on the upper leaves of many trees, and may be extracted by

* Nicholson's Journal, ix. 182.

first removing, by water and alcohol, from the bruised leaves, every thing that is soluble in those fluids; then macerating the remainder with liquid ammonia, which dissolves the wax, and lets it fall on the subsequent addition of sulphuric acid. Wax exists, also, in the substance called lac, in combination with colouring matter; and is obtained, in considerable quantity, from the berries of the *Myrica Cerifera*, by the simple process of boiling them in water, and bruising them at the same time. The wax melts and rises to the surface in the form of a scum, which concretes on cooling.*

In its ordinary state, wax of every kind has considerable colour and smell. It may be deprived of both, by exposing it, in thin laminæ, to the action of the light and air, or still more speedily by oxy-muriatic acid gas. When bleached, it has the following properties:

1. Its specific gravity is about .960, water being 1.000. When heated, it melts at about 155° Fahrenheit, or at about 7° higher than unbleached wax, and forms a transparent fluid, which gradually acquires consistency, till at length it returns to a solid state. If the heat be raised, it boils; and a portion distils over. By a still higher heat, it is decomposed, and a quantity of olefiant and hydro-carburet gases are developed. The residuum of charcoal bears only a small proportion to the wax which has been decomposed. From the results of its combustion, Lavoisier has inferred that wax consists of

82.28 carbon
17.72 hydrogen
<hr/>
100.

Gay Lussac and Thenard, by an improved method of analysis, have lately shown it to consist of

Carbon	81.784
Oxygen	5.544
Hydrogen	12.672
	<hr/>
	100.

Of the hydrogen, part only is sufficient for the saturation of the oxygen; and besides this, there are 11.916 in excess.

2. Wax is insoluble in water.

3. Boiling alcohol dissolves about one twentieth its weight of wax, four fifths of which separate on cooling; and the remainder is immediately precipitated by the addition of water. Boiling ether dissolves about one twentieth of its weight.

4. Caustic fixed alkalis convert it into a saponaceous compound, soluble in warm water. A heated solution of ammonia dissolves it, and forms a kind of emulsion. On cooling, the wax rises to the surface in flocculi.

* Cadet, Annales de Chimie, xlii.

Myrtle wax, it appears from the experiments of Dr. Bostock, differs from bees' wax in being more fusible, (viz. at 109 Fahrenheit,) and in being soluble, to a greater amount, both in ether and in alcohol. The vegetable wax from Brazil, though it appears, from the experiments of Mr. Brande, to possess the principal characters of common wax, differs from it in some properties, and also from myrtle wax.*

SECTION XVI.

The Bitter Principle.

THE bitter taste of certain vegetables appears to be owing to the presence of a peculiar substance, differing from every other in its chemical properties. It may be extracted from the wood of quassia, the root of gentian, the leaves of the hop, and several other plants, by infusing them for some time in cold water. The characters of this substance have been attentively examined by Dr. Thomson, who enumerates them as follows.†

1. When water, thus impregnated, is evaporated to dryness by a very gentle heat, it leaves a brownish yellow substance, which retains a certain degree of transparency. For some time it continues ductile, but at last becomes brittle. Its taste is intensely bitter.

2. When heated, it softens, swells, and blackens; then burns away without flaming much; and leaves a small quantity of ashes.

3. It is very soluble in water, and in alcohol.

4. It does not alter blue vegetable colours.

5. It is not precipitated by the watery solution of lime, barytes, or strontites; nor is it changed by alkalis.

6. Tincture of galls, infusion of nut-galls, and gallic acid, produce no effect.

7. Of the metallic salts, nitrate of silver and acetate of lead are the only ones that throw it down. The effect of nitrate of silver cannot be ascribed to the presence of muriatic acid, since nitrate of lead produces no change in the solution. The precipitate by acetate of lead is very abundant; and that salt, therefore, affords the best test for discovering the bitter principle, provided no other substance be present, by which, also, it is decomposed.

From recent experiments of Mr. Hatchett, it appears that the bitter principle is formed, along with tan, by the action of nitric acid on indigo.

Another modification of the bitter principle has been extracted, by Mr. Chenevix, from unroasted coffee. The infusion of the berries was mixed with muriate of tin, when a precipitate appeared, which was well washed, then diffused through water, and decom-

* Phil. Trans. 1811, p. 267.

† System of Chemistry, v. 95.

posed by sulphuretted hydrogen gas, which carried down the tin. The remaining liquid, evaporated to dryness, gave a semi-transparent substance not unlike horn. This substance did not attract moisture from the air; was soluble in water and alcohol; and the solution, on adding alkali, became of a garnet red. Solution of iron gave it a fine green tinge, or, when very concentrated, threw down a green precipitate; and muriate of tin occasioned a yellow sediment. It was not affected by solution of animal gelatine.

The bitter principle may, also, be formed by artificial processes, chiefly by the action of nitric acid on animal and vegetable substances. Welther obtained it by digesting silk with nitric acid; and Mr. Hatchett has formed it from the same acid and indigo. Its colour is a deep yellow, and its taste intensely bitter. It is soluble in water and alcohol, and is susceptible of a regular crystallized form. It unites with alkalis and composes crystallizable salts. Its compound of this substance with potash detonates when struck with a hammer, and inflames like gunpowder when thrown on hot charcoal. On the whole it appears better entitled to rank as a distinct principle, than that which is extracted, by infusion, from vegetables.

SECTION XVII.

Narcotic Principle.

OPIMUM, and other vegetable products possessed of a narcotic power, are composed of several of the vegetable principles that have already been enumerated. Besides these, however, they contain a peculiar one, in which the narcotic virtue resides.

I. To obtain the narcotic principle from opium, let water be digested upon it, and the strained solution be evaporated to the consistence of syrup. A gritty precipitate will begin to appear, which is considerably increased by diluting the liquid with water. This consists of three distinct substances, resin, oxygenized extract, and the narcotic principle. Boiling alcohol dissolves the resin and narcotic principle only; and the latter falls down in crystals, as the solution cools; still, however, coloured with resin. The crystals may be purified by repeated solutions and crystallizations.

II. 1. The narcotic principle, thus obtained, is white. It crystallizes in rectangular prisms with rhomboidal bases. It is destitute of taste and smell.

2. It is insoluble in cold water, but is soluble in four hundred parts of boiling water, from which it precipitates again as the solution cools. When thus dissolved, it does not affect vegetable blue colours.

3. It is soluble in twenty-four parts of boiling alcohol, and in 100 of cold alcohol. Water precipitates it, in the state of a white powder.

4. Hot ether dissolves, but deposits it on cooling. When heated in a spoon, it melts like wax.

5. It is soluble in acids, and precipitated by alkalis. With nitric acid it dissolves, and becomes red; and much oxalic acid is formed, a bitter substance remaining.

6. It may be combined with water and alcohol, by the intervention of resin and extract, the presence of which seems originally to render it soluble in those fluids.

SECTION XVIII.

Suber and its Acid.

THIS name is used to denote common cork wood, which appears to be possessed of peculiar properties, especially in its relation to nitric acid.

I. To a quantity of cork, grated into powder, and contained in a tubulated retort, add six times its weight of nitric acid, of the specific gravity 1.261; and distil the mixture, with a gentle heat, as long as any red vapours escape. As the distillation advances, a yellow matter, like wax, appears on the surface of the liquid. While the contents of the retort continue hot, they are to be poured into a glass vessel, placed on a sand-bath, and constantly stirred with a glass rod, by which means the liquid gradually becomes thick. As soon as white penetrating vapours appear, let it be removed from the sand-bath, and stirred till it becomes cold. An orange-coloured mass will be obtained, of the consistence of honey, having a strong and sharp odour while hot, and a peculiar aromatic smell when cold. On this, pour twice its weight of boiling water; apply heat till it liquefies; and filter. The filtered liquor, as it cools, deposits a powdery sediment, and becomes covered with a thin pellicle. The sediment is to be separated by filtration; and the liquid reduced, by evaporation, nearly to dryness. This mass is the suberic acid. It may be purified, either by saturating it with alkali, and precipitating by an acid, or by boiling it with charcoal powder.

II. Suberic acid has the following properties:

1. It is not crystallizable.
2. It has an acid and slightly bitter taste; and, when dissolved in boiling water, it acts on the throat, and excites coughing.
3. It reddens vegetable blues, and changes the blue solution of indigo in sulphuric acid to green.
4. Cold water dissolves about $\frac{1}{150}$ th its weight, and boiling water half its weight.
5. It attracts moisture from the air.
6. When heated in a matrass, it sublimes, and is obtained in concentric circles, composed of numerous small points.
7. With alkalis, earths, and metallic oxides, it forms a class of salts called Suberates.

The action of nitric acid on cork, and the properties of the suberic acids and its compounds, have been lately investigated by Chevreul, whose memoir may be consulted in the 23d volume of Nicholson's Journal.

SECTION XIX.

Of Bitumens.

THOUGH bitumens, on account of their origin, are, with more propriety, classed among mineral substances; yet, in chemical properties, they are more closely allied to the products of the vegetable kingdom. Like vegetable substances in general, they burn in the open air, and with a degree of brightness that surpasses even that of resins. By distillation *per se*, they yield a weak acetic acid, an empyreumatic oil, some ammonia, and a considerable quantity of carburetted hydrogen gas, with occasionally a small proportion of carbonic acid and sulphuretted hydrogen. They are neither soluble in water nor in alcohol, and in the latter respect they differ from resins. There can be little doubt that they have been formed originally by the decomposition of vegetables.

The bitumens have been divided into liquid and solid. Formerly it was supposed that the liquid bitumens had been derived, by a sort of natural distillation, from the solid; but Mr. Hatchett has rendered it more probable that the solid bitumens result from the consolidation of the fluid ones.*

The bituminous substances are Naphtha, Petroleum, Mineral Tar, Mineral Pitch, Asphaltum, Jet, Pit-coal, Bituminous Wood, Turf, and Peat. To these some writers have added Amber and the Honey-Stone.

NAPHTHA is a substance well known to mineralogists as a light, thin, often colourless oil, highly odoriferous and inflammable, which is found on the surface of the water of certain springs in Italy, and on the shores of the Caspian Sea. It has a penetrating but not disagreeable odour. Its specific gravity is about .708, or, according to Brisson, .845. It does not congeal at 0° Fahrenheit.†

Naphtha is highly inflammable, and burns with a penetrating smell and much smoke. It may be distilled without alteration. By long exposure to the air it becomes thick and coloured, and passes to the state of petroleum. The addition of a little sulphuric or nitric acid produces the same change more speedily. It is not miscible either with water or with alcohol.

Naphtha appears to be the only fluid we are acquainted with, in which oxygen does not exist in considerable proportion. This circumstance renders it of great use in preserving the new metals discovered by Sir H. Davy. When recently distilled, they have no action on it; but in naphtha that has been exposed to the air, these metals soon oxidate; and alkali is formed, which unites with the naphtha into a kind of brown soap.

PETROLEUM is considerably thicker than naphtha, and has a

* Linnæan Transactions, 1797.

† Most of the naphtha brought from Europe, is I believe nothing more than the product of the distillation of petroleum, &c. C.

greasy feel. It is either wholly or in part transparent, and of a reddish brown colour. Its specific gravity is .878.

When distilled *per se*, a portion of colourless naphtha is first obtained; then an empyreumatic acid liquor; next a thick brown oil; and a portion of black shining coal remains in the retort.

Petroleum is highly inflammable. Sulphuric and nitric acids convert it into a thick bitumen; and exposure to the air produces the same effect more slowly. It has the property of combining with fat and essential oils, with resins, camphor and sulphur; and, when rectified, it dissolves caoutchouc.

MINERAL TAR is thicker and more viscid than petroleum, and of a reddish or blackish brown colour. In chemical properties it resembles petroleum.

The solid bitumens are Maltha, Asphaltum, and Elastic Bitumen or Mineral Caoutchouc, besides the several varieties of Coal and Peat.

MALTHA or MINERAL PITCH has a brownish black colour, and little or no lustre. It is so soft that it is impressed by the nails, but does not stain the fingers. Its specific gravity is from 1.45 to 2.06. It is extremely inflammable, and burns with a bright flame, leaving only a small quantity of ashes.

ASPHALTUM is brownish black in its colour, is brittle, shining, and does not stain the fingers. Its specific gravity varies from 1.07 to 1.65. It is extremely inflammable, and burns with a yellow flame. By distillation *per se*, it yields a light brown oil resembling naphtha, a portion of water impregnated with ammonia, and a quantity of carburetted hydrogen gas. It has been analyzed by Klaproth, whose accounts of it may be seen in the second volume of his "Contributions."

The appropriate solvent of asphaltum is naphtha, of which it requires five times its weight. The solution is of a deep black colour, and forms an excellent varnish.

ELASTIC BITUMEN or MINERAL CAOUTCHOUC is a rare production of nature, and has hitherto been found only in Derbyshire. It is inflammable, and burns with much smoke. By a gentle heat it is melted and converted into petroleum, maltha, or asphaltum. It resists the action of solvents.

RETINASPHALTUM is also a rare production of the same county. It has no elasticity; but is brittle and breaks with a glassy fracture. Its colour is pale ochre yellow; its specific gravity 1.135. It melts on the application of heat, and burns with a bright flame. It is partially soluble in alcohol, potash, and nitric acid. One hundred parts contain 55 resin, 41 asphaltum, and 3 earthy matter.

PIT-COAL is a general term, applied to several distinct varieties of minerals. They have been divided into the three families of brown coal; black coal; and glance coal or mineral carbon.

Brown coal is only imperfectly bituminized, and exhibits, distinctly, the remains of the vegetables, from whose decay it has originated. It is brown, opaque, somewhat flexible and elastic, and nearly light enough to float on water. It burns with a clear flame, and with a bituminous odour mixed with that of sulphur. In the

mode of its combustion, as well as in its external appearance, it bears a considerable resemblance to wood that has been half charred.

Black coal is the substance, which is commonly applied to the purposes of fuel. It shows no remains of the vegetables from which it has originated; but appears to be a compound of bitumen and charcoal; and according to the proportion of these two ingredients, its properties vary considerably. The best kinds melt on the application of a moderate heat, and burn almost entirely away, with a clear bright flame. By distillation, they yield a quantity of water holding carbonate and sulphuret of ammonia in solution; a large proportion of tar is obtained, which, by evaporation and fusion, forms a kind of asphaltum; and an immense production takes place of heavy carburetted hydrogen gas, which may be applied to burning in lamps. In the retort, a hard heavy charcoal remains called *coak*. It contains generally a good deal of sulphur; and emits, during combustion, a suffocating smell of sulphurous acid.

Glance coal appears to consist of almost pure charcoal without any bitumen, and combined only with a proportion of earth. It is common in some parts of this kingdom, where it is known by the name of *stone coal*. It burns with little or no flame; and, when submitted to distillation, yields no tar, and a carburetted hydrogen gas, which, from its inferior density, cannot be advantageously burned in lamps.

In *PEAT* or *TURF*, the remains of vegetable organization are generally very evident; and it consists, indeed, in a great measure, of fibres of several mosses, with occasionally whole branches, and even trunks, of various trees. It is extremely inflammable in the open air; and, when distilled in close vessels, yields products similar to those of coal. The gas, however, which is evolved, approaches more in its characters to carbonic oxide than to carburetted hydrogen. In an excellent account of this substance, given by Mr. Jameson in his *Mineralogy of the Shetland Isles*, peat is said to contain the suberic acid. The sulphates of iron, soda, and magnesia, are, also, occasionally found as ingredients of peat; and, when in considerable proportion, impair its combustibility.

MELLILITE or *HONEY-STONE*, so called from the resemblance of its colour to that of honey, is a very rare production, and has been found, accompanying brown coal, in a very few parts of the continent. It is consumed when ignited in the open air, but without flame or smoke. When long boiled in water, it yields a solution, which, on being concentrated and mixed with alcohol, becomes pitchy. By continued trituration, however, it is dissolved with the exception of some earthy flocculi. The clear liquid, decanted and evaporated, yields a brownish saline mass; from which, by two successive evaporations and solutions, needle-shaped crystals are obtained. These are the pure *mellitic acid*.

The taste of this acid is sweetish, and at the same time sour, with some bitterness. It is combustible when ignited in the air; and is decomposed by nitric acid, without the production of any

oxalic acid. Dropped into the watery solutions of lime, barytes, or strontites, it gives a precipitate, which is soluble in muriatic acid. With acetates of barytes and lead, and nitrates of mercury and iron, it gives precipitates, which are soluble in nitric acid. It neutralizes the three alkalis, and affords with them crystallizable salts.

SECTION XX.

Of the Vegetable Principles of Asparagus, Elm-tree Gum, Elacampagne, Mushrooms, Saffron, and Coccus Indicus.

By an attentive examination of the products of vegetation, some new substances have been discovered, the properties of which do not agree with those of any that have been the subjects of the preceding sections. Hitherto, however, they have scarcely been so much investigated, as to entitle them to rank as distinct species.

1. *Asparagin*. From the juice of asparagus, concentrated by evaporation, Messrs. Vauquelin and Robiquet observed a considerable number of crystals to separate spontaneously *. Of these, some became, after repeated crystallizations, perfectly white and transparent. They were cool and slightly nauseous to the taste; were soluble in water; and neither affected the re-agents for acids nor alkalis. The infusion of galls, acetate of lead, oxalate of ammonia, muriate of barytes, and hydro-sulphuret of potash, produced no change in the solution; and no ammonia was disengaged by potash. When burned in a platina crucible, they swelled up, and emitted penetrating vapours, which affected the eyes and nose like the smoke of wood; and left a large proportion of charcoal, in which no traces of alkali could be discovered. Towards the close of the decomposition, an odour arose similar to that of animal matter, and inclining, also, to that of ammonia. It appears, therefore, that this substance, though crystallizable, cannot be considered as a neutral salt; for it contains neither alkali nor earth. Like other vegetable matters it appears to consist of hydrogen, oxygen, and charcoal, in proportions not yet determined, with perhaps some nitrogen.

2. *Ulm*. In the year 1802, Klaproth received from Palermo, a substance which exudes spontaneously from a species of elm, and which, in external characters, bore a considerable resemblance to gum. It dissolved in a small quantity of water, and gave a transparent solution of a blackish brown colour, which was not, however, mucilaginous, and could not be applied to the purpose of a paste. Nitric acid precipitated from the solution a light brown

* Nicholson's Journal, xv. 242.

substance, which was soluble in alcohol, though the gum itself resisted that solvent. Oxymuriatic acid produced a similar effect. The property of producing a resin by the addition of a little oxygen, is peculiar to this substance, and sufficiently characteristic. Dr. Thomson has proposed for it the name of *Ulm*; and he and Mr. Smithson have recently paid much attention to the investigation of its properties.* It appears to be a very common vegetable product, exuding from various trees, and existing, according to Berzelius, in the bark of most. When pure, it is tasteless; sparingly soluble in water and in alcohol; not precipitated by acids, gelatine or tan; and very soluble in alkaline carbonates, from which it is separated by acids and metallic salts.

3. *Inulin*. When the roots of the *inula helenium* or elecampane are boiled some time in water, the decoction, after standing some hours, deposits a white powder like starch, but differing in its chemical qualities. Rose, who appears to be the only person that has investigated its properties, finds† that it is insoluble in cold water, but readily dissolves in four times its weight of boiling water into a liquid which is somewhat mucilaginous and not quite transparent. After some hours, the substance precipitates from the water, in the form of a white powder; and it is immediately thrown down by alcohol. When placed on burning coals, it melts as readily as sugar, and emits a similar smell. When treated with nitric acid, it yields oxalic and malic acids; or acetic acid if too much nitric acid be employed. It differs, however, from gum in not affording, by this treatment, any saccholactic acid; and from starch (besides separating spontaneously from hot water,) in yielding none of the waxy matter, which is formed when starch is digested with the same acid.

4. *Fungin*. This substance has been extracted by Braconnot‡ from the fleshy part of mushrooms. It may be obtained by washing off the soluble ingredients with hot water, to which a little alkali has been added. There remains a white, insipid, soft, and but little elastic substance. It has a fleshy structure, and is in a high degree nutritious, and free from deleterious properties. When dry, it burns vividly, and emits an odour resembling that of bread. By destructive distillation, it yields ammonia, and not an acid like wood. It differs, also, from lignin, in being insoluble in alkaline solutions, except when they are heated and very strong. Pure ammonia dissolves a portion of it, but deposits it on exposure to air.

Weak sulphuric acid has no action on fungin. The concentrated acid chars it, and sulphurous and acetic acids are formed. Muriatic acid dissolves it slowly, and converts it into a gelatinous matter. When heated with diluted nitric acid, azotic gas is disengaged. In this property, and in the results of its putrefaction,

* See his Annals of Philos. vols. 1 and 2; and Mr. Smithson's paper Phil. Trans. 1813.

† Thomson's Chemistry, v. 54.

‡ 79 Ann. de Chim. 267.

as well as in yielding ammonia on distillation, it approaches very nearly to animal substances.

5. *Polychroite*. This name has been given, by Bouillon La Grange and Vogel, to the extract of saffron prepared with alcohol. It has a very intense yellow colour, a bitter taste, and an agreeable smell. It is soluble in water and in alcohol; and the solution, by exposure to light, gradually loses its colour, which is destroyed, also, by oxymuriatic acid. A few drops of sulphuric acid change the colour to a beautiful blue; and nitric acid, added in like manner, to green.

Polychroite unites with lime, potash, and barytes, and affords with those bases soluble compounds. Sulphate of iron precipitates it of a dark brown colour. By destructive distillation, it yields an acid liquor containing ammonia, and carbonic acid and carburetted hydrogen gases.

6. *Picrotoxine*. This principle is the one which communicates to the *cocculus indicus* its deleterious properties. Boullay obtained it, from that seed, by the following process. The seeds, deprived of their pericarp, were boiled in a sufficient quantity of water; and, to the decoction, acetate of lead was added, as long as any precipitate was occasioned. The liquid was again filtered, and slowly evaporated to the consistence of an extract, which was dissolved in alcohol, and the solution evaporated to dryness. The dry mass consisted of picrotoxine, mixed with a little colouring matter, the latter of which was separated by a very small quantity of water, and the picrotoxine remained in small crystals. Its properties are the following:

1. It is white, and crystallizes in four-sided prisms. Its taste is disgustingly bitter. One hundred parts of boiling water dissolve four of picrotoxine, and one half separates on cooling. The solution does not affect vegetable blues.

2. Alcohol of the specific gravity .810 dissolves one third its weight of picrotoxine. The addition of a little water throws down a precipitate, which a larger quantity redissolves.

3. Sulphuric acid has no remarkable action on it. Nitric acid dissolves it, and affords a yellowish green solution. When heat is applied, oxalic acid is formed. Acetic acid readily dissolves it, and it is precipitated by carbonate of potash. It is soluble, also, in weak solutions of the pure alkalis.

4. The results of its destructive distillation do not materially differ from those of other vegetable matter.

CHAPTER XXI.

RESULT OF THE SPONTANEOUS DECOMPOSITION OF VEGETABLE SUBSTANCES.

SECTION I.

Vinous Fermentation.

THE phenomena and results of this process may be accurately examined, by means of an apparatus similar to that described in Lavoisier's Elements, part iii. ch. vi. A more simple one, however, will sufficiently answer the purpose. It may consist of a large glass matrass, shaped like fig. 4, capable of holding 10 or 12 pints. Into the opening of the neck, a glass tube may be cemented, which is to be twice bent at right angles. The aperture of the other leg may terminate in a two-necked bottle, from which a bent glass tube is to proceed, and to be carried under the shelf of the pneumatic trough, or (which is better) into the receiving-pipe of a gazometer, fig. 35, *b*. The matrass may then be half filled with a solution of sugar in a proper quantity of water, or with an infusion of malt with the addition of a little yeast. When placed in a room, the temperature of which is not below 60° Fahrenheit, the fermentation soon begins to take place; a brisk motion is observed in the liquid; it becomes turbid, and deposits some impurities, while a frothy scum rises to the surface. When the materials are in large quantity, *viz.* sufficient to fill a cask, a hissing noise is heard in the liquid, and its bulk increases so much, that, if the vessel were full, it now overflows. At the same time, a considerable quantity of gas escapes, and passes, through the bent tube, into the receiver inverted in the pneumatic trough, or into the gazometer. During the process of fermentation, the liquor preserves a higher temperature than that of the surrounding atmosphere. After some days, these appearances gradually decline; and, if the process has been well conducted, and suspended at the proper period, the result is a liquor, not sweet, like that submitted to experiment, but having a vinous taste and smell.

When the gas, contained in the gazometer, is examined, it is found to be carbonic acid, holding in solution something which has a smell like that of the fermented liquor. On submitting the latter to distillation, we obtain a liquid considerably lighter than water, and having a strong spirituous taste. This, when deprived of the water with which it is combined, is alcohol.

SECTION II.

Alcohol.

It has been a subject of controversy whether the alcohol obtained by the distillation of wines, and of other fermented liquors, existed *ready formed* in those liquors, or has been actually *produced*, in consequence of a new arrangement of the elements of the fluid by the increase of temperature. The latter opinion was supported by Fabroni,* and had gained considerable currency, till the contrary was fully established by Mr. Brande,† in two memoirs; in the first of which it was shown, that the results of the distillation of wine are not affected by a variation of temperature equal to 20 degrees of Fahrenheit; and in the second, that alcohol may be separated from wine, without the intervention of heat.

When a solution of acetate of lead (sugar of lead) or of sub-acetate of lead (Goulard's Extract) is added to wine, a dense insoluble precipitate is quickly formed, consisting of a compound of the metallic oxide, with the acid and extractive colouring matter of the wine. On filtering the fluid, we obtain a mixture of alcohol, water, and a portion of the acid of the metallic salt; provided the latter has not been added in excess, in which case a part of the salt remains undecomposed. From this liquid, hot and dry sub-carbonate of potash separates the water; and the alcohol floats at the top, forming a distinct stratum. By operating on artificial mixtures of alcohol and water, Mr. Brande found that when the alcohol is not less than 16 per cent. the quantity, indicated by the sub-carbonate, was always within one half part in 100 of the real proportion contained in the mixture. The experiments may be repeated in glass tubes, from half an inch to two inches diameter, accurately graduated into 100 parts.

Gay Lussac‡ has lately recommended the substitution of very finely powdered litharge for the acetate of lead; and has added the important fact that wine distilled in *vacuo*, at the temperature of 60° Faht. affords alcohol; a convincing proof, if any had been required, that the alcohol is merely *separated*, and not *formed*, by distillation.

From an extensive series of experiments, Mr. Brande has constructed the following

* Ann. de Chim. xxx. 220.

‡ 86 Ann. de Chim. 175.

† Phil. Trans. 1811, 1813.

Table of the Quantity of Alcohol, of Specific gravity .825 at 60° Fahrenheit, in various Wines, &c.

Kind of Wine.	100 Measures cont in	Kind of Wine.	100 Measures contain
Port, average	23.48	Frontignac	12.79
Ditto, highest	35.83	Coti Roti	12.32
Ditto, lowest	19	Rousillon	17.26
Madeira, highest	24.42	Cape Madeira	18.11
Ditto, lowest	19.34	Cape Muschat	18.25
Sherry, average of 4 . .	19.19	Constantia	19.75
Claret, ditto of 3 . . .	14.43	Tent	13.30
Calcavella	18.10	Sheraaz	15.52
Lisbon	18.94	Syracuse	15.28
Malaga	17.26	Nice	14.63
Bucellas	18.49	Tokay	9.82
Red Madeira	18.40	Raisin Wine	25.77
Malmsey Madeira	16.40	Grape Wine	18.11
Marsala	25.87	Currant Wine	20.55
Ditto	17.26	Gooseberry Ditto	11.84
Red Champagne	11.30	Elder Wine	9.87
White Ditto	12.80	Cider	9.87
Burgundy	14.53	Perry	9.87
Ditto	11.95	Brown Stout	6.80
White Hermitage	17.43	Ale	8.88
Red Ditto	12.32	Brandy	53.39
Hock	14.37	Rum	53.63
Ditto	8.88	Hollands	51.61
Vin de Grave	12.80		

Some doubt may, perhaps, be excited of the accuracy of this Table, by a reference to the comparative intoxicating effects of port wine and brandy, the latter of which certainly are more than double those of the former. But it is to be remembered, that, in wine, the alcohol is in a state of combination with other ingredients, which must necessarily diminish its activity on the animal system.

I. To prepare alcohol, the spirit of wine of the shops may be employed. To a quantity contained in a glass vessel, the sub-carbonate of potash, perfectly dry, and heated to about 300°, is to be added; the mixture is to be well shaken; the clear liquor decanted; and this is to be repeated as long as the alkali is moistened by the spirit. When enough has been employed, the next addition will fall to the bottom in a perfectly dry state. The dry muriate of lime may be advantageously used as a substitute for alkali. Or it may be employed to strengthen alcohol, which has been prepared with the mild vegetable alkali; but it appears doubtful whether a little ether is not produced by its action. When the muriate is no longer moistened on being added to the spirit, we may conclude that enough has been used. Two distinct strata will then be seen in the liquid, the solution of muriate of lime in water, at the bot-

tom, and the alcohol at the top. The latter is to be decanted, or drawn off by a syphon, and then submitted to distillation, reserving only the portions which first pass over. Gay Lussac recommends quicklime or barytes, in preference to muriate of lime; and Dubuc advises the use of dry alumine, by which he brought alcohol to the specific gravity .817, without any risk of forming ether by the process.*

II. 1. Alcohol is considerably lighter than water, viz. in the proportion of 800 or 820 to 1000. The lightest, that can be obtained, by simple distillation, from spirit of wine, has the specific gravity of 825. By the intervention of substances which strongly attract water, Chaussier brought it to the specific gravity of 798, and Covitz and Saussure jun. to 791 or 792. Alcohol of the specific gravity 820 still contains, according to Lovitz, about $\frac{1}{10}$ th its weight of water. When of the specific gravity 920, it has been called *proof spirits*; the term *above proof* being used to denote a spirit lighter than this, and *under proof* one which contains a still larger proportion of water. Rectified spirit is directed, by the London Pharmacopœia, to have the specific gravity of 835, but it seldom exceeds 840. The quantity of alcohol and water in mixtures of different specific gravities, may be learned from Mr. Gilpin's copious tables, of which the following is an abstract.†

Table, shewing the Specific Gravity of the Mixtures of Alcohol and Water.

Centesimal parts of the Mixture.	SPECIFIC GRAVITIES.	
	According to Chaussier.	According to Gilpin. (last Table.)
Alcohol . . . 100	0.7980	0.825
95	0.8165	0.83887
90	0.8340	0.85244
85	0.8485	0.86414
80	0.8620	0.87606
75	0.87525	0.88762
70	0.8880	0.89883
65	0.9005	0.90941
60	0.9120	0.91981
55	0.9230	0.92961
50	0.9334	0.93882
45	0.94265	0.94726
40	0.9514	0.95493
35	0.95865	0.96158
30	0.96535	0.96736
25	0.97035	0.97239
20	0.97605	0.97723
15	0.9815	0.98213
10	0.9866	0.98737
5	0.99335	0.99327
0	0.99835	1.00000

* 86 Ann. de Chim. 314.

† Philosophical Transactions, 1794, or Nicholson's Journal, 4to. vol. i. Mr. Gilpin's standard alcohol had the specific gravity of 825, and Chaussier's of 798.

2. Alcohol unites chemically with water; and caloric is evolved during this union. Equal measures of alcohol and water, each at 50° Fahrenheit, give by sudden admixture an elevation of nearly 20° of temperature; and equal measures of proof spirit and water an increase of $9\frac{1}{2}^{\circ}$. The bulk of the resulting liquid is less also than that of the two before admixture. Thus a pint of alcohol and a pint of water, when the mixture has cooled to the temperature of the atmosphere, falls considerably short of two pints.

3. Alcohol is highly inflammable. During its combustion, carbonic acid is generated; no charcoal appears; and a quantity of water is produced which exceeds in weight the alcohol employed. An ingenious apparatus, for the purpose of ascertaining this fact, is described in the third part of Lavoisier's Elements, and is represented in the 9th plate of that work, fig. 5. The flame of alcohol acquires a red colour from muriate of lime, a deep blood-red from the muriate of strontites, and a green tinge from boracic acid.

4. Alcohol is a fluid which is remarkably expansible by heat. Dividing the scale between the freezing and boiling points of water into two equal parts, Mr. De Luc has stated that alcohol expands 35 parts for the first 90° , and 45 parts for the second 90° . The strength of his alcohol, however, is described only by the indefinite test of its firing gun powder. Mr. Dalton found that 1000 parts of alcohol of the specific gravity .817 at 50° Fahrenheit become 1079 parts at 170° . At 110° , half way between the two extremes, the alcohol was at 1039, or half a division below the true mean. The more the alcohol is diluted with water, the greater he found the disproportion between the two parts of the scale. When of the specific gravity .967, answering to 75 per cent. water, the ratio of expansion through the first half between 50° and 170° , was to that through the second half as 35 to 45, which is precisely the same as De Luc gives for pure alcohol. In reporting these results no account is taken of the expansion of the glass vessel, and consequently the real expansions may be considered as rather exceeding the apparent ones which have been stated.

5. Alcohol boils at 176° . If water be added, its boiling point is proportionably raised; so that the temperature, at which it boils, is not a bad test of its strength. At this degree of heat it is converted into a vapour, which may be exploded by passing an electric spark through a mixture of it with oxygen gas.

Alcohol of the specific gravity .8152 at 50° Fahrenheit, gives a gas, the density of which is $1\frac{1}{4}$ times that of the atmosphere. To become gaseous, alcohol absorbs 0.436, the caloric required to vaporize an equal weight of water.

6. It has never yet been congealed by any known method of producing artificial cold. Even when diluted with an equal weight of water, it requires a cold of 6° below 0 to congeal it. Mr. Hutton, of Edinburgh, announced, indeed, more than two years ago,* that he had succeeded in congealing alcohol of the specific gravity .798, but the details of his process have not yet been published.

* Nicholson's Journal, xxxiv. 166. See also Thomson's Annals, i. 221, and ii. 63, 471.

7. Alcohol is a powerful solvent. It dissolves soap; vegetable extract; sugar; oxalic, camphoric, tartaric, gallic, and benzoic acids; volatile oils; resins; and balsams. It combines, also, with sulphur, phosphorus, and the pure alkalis; but not with their carbonates. Of the class of salts with alkaline, earthy, and metallic bases, alcohol dissolves some copiously, others sparingly, and others not at all. The proportion in which some of these are taken up, is stated in the following Table by Wenzel, the principal defect of which is the omission of the specific gravity of the alcohol employed.

Two hundred and forty grains of boiling alcohol dissolve of

	Grains.
Borate of ammonia . . .	1
Fluate of alumine . . .	1
—— ammonia . . .	1
Muriate of ammonia . . .	17
—— lime . . .	288
—— magnesia . . .	1313
—— potash . . .	5
Nitrate of alumine . . .	240
—— ammonia . . .	214
—— lime . . .	288
—— magnesia . . .	694
—— potash . . .	5
—— soda . . .	23
Oxalate of alumine . . .	7
Tartrate of alumine . . .	7
—— ammonia . . .	7
—— potash . . .	1
Super-tartrate of potash . . .	7
—— oxalate of potash . . .	7

Mr. Kirwan, also, has given us a very useful Table, showing the power of alcohol at different specific gravities to dissolve several of the neutral salts. The salts were first deprived of their water of crystallization, and were digested, during three days, with alcohol, the temperature of which never exceeded 80° Fahrenheit.

100 Grains of Alcohol at

	.900	.872	.848	.834	.817
Sulphate of soda . . .	0	0	0	0	0
—— magnesia . . .	1	1	0	0	0
Nitrate of potash . . .	2.76	1	0	0	0
—— soda . . .	10.5	6	..	0.38	0
Muriate of potash . . .	4.62	1.66	..	0.38	0
—— soda . . .	5.8	3.67	..	0.5	
—— ammonia . . .	7.5	4.75	..	1.5	
—— magnesia . . .	21.25	..	23.75	36.25	50
—— barytes . . .	1	..	0.29	0.18	0.09
—— crystallized . . .	1.56	..	0.43	0.32	0.06
Acetate of lime . . .	2.4	..	4.12	4.75	4.88

Some salts, also, when actually dissolved in water, are precipitated by the addition of alcohol. This is the case chiefly with the sulphates, several of which are precipitated immediately, while others are not separated without the application of heat and a few days repose.

8. Alcohol, when transmitted through a red-hot copper tube, is decomposed. The tube is found lined with a very fine light soot resembling lamp-black, and an enormous quantity of carburetted hydrogen gas is evolved, not less, as appears from an experiment of Van Marum, than ten cubic feet by the decomposition of three ounces of alcohol. From the analysis of this gas, Mr. Cruickshank has inferred that in alcohol the carbon is to the hydrogen in the proportion of 4 to 1.*

9. In order to determine accurately the composition of alcohol, Lavoisier burned a quantity with very minute attention to the products. The weight of alcohol consumed amounted to 93.5 grains, and 110.32 grains of oxygen were expended in the combustion. The water produced amounted to 106.2 grains, and the carbonic acid to 93.8. From the known quantity of carbon in carbonic acid, and of hydrogen in water, Lavoisier inferred that the alcohol, on which he operated, consisted of

Carbon	28.53
Hydrogen	7.87
Water (existing in the alcohol)	63.6
	<hr/>
	100.

Comparing, then the composition of alcohol with that of sugar (a compound, as has already been stated, of eight parts hydrogen, 64 oxygen, and 28 carbon), the same distinguished philosopher was led to the conclusion, that, during the vinous fermentation, part of the carbon, by uniting with the oxygen, passes to the state of carbonic acid, and that the remaining carbon, with the hydrogen of the sugar, composes alcohol. If, therefore, it were possible to combine carbonic acid and alcohol, sugar ought to be regenerated.

An analysis of alcohol has lately been executed with considerable skill by Saussure, jun. Two different methods were employed in his experiments. Alcohol was transmitted through a red-hot porcelain tube; by which operation it afforded water, and a quantity of gas, which readily admitted of analysis. By an elaborate set of experiments, alcohol, of specific gravity .792 at 68°, was proved to contain, per cent.

Carbon	51.98
Oxygen	34.32
Hydrogen	13.70
	<hr/>
	100.

* Nicholson's Journal, 4to. v. 7.

Beside the hydrogen, necessary to form water with the 34.32 parts of oxygen, there are 9.15 parts of hydrogen in excess. Now it is remarkable that this excess of hydrogen is to the carbon in alcohol (51.98) in the same proportions as the hydrogen is to the charcoal of olefiant gas; and we are, therefore, entitled to consider 100 parts of alcohol, of specific gravity .792, as constituted of $(9.15 + 51.98 =)$ 61.13 parts of olefiant gas and 38.87 of water; or of two atoms of olefiant gas, and one of water; or of two atoms of charcoal, three of hydrogen, and one of oxygen.

In 100 parts of alcohol, specific gravity .792, we have, therefore, the elements of 100 parts of olefiant gas, united with those of 63.6 water. But as this alcohol may still be supposed to contain 8.3 per cent. water, real alcohol is probably constituted of 100 parts of the elements of olefiant gas, and of fifty parts of water.

By distillation with the more powerful acids, alcohol undergoes an important change. It is converted into a liquid considerably lighter than alcohol, and much more volatile and inflammable, and miscible only in small proportion with water. This fluid has received the generic name of ETHER; and the peculiar varieties are distinguished by adding the name of the acid, by the intervention of which they have been prepared.

SECTION III.

Ether.

I. To prepare *sulphuric ether*, pour into a retort any quantity of alcohol, and add, at intervals sufficient to allow the mixture to cool after each addition, an equal weight of concentrated sulphuric acid, agitating them together each time, and taking care that the temperature of the mixture does not rise above 120° Fahrenheit. Let the retort be placed in a sand-bath previously heated to 200°, and be connected, by means of an adopter, with a tubulated receiver. To the tubulure of the receiver, a glass tube, twice bent at right angles, may be luted; and its aperture be immersed in a cupful of water or mercury. The condensable vapour is thus confined; while the gases that are produced are allowed to escape. The receiver and adopter should be kept cool by the application of ice or of moistened cloths. As soon as the materials begin to boil, ether is produced, and passes over into the receiver. The ebullition is to be continued, till white vapours appear in the retort, or a smell of sulphurous acid is perceived; and the receiver is then to be removed. The liquor, which it contains, will probably have a smell of sulphurous acid. To purify it, a small quantity of black oxide of manganese may be added, and the mixture may be kept in a bottle about 24 hours, agitating it occasionally. The clear liquid is then to be decanted, and distilled in a water bath, till one half has come over. This is to be preserved in a well-closed phial. It will be, to the alcohol employed, as about one to three.

If, when the ether ceases to be formed, the receiver be removed, and the heat still continued, sulphurous acid is produced abundantly, and a yellowish liquor, very different from ether, distils over. This may be mixed with a small quantity of liquid potash to correct the sulphurous smell, and then submitted to a heat sufficient to drive off the small proportion of ether. The *oil of wine* remains swimming on the watery liquid.

II. *Nitric ether* may be prepared as follows. To two pints of alcohol, contained in a glass retort, add, by degrees, half a pound of nitric acid; and, after each addition, cool the materials, by setting the retort in a vessel of cold water. Distil the mixture by a very cautiously regulated heat, till about a pint and a half have come over. In this state the ether is far from being pure, and must be redistilled, with the addition of pure potash, preserving only the first half or three fourths that come over.

Thenard prepared nitric ether by the following process. Into a retort, he put equal parts (about 16 oz. of each) of alcohol and nitric acid; and adapted to it in succession, by means of glass tubes, five tall bottles, half filled with a saturated solution of muriate of soda. In the last, was a bent tube, opening under a jar, to receive the gas. The bottles were surrounded by a mixture of pounded ice and salt, which was stirred occasionally. To commence the operation, a little fire was applied, but it soon became necessary to extinguish it, and to cool the retort. On the surface of the saline solution, in each of the bottles, was found, after the process was concluded, a yellowish liquid, equal in weight to about half the alcohol employed. That in the first bottle was impure; but the remaining four contained nitric ether free from admixture.

Nitric ether, thus prepared, is specifically lighter than water, but heavier than alcohol. It dissolves in the latter fluid, but requires for solution 48 parts of water. It reddens litmus; and though this property may be destroyed by a little lime, yet the ether soon becomes acid again by keeping. It is highly combustible; and much more volatile than the best sulphuric ether. It is composed, in 100 parts, of 16 azote, 39 carbon, 34 oxygen, and 9 hydrogen.*

III. To prepare *muriatic ether*, add, to a mixture of 8 parts of manganese and 24 of muriate of soda, in a retort, 12 parts of sulphuric acid, previously mixed, with the necessary caution, with 8 of alcohol, and proceed to distillation. The ether, thus obtained, requires to be rectified by a second distillation from potash; and is still liable to be contaminated with sulphuric ether. A more certain process, which is not, however, unaccompanied with some difficulty, consists in passing oxygenized muriatic gas through alcohol; and, according to Klaproth, this kind of ether may, also, be safely and effectually prepared by distilling equal parts of alcohol and oxymuriate of tin. The distilled liquid is to be rectified by a second distillation with caustic potash. An improved mode of preparing this ether, and an account of its properties, by Thenard,

* Nicholson's Journal, xviii. 144.

may be found in Nicholson's Journal, xviii. 177, or in the Philosophical Magazine, xxx. 101.

IV. *Phosphoric ether* may be obtained, by distilling a mixture of thick tenacious phosphoric acid and alcohol. The first product is a portion of unchanged alcohol. After this, a liquid passes over, which has an ethereal smell, and a specific gravity inferior to that of alcohol. It is very volatile, requires for solution eight or ten parts of water; boils at 100° ; and burns with a white flame, without leaving any trace of acid.*

V. *Fluoric ether* has been obtained by distilling, in a leaden retort, a mixture of equal parts of fluuate of lime, sulphuric acid, and alcohol. The product of this distillation was again distilled till one half had come over, to which potash was added. This precipitated so much silex, as to gelatinate the whole mass, which, on being again distilled, gave a light ethereal liquid of the specific gravity 720.†

VI. *Acetic ether* may be formed by repeatedly distilling concentrated acetic acid (procured from acetate of copper) with alcohol, and returning the distilled liquor to the charge in the retort. The ether, thus produced, may be freed from a redundance of acid, by distillation with a small quantity of potash. It is heavier than other ethers, its specific gravity being .866. It is volatile; boils at 128° , and burns with a yellowish white flame. During combustion, acetic acid is developed, though none can be discovered in the ether before.

This process has been lately repeated, with considerable attention, by Mr. Chenevix. By repeatedly distilling to dryness a mixture of ten parts of alcohol with ten parts of acetic acid, he ascertained that no change in the specific gravity of the product took place after the first distillation. Seven twelfths of the acetic acid were decomposed. Dry carbonate of potash, added in sufficient quantity to absorb all the water, gave a quantity of ethereal liquor, which weighed 7.4 parts, and had the specific gravity of 8.621.‡

Sulphuric ether will be best employed to exhibit the properties of this substance, which are the following:

1. It is extremely light, having the specific gravity of .730, or, according to Lovitz, even of .632.

2. It does not, like alcohol, combine with water; and when the two fluids are shaken together, they separate again on standing. Water, however, retains about one tenth its weight of ether. By repeated agitation with water, ether is brought to a high degree of purity, and acquires the property of dissolving caoutchouc.

The process, as performed in presence of Faujas de St. Fond, by Mr. Winch of London, is described by the former as follows: Let a pint of good sulphuric ether be put into a bottle (or, in prefer-

* See Boullay, Annales de Chimie, lxii. 192.

† Nicholson's Journal, viii. 143.

‡ Annales de Chimie, lxix. 45. See also Thenard on the Action of Vegetable Acids on Alcohol, Mém. d'Arcueil, ii. 5. or 37 Phil. Mag. 216.

ence, into the separator, plate i. fig. 3,) along with two pints of water; agitate the two liquids repeatedly together; then let them stand till the ether has risen to the surface; and draw off the water through the lower cock *b*, leaving the ether in the vessel. Repeat this process three or four times, or till scarcely one third of the ether remains; and decant the residue into a well-stopped phial. In this ether the elastic gum, cut into thin slips, soon begins to swell; but its action is slow, and about the end of five days, the solution is completed. The method of forming tubes, &c. with this solution, is described in the first volume of Faujas de St. Fond's Travels in England, chap. i.

3. Ether is extremely volatile. A few drops, poured on the hand, evaporate instantly; and produce a sense of great cold. By pouring a small stream of ether, from a capillary tube, on a thermometer bulb filled with water, the water is frozen, even in a warm summer atmosphere. Under the pressure of the atmosphere, it boils at 98° Fahrenheit, and in vacuo considerably below 32° . Two ounce measures, when converted into gas at the temperature of $72\frac{1}{2}^{\circ}$ Fahrenheit, fill the space of a cubic foot.* According to Gay Lussac, ether, of specific gravity 0.7365 at temperature 50° Fahrenheit, produces a gas, the density of which is to that of air as 2.35 to 1.

4. A mixture of sulphuric and muriatic ethers evaporates instantaneously, and produces a degree of cold considerably below 0 of Fahrenheit.

5. Ether assumes a solid form, by reducing its temperature to -46° Fahrenheit.

6. Ether is converted into a gas, either by raising its temperature, or diminishing the pressure of the atmosphere on its surface. The experiments proving this have already been described, chap. iii. sect. 4.

7. Ether does not dissolve the fixed alkalis, but it combines with ammonia.

8. It dissolves essential oils and resins, and takes up about a twentieth of its weight of sulphur, which is deposited as the sulphur volatilizes. Ether dissolves, also, a small portion of phosphorus, and the solution, when poured on the surface of warm water in the dark, emits a lambent blue flame.

9. It is highly inflammable. This is best shown by passing a few drops into a receiver furnished with a brass cap and cock, to which a small pipe is screwed, and inverted in water of the temperature of 100° . The receiver will be filled with the gas of ether, which may be expelled through the pipe and set on fire. It burns with a beautiful deep blue flame.

10. When ether is previously mixed with oxygen gas, it detonates loudly. Into a strong two-ounce phial, filled with oxygen gas, and wrapped round with a cloth, let fall a drop of ether. On applying the flame of a candle, a violent detonation will ensue. Or to a portion of oxygen gas, contained in the detonating tube, fig. 28,

* Saussure, jun.

pass up a drop or two of ether. The volume of the gas will be doubled; and, on transmitting an electric spark, a violent detonation will ensue, which will probably shatter the tube. In an experiment of Mr. Cruickshank, three measures of oxygen and one of ethereal gas detonated most violently, and $2\frac{1}{3}$ measures of carbonic acid gas were produced.

The following experiment, evincing the inflammability of ether, is described, by Mr. Cruickshank, in Nicholson's Journal, 4to. v. 205 :

Fill a bottle of the capacity of three or four pints, with pure oxy-muriatic acid gas, taking care to expel the water as completely as possible. Then throw into it about a drachm or a drachm and a half of good ether, covering its mouth immediately with a piece of light wood or paper. In a few seconds white vapour will be seen moving circularly in the bottle, and this will soon be followed by an explosion, accompanied with flame. At the same time a considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas.

The same effect is produced, but more slowly, by alcohol; and, along with the carbonic acid and carbon, a little ether is produced.

11. According to Mr. Cruickshank, the proportion of carbon to hydrogen is in alcohol as eight or nine to one, and in ether as five to one.* Mr. Saussure, however, has lately submitted ether to analysis with somewhat different results. By following the same processes as those which have been already described, and, also, by the rapid combustion of ether with oxygen gas, he found that 100 parts of sulphuric ether, of specific gravity 0.7155 at 68° Fahrenheit, contain

Carbon	67.98
Oxygen	17.62
Hydrogen	14.40
	<hr/>
	100

The excess of hydrogen, above what is necessary to form water with 17.62 parts of oxygen, is 12.07 parts, which, when added to the carbon ($12.07 + 67.98$) give 80.05 for the olefiant gas in 100 parts of ether. The remainder 19.95 parts are water. Ether, therefore, is constituted of 5 atoms of olefiant gas, and one atom of water; or of six atoms of hydrogen, five of charcoal, and one of oxygen.

To understand the conversion of alcohol into olefiant gas or ether, it is necessary to compare the proportion of their elements.

Alcohol consists of	100 parts olefiant gas	+ 50 water.
Ether —————	100 parts ditto	+ 25 water.

If then, to alcohol, we add a proportion of sulphuric acid sufficient to take away the whole of the water, we obtain only olefiant gas.

* Nicholson's Journal, 4to. v. 205, n.

But if we use no more sulphuric acid, than is sufficient to abstract half the water contained in alcohol, we then obtain ether. It must not, however, be supposed that, in practice, we are ever able to effect these conversions without loss; for a certain proportion of the alcohol is decomposed, by the too energetic action of the acid, into its ultimate elements, especially towards the close of the process; and beside ether or olefiant gas (whichever it may be our object to prepare) we obtain sulphurous and carbonic acids, and a charry residue. It is nevertheless true that the sulphuric acid is efficient in the formation of ether, merely by abstracting water; and that nothing, by this process, is transferred from the acid to the alcohol; for if it be stopped in time, the whole of the acid may be recovered.

SECTION IV.

Acetous and Acetic Acids.

THESE two names were applied, by the framers of the new chemical nomenclature, to denote what were supposed to be two distinct acids, common vinegar purified by distillation being termed the *acetous*, and the highly concentrated acid, formerly called radical vinegar, being denominated *acetic*. To account for the superior strength of the latter, it was supposed to hold in combination a larger proportion of oxygen derived from the metallic oxide, from which acetous acid is generally distilled, when converted into acetic. The experiments of Adet were the first that threw doubt upon this conclusion; and though they appeared to be contradicted by the subsequent ones of Chaptal and Dabit, yet they received the fullest confirmation from the researches of Darracq. The last-mentioned chemist succeeded in converting distilled into radical vinegar, under circumstances where no farther oxygenation could possibly be effected, viz. by repeated distillation from dry muriate of lime; which can only act by abstracting water. Both terms, however, may be retained for the sake of brevity, the *acetous acid* denoting the dilute acid obtained by fermentation; and the *acetic*, the acid in its most dephlegmated state.*

Acetous acid may be procured by exposing to the atmosphere, at a temperature between 75° and 90° of Fahrenheit, the liquor which has been obtained, by the vinous fermentation, from malt, sugar, or other substances. The liquor soon becomes warm; a number of ropey filaments appear; and, after several days, it acquires an acid taste and smell. Little or no gas is evolved; but,

* As there is in fact but one acid of vinegar, the only name to be appropriated to it, is the acetic. There is, therefore, only one class of salts, viz. acetats. The names of *acetous acid* and of *acetites* ought not to be admitted into chemical writings. It would certainly be much better to call the one above named *acetous*, by the term of diluted acetic acid—for no error of opinion can then occur as to its composition and nature. C.

on the contrary, an absorption of oxygen takes place. There is an essential difference, therefore, between the vinous and acetous fermentations. The latter requires the access of air as an indispensable condition; whereas the vinous fermentation may be performed in close vessels, or at least in vessels which only allow egress to the elastic fluids that are produced.

Common vinegar may be purified, by submitting it to distillation in a glass retort. The best malt vinegar, unadulterated by sulphuric acid or colouring, has a specific gravity of 1.0204. When distilled, the first eighth part is of sp. gr. 0.99712, and contains so much acid, that a fluid ounce dissolves from 4.5 to 5 grains of precipitated carbonate of lime. The subsequent six eighths are of the sp. gr. 1.0023, and a fluid ounce decomposes 8.12 grains of carbonate of lime. A similar quantity, of sp. gr. 1.007, decomposes from 15 to 16 grains of precipitated carbonate of lime, or 13.8 grains of marble.* By distillation, vinegar can only be imperfectly purified. The distilled liquor always contains an extractive matter, which Darracq considers as mucilage; and, also, as Mr. Chenevix has shown, a small portion of alcohol. The extractive matter, it has been found by the latter chemist, cannot be removed by repeated distillations. In French vinegar, he discovered a larger proportion both of acid and alcohol, with less mucilage, than in the vinegar of this country. From four pints of distilled French vinegar, he obtained nearly an ounce measure of ardent spirit.

Acetous acid is prepared, also, in very considerable quantity by the distillation of wood. The wood is inclosed in iron cylinders or retorts, which are exposed to a red heat. An immense quantity of inflammable gas is produced; and a liquid is condensed, which consists of acetous acid holding in solution a quantity of tar and of essential oil. These impurities it is scarcely possible to remove entirely; so that the acid, thus prepared, can be applied only to the manufacture of solutions for the dyer and calico-printer, to whom its disagreeable smell is not objectionable.

A new process, for the decoloration of all kinds of vinegar, has been lately proposed by Figuer. The agent he employs is animal charcoal, which may be prepared by calcining the most compact beef or mutton bones in a crucible, to which a cover must be luted, having a small aperture, to allow the escape of the gases, and of the other volatile substances. Towards the close of the calcination, when no more flame issues, this aperture must be closed, and the heat raised for half an hour. To a wine quart of cold vinegar, an ounce and half of this charcoal, finely powdered, is to be added, and occasionally stirred. In 24 hours, the vinegar begins to lose its colour, and, in three or four days, is entirely deprived of it. It is then to be filtered through paper, and it will be found (if the charcoal has been well prepared) to retain its acidity, without having acquired any unpleasant flavour. By reducing the quantity of charcoal to one half, the change is still effected, but more slowly.

Acetous acid unites with alkalis, earths, and metallic oxides.

* Phillips on the London Pharm. p. 7.

When potash, saturated with this acid, is evaporated to dryness, the salt assumes a black colour. On being redissolved, however, and again evaporated, the salt is obtained white, and, when fused and suffered to cool, affords the acetate of potash.

This salt strongly attracts moisture from the air, and is very soluble in water. When exposed to a pretty strong heat it is decomposed; carbonic acid and carburetted hydrogen gases come over; and, in the retort there remains a mixture of carbon with carbonate of potash.

When this salt is distilled, with half its weight of sulphuric acid, the vegetable acid is expelled in a very concentrated form, mixed with sulphurous acid. Digestion with a small portion of manganese, and subsequent distillation, affords it pure. It may be obtained, also, by distilling equal parts of acetate of lead and sulphate of copper. Or

The crystallized acetate of copper, contained in a glass retort, which may be nearly filled with the salt, may be submitted to distillation in a sand-heat. The acid that comes over has a green colour, and requires to be rectified by a second distillation. Its specific gravity then varies from 1056 to 1080. If the products be reserved in separate portions, it has been observed by M. M. Derosne,* that those which are obtained towards the close, though specifically lighter than the earlier ones, are still more powerfully acid, assuming, as the test of their strength, the quantity of alkali which they are capable of saturating. The last products, it was found also, when submitted to distillation, yield a liquid which has even less specific gravity than water. This liquid may be obtained, in a still more perfect state, by saturating the latter portions of acetic acid with caustic and solid potash; the acetate of potash precipitates; and a fluid swims above it, which may be rectified by distillation at a gentle heat. It is perfectly limpid; has a penetrating taste; is lighter than alcohol; evaporates rapidly with the production of cold when poured upon the hand; and is highly inflammable. It does not redden litmus. Excepting that it is miscible, in any proportion, with water, it has all the qualities of ether, and like that fluid has the power of decomposing the nitro-muriate of gold. M. M. Derosne have proposed for it the name of *pyro-acetic ether*. Its production, they observe, is confined to the latter stages in the distillation of acetate of copper, and is owing, they suppose, not to any modification of alcohol, but to changes in the arrangement of the elements of the salt.

These observations are confirmed by the subsequent ones of M. Mollerat.† Examining two portions of acetic acid, which had precisely the same specific gravity (*viz.* 1063), he found that the one contained 87 *per cent.* of real acid, and the other only 41. The first he is disposed to consider as the strongest acetic acid that can be procured. It may be distilled at a very moderate heat with great rapidity, and without entering into ebullition. To this acid, having

* Annales de Chimie, lxiii. 267.

† Annales de Chimie, lxviii. 88: or Nicholson's Journal, xxv. 155.

the specific gravity 1063 (and of which 100 grains required for saturation 250 of sub-carbonate of soda), he gradually added water, and found, though water is lighter than the acid, yet that the density of the mixture increased till it became 1079. From this point, the additions of water occasioned a regular diminution of specific gravity. Mr. Chenevix has since observed the same anomaly, in the acid produced from acetate of silver.

Acetic acid, thus prepared, has several remarkable properties. Its smell is extremely pungent, and it raises a blister when applied to the skin for a sufficient length of time. When heated in a silver spoon over a lamp, its vapour may be set on fire. At the temperature of about 38° Fahrenheit it becomes solid, and shoots into beautiful crystals, which again liquefy at 40° . It appears not to be easily destructible by heat; for Mr. Chenevix transmitted it five times through a red-hot porcelain tube, with the effect of only a partial decomposition.

Gay Lussac and Thenard, and Berzelius have recently analyzed acetic acid; the two first by the combustion of acetate of barytes, of known composition, with hyper-oxymuriate of potash. Their results are as follow. One hundred grains of acetic acid consist of

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac . .	50.224 . . .	44.147 . . .	5.629
————— Berzelius . . .	46.8 . . .	46.9 . . .	6.3

The proportions obtained by Gay Lussac and Thenard may be stated also as follows :

Carbon	50.224
Oxygen and hydrogen in the } same proportions as in water }	46.911
Excess of oxygen	2.865
	<hr/> 100.

The acetic acid enters, like vinegar, into combination with alkalis, earths, and metallic oxides.

The ACETATE OF POTASH, formed with this acid, is perfectly white; and does not, when liquefied by heat, become blackened by the separation of charcoal, like that afforded by common vinegar. It is deliquescent, and soluble in about its own weight of cold water; and in twice its weight of boiling alcohol. By distillation *per se*, its acid is decomposed and resolved into pyro acetic ether, carbonic acid, and carburetted hydrogen gases.

ACETATE OF SODA is crystallizable; does not deliquesce in the air: dissolves in less than its own weight of cold water, or in twice its weight of boiling alcohol; and gives, by destructive distillation, similar products to the acetate of potash. Berzelius found it to consist of

Acetic acid	. . .	36.95
Soda	. . . .	22.94
Water	. . . .	40.11
		<hr/>
		100
		<hr/>

Or exclusively of water,

Acid	. . . .	61.689	. .	100
Soda	. . . .	38.311	. .	62.1
		<hr/>		
		100.		

ACETATE OF AMMONIA derives its only importance from having been long employed in a liquid form in medicine, under the name of *Spirit of Mindererus*. The solution does not yield crystals by evaporation, but affords a deliquescent mass, which is readily soluble in water and in alcohol; and, in its solid form, is volatilized at 250° Fahrenheit.

ACETATE OF LIME may be made, by careful evaporation, to crystallize in the form of small silky needles. It is permanent in the air, and very soluble both in water and alcohol. According to Berzelius, it is composed of

Acid	. . .	64.218	. .	100
Lime	. . .	35.782	. .	55.74
		<hr/>		
		100.		

ACETATE OF BARYTES is a crystallizable salt, which does not grow moist, but rather loses a portion of its water, by exposure to the air. It requires for solution about twelve parts of cold, and not quite two parts of boiling water. Alcohol dissolves only a very small proportion. By distillation *per se* Mr. Chenevix finds that it gives pure pyro-acetic ether, of the specific gravity, 0.845, coloured by a little empyreumatic oil. Gay Lussac and Thenard states its composition to be

Acid	. . .	43.17
Base	. . .	56.83
		<hr/>
		100.

ACETATE OF STRONTITES is more soluble than the last mentioned acetate, requiring only about twice its weight of cold water for solution. Its properties have not been fully investigated.

ACETATE OF MAGNESIA cannot be obtained in crystals, but only in the state of a thick viscid mass, which is extremely deliquescent, and soluble both in water and alcohol.

ACETATE OF ALUMINE is generally formed, by double decomposition, from the mixed solutions of acetate of lead or lime and sulphate of alumine. It is a compound of considerable importance from its use in dyeing and calico-printing. When applied, however, to these purposes, it contains always a quantity of common alum, and the properties of the pure combination of alumine with acetic acid are but imperfectly known. Gay Lussac,* however, has found that it has the remarkable quality of being decomposed by heat, and of depositing alumine, which it redissolves on cooling. The effect takes place, even in vessels hermetically sealed, and when the solution has an excess of acid. It appears to bear some analogy to the coagulation of animal albumen.

The METALLIC ACETATES have been, for the most part, already described in the history of the individual metals. To our knowledge of this class of salts, some valuable additions have lately been made by a memoir of Mr. Chenevix.† By distilling *per se* the different metallic acetates, that excellent chemist found that the salts with bases of lead, zinc, and manganese, yield a liquid lighter considerably than water, but heavier than alcohol, and containing only a very small proportion of acid. This degree of levity is owing to the presence of the peculiar fluid, which Derosne has termed pyro-acetic ether, but to which Mr. Chenevix is of opinion, the less definite name of *pyro-acetic spirit* will be better adapted, till we obtain a more accurate knowledge of its nature and properties.

Of all the metallic acetates, that of silver gave a product of the greatest specific gravity, and of greatest power in neutralizing alkalis. In this respect, it exceeded, by about one fifth, an equal weight of the acid distilled from copper. It contained, however, none of the pyro-acetic spirit discovered in the acid from copper. The residuum in the retort contained, in every case, a proportion of charcoal. When the acetates of silver, nickel, copper, or lead were distilled, the metal was found in a metallic state; but zinc and manganese were left in the state of oxides.

The pyro-acetic spirit, obtained from the acetate of lead, Mr. Chenevix describes as perfectly limpid and colourless. It has a taste, which at first is sharp and burning, but afterwards becomes cool and somewhat resinous. Its smell resembles that of volatile oils, but it is not easy to say of which particular one. Its specific gravity, when rectified by muriate of lime, is 0.864. It is very combustible, and leaves no sensible residue. Its boiling point is 138° Fahrenheit. It is miscible in all proportions, with water, with alcohol, and with all the volatile oils, and, at a temperature considerably below its boiling point, with the fixed oils. When heated it dissolves sulphur and wax.

* 74 Ann. de Chim. 93.

† Annales de Chimie, lxxix; or Nicholson's Journal, xxvi.

CHAPTER XXII.

ANIMAL SUBSTANCES.

THE products of vegetable and of animal life, though they agree frequently in external characters, and even in some of their chemical relations, present several circumstances of distinction, which, in general, sufficiently discriminate the two classes. Animal substances are the results of still more delicate processes, and of a more refined organization; and the balance of affinities, by which they exist, is disturbed by still slighter causes. To the three great components of vegetable matter (oxygen, hydrogen, and carbon) a fourth is, in animal substances, added, and constitutes a large proportion of their structure. To the nitrogen, which they contain, are owing some of the most important qualities, that distinguish this class of compounds. Hence it is, that instead of passing through the vinous or acetous fermentations, they are peculiarly prone to undergo putrefaction; and that, during this change, they yield, among other products, both nitrogen gas and ammonia. When exposed to a high temperature, ammonia is, also, generated, in great abundance, by their decomposition; little or no acetic acid is produced; and the coal, which remains, differs from vegetable charcoal, in being much less combustible. This general description, however, though it applies to most individuals of the animal kingdom, is not strictly true with respect to all. Animal jelly, for example, is rendered sour by spontaneous decomposition. A few vegetable substances, it may also be added, gluten for instance, become at once putrid; and furnish ammonia when decomposed by heat.

In the analysis of animal substances, less precision had till lately been attained, than in that of mineral and vegetable products. It may be considered as of two different kinds. By the first we obtain the *proximate* principles of animal matter or certain compounds which, we may presume, are separated by the simple processes used for their extraction, in a state identical with that, in which they exist in the mineral structure. Thus by the long continued action of hot water on bones, we form a solution, which separates spontaneously into two distinct substances, fat and gelatine; while the earthy ingredients remain undissolved. The substances, thus obtained, are not very numerous; and to distinguish them from more complicated products they may be called *primary animal compounds*. But, by spontaneous decomposition, or by the agency of heat, we give origin to a set of bodies which had no existence in the subject of experiment, the *ultimate elements* of which are thus disunited, and are recombined in a new manner. Bones, for example, though they contain no volatile alkali, are yet composed, in

part of its elements (nitrogen and hydrogen), which, at a high temperature, unite and generate ammonia.

The method of analysis, so successfully applied, by Gay Lussac and Thenard, to the products of the vegetable kingdom, has been extended, also, to animal substances; and, in the history of each, the proportion of its ultimate elements will be stated, chiefly on their authority. Animal substances, they observe, contain much more carbon than those derived from the vegetable world; in all of them, the hydrogen is in excess with relation to their oxygen; and lastly, the greater this excess, the more azote they contain. It is remarkable, moreover, that this azote, and the excess of hydrogen, are very nearly in the proportions required to constitute ammonia.

Animal matters, then, such as fibrin, albumen, gelatine, &c. are composed of charcoal; of hydrogen and oxygen, in the proportions required to form water; and of hydrogen and azote, in the proportions necessary to constitute ammonia. They hold, therefore, among animal matters, the same rank that sugar, gum, lignin, &c. possess among vegetable substances. The animal acids, again, consist, probably, of carbon, oxygen, hydrogen, and azote, in such proportions, that the oxygen and azote are in excess relatively to the hydrogen. And the animal oils, on the other hand, will in all probability be shown to contain more hydrogen, than is sufficient to convert their oxygen into water, and their azote into ammonia. Thus animal substances will be divided, like vegetable ones, into three great classes, relatively to the quantities of hydrogen, oxygen, and azote, which they contain.

The primary animal compounds are not very numerous; the following list comprehending, perhaps, the whole of those which are sufficiently well characterized.

- | | |
|--------------|-----------|
| 1. Gelatine. | 6. Resin. |
| 2. Albumen. | 7. Sugar. |
| 3. Mucus. | 8. Oil. |
| 4. Fibrin. | 9. Acids. |
| 5. Urea. | |

SECTION I.

Animal Jelly, or Gelatine.

ANIMAL jelly is an abundant ingredient not only of the fluids of the body, but of the hard and solid parts. Berzelius, indeed, in his *View of Animal Chemistry*, p. 50, considers gelatine as a *product* of the operation of boiling; and denies its existence in any one fluid of the body. This opinion, however, requires further evidence in its favour. By long continued boiling it may be extracted from the skin, membranes, ligaments, cartilages, and even from the bones. The solution, on cooling, forms a tremulent and im-

perfectly cohering mass, well known by the name of *jelly*; and, if the watery part of this mass be dissipated by a very gentle heat, we obtain a hard semi-transparent substance, which breaks with a glassy fracture, and, according to the source from which it has been obtained, has the names of isinglass, glue, portable soup, &c.; all of which are varieties of animal gelatine. Isinglass, however, as the purest form under which gelatine commonly occurs, will be best employed for the exhibition of its chemical properties.

1. Dry gelatine, when immersed in water, gradually absorbs it, swells considerably, and becomes soft and elastic. At common temperatures, however, it is not dissolved; all that is thus effected being the absorption of a quantity of water, which it loses again by a gentle heat. But in hot water it dissolves slowly, yet completely; and affords a liquid which again gelatinates on cooling. These alternate solutions and desiccations may be repeated for any number of times, without occasioning any change in the chemical properties of the gelatine, which is submitted to them.

The proportion, in which gelatine forms a solution capable of concreting by cooling, has been determined by Dr. Bostock.* One part of dry gelatine to 100 parts of water gave a solution, that completely stiffened by cooling; but one part of gelatine to 150 parts of water produced a compound, which, though evidently gelatinous, did not assume the concrete form.

2. Gelatine in a solid state seems to be absolutely indestructible when kept in a dry place; but, when in the form of solution or of jelly, it is generally said to become first sour, and afterwards putrid. The production of acid, however, Dr. Bostock informs me, he is disposed to question.

3. Gelatine is insoluble in alcohol, but it is not precipitated, by that fluid, from its watery solution.

4. It readily dissolves in most of the acids. Isinglass, dissolved in common vinegar by the assistance of a gentle heat, forms a very useful and adhesive cement. Nitric acid, even when cold and very dilute, is a powerful solvent of gelatine. When the solution is evaporated, the acid and gelatine re-act upon each other; nitrous gas is disengaged; and, if the concentration be not carried too far, oxalic and malic acids are obtained from the residuum. Muriatic acid dissolves gelatine, and retains it unchanged in solution. If oxymuriatic acid be passed through a solution of gelatine, white filaments appear, which, when collected, are found to be very flexible and elastic. They consist of gelatine, very little altered, and united with muriatic acid and oxymuriatic acid. They are insipid; insoluble in water and in alcohol; not putrescible; and exert a feeble action on blue vegetable colours, although they contain a large proportion of acid. Exposed to the air during some days, they emit oxymuriatic acid at common temperatures; and still more abundantly when heated. In alkaline solutions they disappear, and muriatic salts are formed.†

* Nicholson's Journal, xi. and xiv.

† Thenard, Mémoires d'Arcueil, ii.

5. Gelatine is soluble in pure liquid alkalis. The solution is a brownish viscid substance, which has none of the characters of soap,* and is not precipitated by acids. This is a property which distinguishes gelatine from albumen, fibrin, and other animal products; and which points out a method of separating it from them in analysis. Owing to the solvent power of alkalis, they do not occasion any precipitation in acid solutions of gelatine; but when added in excess, dissolve it.

6. Several of the metallic salts and oxides have the property of precipitating gelatine; but not so unequivocally, as to be good tests of its presence. Goulard's extract of lead (prepared by boiling litharge in distilled vinegar) effects no change in a solution of gelatine. The same may be said of corrosive muriate of mercury. Nitrate of silver and nitro-muriate of tin produce a slight, and almost imperceptible opacity. The addition of nitro-muriate of gold causes a small quantity of a dense precipitate, from a solution containing $\frac{1}{50}$ th of gelatine, but not from more dilute solutions.

7. One of the most active precipitants of jelly is tan; and Dr. Bostock finds the extract of rhatania, digested in hot water, and filtered after it becomes cold, to be a convenient form for keeping that test. When the proportion of gelatine to water is so small, as to compose only $\frac{1}{3000}$ th part of the solution, a considerable precipitate is produced by an infusion of galls (prepared by macerating an ounce of galls in a pint of water.) The stronger the solution of jelly, the more copious is the precipitate; till at length, when the gelatine is in large proportion, a dense coagulum is formed, which, after being dried in the open air, becomes a hard substance with a vitreous fracture. This compound appears to be equally formed, when animal solids, composed chiefly of gelatine, are immersed in solutions of tan; as when the skins of animals, for instance, are steeped in an infusion of oak bark. It is perfectly insoluble in water, and incapable of putrefying; and it constitutes the preservative part of tanned leather, to which it imparts the property of resisting the transmission of moisture.† The operation of tanning, consists essentially in the attraction of tan, from liquors which contain it, by the gelatine of the skins.

It would have been an important step towards the accuracy of the analysis of animal substances, if we could have ascertained the quantity of gelatine in any fluid, by precipitating it with tan. But to this there are two obstacles. Tan acts, also, on other animal fluids; upon albumen for instance. It appears, also, that into the precipitate of tan and jelly, these substances do not enter in absolutely fixed proportions. In general, however, Dr. Bostock has been led to conclude that the compound, formed by the union of jelly and tan, consists of somewhat less than two parts of tan to three of gelatine. And as we always have it in our power to ascertain what quantity of tan is employed in precipitating any solu-

* Hatchett, Philosophical Transactions, 1800.

† This is the substance which, in its soft state, I have before suggested as proper for the formation of bougies, catheters, &c. C.

tion of jelly, we may, by an easy calculation, approximate the quantity of jelly, contained in the fluid we are examining.

8. Gelatine has been analyzed by Gay Lussac and Thenard, who employed the oxymuriate of potash for its decomposition. One hundred parts were found to contain

Carbon	47.881
Oxygen	27.207
Hydrogen	7.914
Azote	16.998
	<hr/>
	100

In this analysis, there are 4.204 parts of hydrogen, beside what is sufficient to saturate the oxygen.

We are not acquainted with those circumstances, that occasion the differences in the several kinds of animal gelatine. Some valuable remarks on them may be found in Mr. Hatchett's "Observations on the component parts of Animal Membrane."*

SECTION II.

Albumen.

WITH the exception of gelatine, no fluid appears to enter so largely into the composition of animal substances, as albumen. It forms a large proportion of the blood and of various secretions; and appears to be the chief basis of several of the solids; viz. of the thin membrane which constitutes the cellular texture, as well as of the skin, glands, and vessels that convey the fluids.

The white of an egg, though not composed of absolutely pure albumen, contains it sufficiently so far for the exhibition of its properties. These will be found to be the following:

1. By agitation with water, the two fluids unite, and form a viscid liquid, the component parts of which do not separate by standing. This solution gives a green tinge to vegetable blue colours; a proof of the presence of uncombined alkali.

2. At the temperature of 160° Fahrenheit, undiluted albumen becomes solid, a change which is called its *coagulation*. When the solid mass is cut into slices, and suffered to remain for some hours, a few drops of a brownish viscid fluid ooze out, amounting to about 4½ grains from 100 of the original albumen submitted to experiment. By a long continued gentle heat, the coagulated substance itself loses at least four-fifths of its weight; and the solid matter is left behind, in the form of a hard brittle transparent substance. Hence it will follow, that 100 grains of the white of egg consist of 80 grains of water, 4½ uncoagulable matter, and only 15½

* Philosophical Transactions, 1800.

of pure albumen. At a temperature below that required for its coagulation, Dr. Bostock finds that it may be dried, and redissolved in water.*

Coagulation by heat is the distinguishing character of albumen, and affords an easy and obvious test of its presence; even when it forms a very minute proportion of certain fluids. By adding it, in gradually diminished quantity, to water, Dr. Bostock found that a solution, containing only $\frac{1}{1000}$ its weight of albumen, was rendered perceptibly opake by a boiling temperature. For all practical purposes, therefore, this may be considered as a sufficiently accurate test of its presence in any fluid.

The uncoagulated part of the white of egg, Dr. Bostock ascertained, was not affected by muriate of mercury, or by infusion of galls; but was copiously precipitated by Goulard's extract of lead. He considers it as a peculiar fluid to which he has given the name of *mucus*. Dr. Marcet, who finds it to be an ingredient of several morbid fluids, has proposed to call it *muco-extractive matter*.†

Albumen, which has been coagulated by heat, though perfectly insoluble in water, unless by long boiling aided by a Papin's digester, appears to have undergone no change in its chemical constitution. During coagulation, there is no absorption of oxygen; no gas is extricated; and hence there appears to be no re-action of the principles of the compound on each other. The coagulum is taken up by dilute liquid alkalis with a disengagement of ammonia. From this combination it is precipitated, unchanged, by acids.‡ By long boiling in water, however, though no apparent solution takes place, Mr. Brande obtained, from coagulated albumen, a fluid which had alkaline properties; and which gave, after evaporation, a viscid substance soluble in water. This fluid he apprehends to be a dilute solution of albumen in alkali.§

3. Albumen is coagulated by alcohol, and by acids. The coagulum, formed by the latter, always retains in combination, according to Thenard, a portion of the acid which has been employed. That produced by nitric acid is least soluble; and hence nitric acid occasions a precipitate from solutions of albumen, which are so dilute as not to be affected by other acids. The coagulum, produced by acids, is redissolved by pure alkalis, even, as Thenard finds, by ammonia, which does not dissolve albumen that has been coagulated by heat.

Alum, probably in consequence of its excess of acid, coagulates albumen; but does not act on very dilute solutions. One part in 500 of water is rendered slightly turbid by a solution of alum; but no precipitate is formed.

4. Albumen is coagulated by several of the metallic salts. Solution of corrosive muriate of mercury, which has no effect on gelatine or mucus, is a delicate test of the presence of albumen. A single drop of the solution, added to a liquor containing $\frac{1}{1000}$ its

* Medico-Chir. Trans. ii. 169.

† Ditto, 377.

‡ Thenard, Annales de Chimie, lxvii. 321.

§ Philosophical Transactions, 1809.

weight of albumen, renders it visibly milky; and, at the end of some hours, a flocculent precipitate falls to the bottom of the vessel. The same re-agent produces a sensible effect on a liquid, containing only half that quantity, or $\frac{1}{2000}$ of albumen.

Solution of corrosive sublimate, however, does not separate the whole of the albumen, unless heat is employed. The precipitate is a compound of the metallic salt with albumen, in the proportion of about one of the former to three or four of the latter. From the quantity of corrosive sublimate, therefore, required to decompose entirely a solution of albumen, we may infer the quantity of the latter; for three grains of the metallic salt, being entirely decomposed, indicate $10\frac{1}{2}$ grains of albumen.

Nitro-muriate of tin precipitates albumen, but less actively than the foregoing salt. Water, holding $\frac{1}{300}$ of albumen, was not altered by this test, till after some hours, when it became milky. Nitrate of silver occasions a precipitate; but the effect is equivocal, from its precipitating, also, the muriate of soda. Nitro-muriate of gold throws down a dense precipitate from a solution containing $\frac{1}{1000}$ of albumen. Goulard's extract occasions an abundant dense coagulum.

5. Solutions of albumen are decomposed by the addition of tan. When an infusion of galls, containing $2\frac{1}{2}$ parts of solid extract in 100, is added to a liquor, of which albumen forms only $\frac{1}{1000}$ part, no immediate effect is apparent; but, after some time, a precipitate ensues. If infusion of tan be poured into a concentrated solution of albumen, the precipitate has the consistence of pitch; is not susceptible of putrefaction; and, when dry, is brittle like overtanned leather. The precipitate by tan from diluted albumen, Dr. Bostock observes, is incoherent, subsides very slowly, and can scarcely be separated by a filtre; whereas the precipitate from solution of jelly of the same strength is a hard dense substance, which almost immediately separates from the fluid, and may be collected in a distinct mass.

6. Albumen, in whatever way it has been coagulated, appears to be slow in undergoing putrefaction. Mr. Hatchett kept it for some weeks under water, without any tendency to that state. According to Scheele, a small portion of coagulated albumen is soluble in dilute acids, and precipitable by the same acids when concentrated. By steeping albumen, for a month, in dilute nitric acid, Mr. Hatchett converted it into a substance, which was soluble in water, and affected chemical tests like gelatine.

7. Albumen contains a portion of sulphur in intimate combination, which gives it the property of blackening silver. This effect is often observed to be produced by eggs on spoons of that metal; and blood, evaporated in silver vessels, stains them with sulphuret of silver.

Many theories have been formed of the cause of the coagulation of albumen; but the first probable conjecture on the subject appears to have originated with Dr. Thomson.* The fluidity of albu-

* System of Chemistry, v. 489.

men he supposed to depend on the presence of alkaline matter, and its coagulation on the removal of the alkali, or its saturation with some other substance. This suggestion has been confirmed by some well devised experiments of Mr. Brande.* When the white of an egg was exposed to the action of a galvanic battery, a rapid and abundant coagulation took place round the negative pole, while a thin film only collected at the positive wire. This more copious precipitation at the negative pole appears to have been owing to the separation of alkali; and as it required, in order to produce the effect, a comparatively high electrical power, it should follow that the *rapid* abstraction of alkali is necessary to the perfect coagulation of albumen.

White of egg, then, is a compound of albumen with alkali and water. When heat is applied, the alkali is transferred to the water, and the albumen becomes insoluble. The alkaline liquor, which is thus produced, re-acts upon and dissolves a small quantity of coagulated albumen. When alcohol or acids are the coagulating powers, the effect is owing to a like transfer of alkali.

When the uncoagulable part of white of egg was exposed to a strong galvanic power, uncombined soda was found in the negative cup; and muriatic acid with a little coagulated albumen in the positive one. Hence fluid albumen contains both free soda and muriate of soda. In the experiments of Mr. Hatchett, 500 grains of dry albumen afforded $74\frac{1}{2}$ of coal, of which $11\frac{1}{4}$ were saline matter, composed, besides the salts that have been mentioned, of phosphate of lime and of phosphate and carbonate of soda.

From the researches of Mr. Brande it appears that galvanism may be applied to the discovery of very minute quantities of albumen, which are not rendered sensible by any other test. In this way, he produced a rapid coagulation, at the negative pole, in several animal fluids, in which albumen had not been supposed to exist. It has been ascertained, also, by Sir E. Home, that albumen is coagulated by galvanic arrangements of too low a power to affect even the most delicate electrometer; and hence he has proposed albuminous fluids as tests of the presence of small quantities of electricity.†

Albumen was found by Gay Lussac and Thenard, to consist of

Carbon	52.883
Oxygen	23.872
Hydrogen	7.540
Azote	15.705
	<hr/>
	100

Beside, therefore, the hydrogen required to saturate the oxygen, there are 4.285 parts in excess.

* Philosophical Transactions, 1809. † Ditto,

SECTION III.

Mucus.

THE term mucus had been employed in a vague and general sense, until Mr. Hatchett, in his valuable paper on the component parts of animal membrane,* attempted to assign to it a more definite meaning. Jelly and mucus he considers as modifications of the same substance, and as not essentially differing from each other. The latter term he restricts to that animal substance, which is soluble in cold water, and which cannot be brought to assume the gelatinous state. Dr. Bostock, however, has endeavoured to prove that mucus is a distinct fluid, characterized by a train of properties, which are entirely different from those of animal gelatine.† Fourcroy and Vauquelin have admitted, also, its claim to be considered as a peculiar compound.‡ They apply the term, in an enlarged sense, to the viscid liquor, which lubricates the mouth, the œsophagus, the stomach, the intestines, and, in general, all the cavities and passages of the body. It differs, they suppose, from vegetable gum, in nothing but in containing a proportion of nitrogen. In the descriptions of its characters, however, they are much less precise than either of the English chemists. Berzelius, on the other hand, seems scarcely to admit any fluid entitled to the general name of *mucus*; and finds that its chemical characters vary in different parts of the body, according to the purpose which it is intended to fulfil in the animal economy.§

The substance on which Dr. Bostock's experiments were made, was the saliva of the mouth, dissolved in water by agitation. No appearance of coagulation was produced by raising the temperature of this liquid to 212° , nor, when the liquid was evaporated, and suffered to cool, did it show any tendency to gelatinate.

No distinct effect was produced on the solution of mucus, by adding nitro-muriate of tin, muriate of mercury, or infusion of galls. Goulard's extract occasioned an immediate opacity, and, after some time, a flaky precipitate. Hence the effects, produced by the tanning principle and by Goulard's extract, establish a decided and essential difference between mucus and gelatine. Tan is a most delicate test of gelatine; but does not, in any degree, affect mucus. Goulard, again, is a sensible test of mucus, but not of jelly. Corrosive muriate of mercury, on the contrary, which discovers very small proportions of albumen, is not affected by either jelly or mucus.

Hitherto, however, Dr. Bostock has not been able to devise a method of determining, exactly, the proportion of mucus in any compound fluid. One great obstacle to all attempts of this kind is, that mucus, beside animal matter, appears always to contain common salt, which acts upon the tests; so that it is impossible to

* Philosophical Transactions, 1800.

† Nicholson's Journal, xi. and xiv.

‡ Annales de Chimie, lxxvii.

§ View of Animal Chemistry, p. 58.

say, how much of the effect is owing to each of these separate causes. The precipitates, thrown down from mucus by acetate of lead and nitrate of silver, Mr. Brande has found to consist both of the muriates and phosphates of those metals. From 1000 grains of saliva, he obtained by evaporation 120 grains of dry residuum, of which twenty grains were saline matter. The proportion of salts, in the mucus of the trachea, was even still greater. This variety of mucus, was not coagulated either by heat, by alcohol, or by acids.

In order to obtain mucus free from neutral salts, it occurred to Mr. Brande to attempt their decomposition by electricity. With this view, a mixture of saliva and water was placed in a vessel intermediate between two others, which contained water only (see i, fig. 82), and which were connected, the one with the positive, the other with the negative, extremity of a galvanic apparatus. Fibres of cotton connected the central vessel with the two others. In about ten minutes, a considerable quantity of white coagulum was formed upon the cotton on the negative side; but none on the positive. Thus albumen appears to be a constituent part of saliva, though not discoverable by the usual tests. A separation of alkali took place on the negative side; and hence Mr. Brande is disposed to consider mucus as a compound of albumen and muriate of soda, or of albumen and pure soda. The whole of this subject, however, is still obscure; and requires to be illustrated by farther experiments.

When mucus is evaporated to dryness by a gentle heat, no material change is produced in it. The result is a semi-transparent substance resembling gum, and, like it, soluble again in cold water. Neither alcohol nor ether dissolve it. By destructive distillation, it yields only the common elements of animal matter.

Mucus, as appears from Dr. Marcet's experiments, beside forming an ingredient of several healthy secretions, exists in some morbid fluids, particularly in that effused in all the forms of dropsy.

SECTION IV.

Fibrin, or Animal Gluten.

FIBRIN forms the basis of the muscular or fleshy parts of animals, and remains, combined with albumen, when all the soluble parts have been washed away by water. It may also be obtained from blood, by laying the coagulum on a linen strainer, and pouring water upon it, till a white fibrous matter alone remains.

For the purpose of submitting fibrin to a series of experiments, Mr. Hatchett obtained it by digesting shreds of lean beef, during 15 days, in water, which was changed daily, the temperature being such as not to excite putrefaction. The shreds of the muscle were

then boiled for five hours every day, during three weeks, changing the water at each boiling; and, finally, the residue was put into a press, and dried by the heat of a water bath.

The following history of the chemical properties of fibrin is derived chiefly from a memoir of Berzelius.

1. Fibrin is insoluble in cold water; but water, after being boiled upon it for some hours, is found to have acquired a milky hue, and, on the addition of infusion of tan, affords a precipitate of white and distinct flocculi, which do not cohere like those produced by gelatine. The liquid, obtained by boiling fibrin, does not gelatinate, to whatever degree it may be concentrated, but gives a white, dry, hard, and friable residue, which is soluble in cold water. By long boiling in water, fibrin loses its property of softening and dissolving in acetic acid.

2. Alcohol, of the specific gravity .810, converts fibrin into a kind of adipocirous matter, which is soluble in alcohol, and is precipitated by the addition of water. When alcohol, which has been digested on fibrin, is evaporated, a fatty residue is left, which did not pre-exist in the fibrin. By the action of ether, fibrin is converted into an *adipocire*, similar to the preceding, but in much greater abundance, and distinguished by a much more disagreeable odour.

3. In concentrated acetic acid, fibrin immediately becomes soft, transparent, and, with the assistance of heat, is converted into a tremulous jelly. By the addition of warm water, this jelly is completely dissolved, with the evolution of a small quantity of azotic gas. The solution is colourless, and of a mawkish and slightly acid taste. By sufficient evaporation, the gelatinous substance is reproduced, which, when completely desiccated, is a transparent mass, insoluble in water without the addition of fresh acetic acid. The solution gives a white precipitate with ferro-prussiate of potash, and with pure alkali; but a slight excess of alkali re-dissolves it. Sulphuric, nitric, and muriatic acids also occasion a precipitate, which consists of fibrin and the acid that has been employed. When laid on a filtre and washed, a certain quantity of this acid is carried off by the water, and the remaining substance is soluble in pure water.

4. In weak muriatic acid, fibrin shrinks, and gives out a little azotic gas, but scarcely any portion is dissolved, even by boiling. Concentrated muriatic acid, when boiled on fibrin, decomposes it, and produces a red or violet coloured solution. Fibrin, that has been digested with weak muriatic acid, is hard and shrivelled. By repeatedly washing with water, it is at length converted into a gelatinous mass, which is perfectly soluble in tepid water. The solution reddens litmus paper, and yields a precipitate with acids, as well as with alkalis.

5. Concentrated sulphuric acid decomposes and carbonizes fibrin. The same acid, diluted with six times its weight of water, and digested with fibrin, acquires a red colour, but dissolves scarcely any thing. The undissolved portion is a compound of fibrin with an excess of sulphuric acid; and when this excess is removed by water, a neutral combination is obtained, which is so-

luble in water, and possesses the same characters, as the neutral compound of fibrin and muriatic acid.

6. Nitric acid of the specific gravity 1.25 disengages at first azotic gas from fibrin, pure and unmixed with nitrous gas. By continuing the digestion 24 hours, the fibrin is converted into a pulverulent mass, of a pale citron colour, which when placed on a filtre and washed with a large quantity of water, becomes of a deep orange colour. This yellow substance was discovered by Fourcroy and Vauquelin, who obtained it by treating muscular flesh with nitric acid, and who gave it the name of yellow acid. Berzelius has ascertained that it is a combination of nitric and malic acids with fibrin, which is in some degree altered by the process.

7. In caustic fixed alkali, fibrin increases in bulk, and, at length, is completely dissolved. The solution is yellow with a shade of green; and is decomposed by acids, but the precipitated fibrin seems to have undergone some change, for it is not, as before, soluble in acetic acid. The compound of fibrin and alkali has not any analogy with soap, which Fourcroy asserts that it resembles.

8. Fibrin has been analyzed by Gay Lussac and Thenard, and found to consist of

Carbon	53.360
Oxygen	19.685
Hydrogen	7.021
Azote	19.934
	<hr/>
	100.

Besides the oxygen and hydrogen in the proportions required to form water, there is an excess of 4.337 parts of hydrogen per cent.

SECTION V.

Urea.

1. UREA may be obtained by the following process:—Evaporate, by a very gentle heat, a portion of human urine, voided six or eight hours after a meal, to the consistence of a thick syrup. In this state it concretes, on cooling, into a crystalline mass. Pour on this, at different times, four times its weight of alcohol, and apply a gentle heat, which will effect the solution of the greater portion. Decant the alcoholic solution, and distil it by a water bath, till it acquires the consistence of syrup, which is to be poured out of the retort. On cooling, it forms a crystallized substance, which is the urea.*

* Thenard recommends the following process as the best to obtain urea. "Evaporate urine to the consistence of a syrup, carefully managing the fire, especially at the close of the evaporation; add to this syrup by little and little, its volume

II. 1. Urea has the form of crystalline plates, crossing each other in various directions. It has a yellowish white colour; a smell somewhat like that of garlic; is viscid, and difficult to cut; and has an acrid strong taste. It deliquesces, when exposed to the air, into a thick brown liquid. It is extremely soluble in water, and absorbs caloric during solution. Alcohol dissolves it readily, but in less proportion than water; and the alcoholic solution yields crystals more readily than the watery one. Berzelius, by processes which he has not described, obtained urea quite free from colour, and forming distinct prismatic crystals like nitre.* Even in this state, he observes, it is still obstinately combined with lactic acid, lactate of ammonia, and the peculiar animal matter, which always accompanies the lactates. It is this animal matter, which gives the urine its colour.

2. The concentrated solution of urea in water yields, on the addition of nitric acid, a copious precipitate of bright pearl-coloured crystals, resembling the boracic acid. No other acid produces this singular effect.

3. The concentrated solution of urea, in water, is brown; but becomes yellow, when largely diluted. Infusion of galls gives it a yellowish brown colour, but causes no precipitate; nor is it precipitated by infusion of tan.

4. When heat is applied to urea, it melts, swells, and evaporates, with an insufferable fetid smell. By distillation, it yields above two thirds its weight of carbonate of ammonia; about one fourth of benzoic acid; besides carburetted hydrogen, and a residuum composed of charcoal with muriates of soda and ammonia.

5. The solution of urea in water putrefies, and is slowly decomposed; but much more rapidly, if a little gelatine be added. Ammonia and acetic acid are the products of its decomposition. If the solution, instead of being left to putrefy, be kept in a boiling temperature, and fresh water be added as the evaporation goes on, the urea is at length wholly decomposed. The condensed vapour is found to contain carbonate of ammonia; acetic acid is formed; and a portion of charcoal remains in the fluid contents of the retort. It has been ascertained, by those who distil the volatile alkali from urine, in manufacturing processes, that an equal quantity of ammonia is obtained whether the urine has undergone putrefaction or not.

6. When a mixture of urea, with one fourth its weight of diluted sulphuric acid is distilled, a quantity of oil appears on the sur-

of nitric acid at 24° . Agitate the mixture and place it in a bath of ice, to harden the crystals of the acid nitrate of urea which precipitate; wash these crystals with water at 0 . (32°) let them drain, and compress them between blotting paper. When we have thus separated the foreign matters which adhered to them, dissolve them in water; and add sufficient carbonate of potash to separate the nitric acid; then evaporate the liquor by a gentle heat almost to dryness: and treat the residue with very pure alcohol, which only dissolves the urea; concentrate the alcoholic solution, and the urea crystallizes." *Traité de Chimie*, 3d. vol. 445. C.

* View of Animal Chemistry, 8vo. p. 101.

face, which concretes by cooling; acetic acid passes over into the receiver; and sulphate of ammonia remains in the retort. The repetition of this process converts the whole of a portion of urea into ammonia and acetic acid.

7. Nitric acid acts rapidly on urea; nitrous, azotic, and carbonic acid gases, are disengaged; and prussic acid and ammonia are generated. The residuum, when dried and ignited, detonates like nitrate of ammonia.

8. Muriatic acid dissolves urea without alteration. When a steam of oxymuriatic acid gas is passed through a solution of urea, the gas is rapidly absorbed; and white flakes are formed, which soon assume a brown colour. After the solution has become saturated with gas, the effervescence still continues; and carbonic acid and nitrogen gases are evolved. The residuary liquid contains both carbonate and muriate of ammonia.

9. Urea is soluble in alkaline solutions; and, at the same time, undergoes a partial decomposition. A strong smell of ammonia arises, probably from the action of the potash on the muriate of ammonia which is contained in urea. When solid potash, however, is triturated with urea, the disengagement of ammonia is too great to be explained in this way; and can only be accounted for, by supposing the volatile alkali to be formed by the union of its elements. A strong solution of potash, heated with urea, produces a similar effect; a large quantity of ammonia is generated; the residuum diluted with water effervesces violently from the escape of carbonic acid gas; a flocculent precipitate is formed, which has the qualities of a concrete oil; and the liquor, when distilled, gives both acetic and benzoic acids.

10. Urea has the property of changing the form of the crystals of muriate of soda; a solution of that salt, mixed with one of urea, affording, on evaporation, octohedral crystals.* Muriate of ammonia, on the contrary, which usually crystallizes in octohedrons, has the form of its crystals altered by similar treatment, to that of cubes.

Of all the animal fluids, urea appears most readily to undergo decomposition, both from spontaneous changes in the arrangement of its elements and from the action of other substances. From a careful examination of the products of its distillation, Fourcroy and Vauquelin have given the following as the proportions of its elements, which are to be considered, however, as no more than approximations. One hundred parts consist of

Oxygen	. .	39.5
Nitrogen	. .	32.5
Carbon	. .	14.7
Hydrogen	. .	13.3

100.

* It is not necessary to take the urea itself; common salt dissolved in urine, and spontaneously evaporated, will afford many crystals of an octohedral shape. I once obtained several crystals from such a solution in very flat six-sided oblong tables: which however I could not preserve, for in less than a week, even in close bottles, they completely deliquesced. C.

SECTION VI.

Animal Resins.

THE properties of animal resins have not been fully investigated; but, so far as they have hitherto been examined, they appear to differ considerably from those of the vegetable kingdom.

THE RESIN OF BILE may be obtained by the following process : To thirty two parts of recent ox bile, add one of concentrated muriatic acid. When the mixture has stood some hours, strain it, in order to separate a white coagulated substance. Pour the filtered liquor, which has a fine green colour, into a glass vessel, and evaporate by a gentle heat. At a certain point of concentration, a green sediment falls down, which, after being separated from the liquid part, and washed, affords what has been considered as resin. Berzelius, however, (as will be more fully stated in the section on bile) denies that it is a true resin.

1. The resin of bile has a dark brown colour ; but, if spread out fine, on a white ground, it exhibits a bright grass-green. It is intensely bitter.

2. At about 122° it melts, and in a high temperature burns rapidly. It is soluble both in cold and hot water, and still more soluble in alcohol, from which it is in part precipitated by water.

3. With pure alkalis it combines, and forms a compound, which has been compared to soap. From these it is precipitated unchanged by acids.

4. When farther oxygenized, by adding oxymuriatic acid to bile, the resinous portion has its properties considerably altered ; it acquires the colour and consistence of tallow ; melts at 104° ; and dissolves in alcohol and in hot water.

Besides this resin, there are several animal substances which possess similar qualities. Such are the ear-wax, ambergris, castor, &c. ; for an account of which the reader may consult the fifth volume of Thomson's Chemistry.

SECTION VII.

Animal Sugar.

SUGAR enters pretty largely into the composition of milk ; and into the urine, when altered by disease. It may be obtained from milk by the following process :

- I. Let whey be evaporated to the consistence of honey, and allowed to cool. It concretes into a solid mass, which is to be dissolved in water, clarified by white of eggs, filtered, and again evaporated to the consistence of syrup. On cooling, a number of brilliant white crystals are deposited, which are the sugar of milk.

1. Sugar of milk has a sweetish taste, and no smell.
2. It requires for solution, seven parts of cold or four of boiling water; and is insoluble in alcohol. In these properties it differs from common sugar, and also in its relation to nitric acid, which will be afterwards stated, under the head of saccholactic acid.

Gay Lussac and Thenard have ascertained it to be composed of

Carbon	38.825
Oxygen	53.834
Hydrogen	7.341

100.

The oxygen and hydrogen are in the proportions necessary to form water; and the carbon is in excess.

3. When exposed to heat, it melts and burns with the same appearances as common sugar, and with a similar smell.

II. The urine of diabetic patients yields sugar on evaporation, which approaches more nearly in its characters to those of vegetable sugar, but is generally said to be incapable of crystallization. By exposing the solution, however, for some time to the air, and removing occasionally the scum which is formed, I have obtained beautiful white crystals, not inferior to those of vegetable sugar.*

SECTION VIII.

Animal Oils.

ANIMAL oils differ from the vegetable oils, in being generally solid at the temperature of the atmosphere, but are similar to them in other properties. Among animal oils, may be ranked butter, tallow, lard, suet, spermaceti, &c.

I. SPERMACETI bears some resemblance to wax, but differs from it in other properties. It is more readily fusible, viz. at 112° Fahrenheit; and is less soluble in boiling alcohol, of which it requires 150 times its weight. It is copiously dissolved by boiling ether; and the solution, on cooling, becomes a solid mass. Pure potash acts on it more remarkably than on wax; and the compound is quite soluble. A heated solution of ammonia affords a liquid, which is not precipitated by cooling, or by the addition of water; but is decomposed by acids.

II. A singular instance of the production of animal oil from the lean or muscular part of animals, is presented by the conversion

* By dissolving the extract of diabetic urine in alcohol, evaporating to dryness, redissolving in lime water, and again evaporating, I obtained a very beautiful crystalline mass of a yellow colour, but which I could never procure in a perfectly regular form. C.

of muscle into a substance resembling spermaceti, and called by the French chemists ADIPOCIRE. To effect this conversion, it is only necessary to confine the fleshy part of an animal in a box, with several holes in it, under the surface of a running stream. When thus confined, the change takes place spontaneously in the course of a few months. But it may be accomplished much sooner, by digesting animal muscle in strong nitric acid, and washing off the acid by water, as soon as the change has ensued. The substance, thus obtained, may be bleached, by exposure to the oxymuriatic acid gas.

Adipocire has a light yellow colour, the consistence of tallow, and a homogeneous texture. It melts at an inferior temperature to either of the foregoing bodies, *viz.* at 92° Fahrenheit. Cold alcohol has little action, but when heated, dissolves about $\frac{1}{4}$ or $\frac{1}{3}$ its weight. On cooling, it is deposited nearly white, and the alcohol has acquired a yellow tinge. Boiling ether dissolves nearly one fourth, which separates, almost white, on cooling. Fixed alkalis act on this substance, as on wax and spermaceti. Cold ammonia scarcely attracts it, and in this respect it differs from both the preceding substances.

III. The FAT of animals may be separated from the membranous and other substances, with which it is united, by melting it with a gentle heat, and with the addition of a small quantity of water. Fat, which has been thus prepared, is called *lard* when of a soft consistence, and *tallow* when harder. From the whale and some other animals, the fat is obtained fluid, and is then called animal oil.

Animal fat is insipid and free from smell. It cannot be combined either with water or with alcohol; but it unites with alkalis and forms soap. It is apt to become rancid by keeping, owing to the formation of an acid, most probably by the oxygenation of gelatine, or of some other animal substance which the fat contains.

Fat melts at a very moderate heat. Lard becomes fluid at about 92° Fahrenheit, and tallow a few degrees higher. At a still higher temperature, it is decomposed, and yields, among other products, a large quantity of olefiant gas. Hence its fitness for artificial illumination.

If fat be melted with about one sixteenth its weight of nitric acid, the mixture, being kept fluid, and constantly stirred for some time, a considerable change is produced in its appearance. Nitric oxide and nitrogen gases are evolved; and the lard becomes granular, of a firmer consistence, and soluble in alcohol. Any adhering acid may be removed by washing it with water. In this state, it has been called by the French chemists *oxygenated fat*.

Melted fat dissolves both sulphur and phosphorus. It unites, also, with several metallic oxides, and forms compounds, which have nearly a solid consistence.

SECTION IX.

Animal Acids.

OF the acids, that have hitherto been discovered to enter into the composition of animal substances, several have already been described, *viz.* the phosphoric, sulphuric, muriatic, carbonic, benzoic, acetic, and malic. Besides these, the following are either component parts of animal substances, or are formed by treating them with chemical agents.

I. The *uric acid*, or *lithic acid*, exists in human urine, even in its most healthy state. The substance, occasionally voided along with the urine, and called gravel, consists for the most part of uric acid; and this acid forms, also, one of the most common ingredients of urinary calculi. It may be obtained, by dissolving a calculus of this kind (the external characters of which will be hereafter described) reduced to fine powder, in solution of potash; decomposing the clear solution by muriatic acid *added in excess*; and washing the precipitate with a large quantity of distilled water. The precipitate may be drained, and dried at a moderate heat.

1. Uric acid, when pure, is destitute of colour, taste, and smell; it dissolves in 1720 parts of cold water, or in 1150 parts of boiling water; from which, on cooling, much of the acid precipitates. The solution reddens vegetable blue colours, and combines readily with pure alkalis, but does not effervesce with the alkaline carbonates. Fixed alkaline solutions dissolve a considerable quantity of uric acid, if the alkali be in excess. The saturated compounds, however, of uric acid with alkalis, termed urates, are not much more soluble than the acid itself. The combination of uric acid with soda, constitutes the principal part of the concretions found near the joints of gouty persons.

2. Nitric acid dissolves the uric acid, and the solution stains the skin of a pink colour. If the solution be boiled, carbonic acid and nitrogen gases escape, and prussic acid is formed. On evaporation to dryness, a bright red mass remains. By repeatedly distilling nitric from uric acid, the latter is at length wholly decomposed; carbonic acid and nitrogen gases are evolved; and a strong smell of prussic acid is produced. The residuary fluid deposits crystals, which Dr. Pearson found to be nitrate of ammonia. Oxymuriatic acid occasions the formation of muriate of ammonia, and of oxalic and malic acids.

3. When the uric acid is distilled *per se*, about one fourth its weight of a yellow sublimate arises, which contains no uric acid; but a new and peculiar one combined with ammonia. A few drops of thick oil make their appearance; and carbonate of ammonia, with some prussic acid, water, and carbonic acid are obtained. In the retort there remains about one sixth of charcoal.

II. There is a substance well known to physicians, as a deposit

from the urine at certain stages of fever, and in other diseases, under the name of laticious sediment. According to Proust, this sediment contains, mixed with uric acid and phosphate of lime, a peculiar acid, which he terms the *rosacic*, from its resemblance in colour to that of the rose. This acid, he observes, differs chiefly from the uric, in being very soluble in hot water; in having little tendency to crystallize; and in precipitating muriate of gold of a violet colour. It does not appear, however, that its properties have been hitherto investigated by any other chemist; and its existence may be considered, at present, as in some degree questionable.

III. The *amniotic acid* has been discovered by Fourcroy and Vauquelin, in the liquor of the amnios of the cow, from which, by slow evaporation, it separates in white crystals. It has a brilliant appearance; a slight degree of sourness; reddens vegetable blues; is scarcely soluble in cold water, but readily in hot, from which it separates, on cooling, in long crystals. It is also soluble in heated alcohol. It combines readily with alkalis and forms neutral salts, from which the amniotic acid is precipitated by other acids. It does not decompose alkaline carbonates; nor does it precipitate salts with earthy bases, nor the nitrates of silver, mercury, or lead. By a strong heat, it is decomposed, emits ammonia and prussic acid, and leaves a bulky charcoal.

IV. The *lactic acid* forms a component part of sour milk; from which the acid may be obtained by gently evaporating it to about one-eighth; filtering to separate the curd; and adding lime-water to the residue. An earthy precipitate is formed; from which it may be precipitated by oxalic acid. The lactic acid is thus obtained in an impure state, dissolved in water. Evaporate the solution to the consistence of honey; on this pour alcohol, and filter the solution. When the alcohol is separated by distillation, the lactic acid remains pure.

This acid has a yellow colour, is not susceptible of being crystallized, and attracts the humidity of the air. It combines with alkalis and earths, and forms deliquescent salts. It dissolves iron and zinc, with a production of hydrogen gas. It unites also with the oxides of other metals. In its properties, it bears most resemblance to acetic acid. Fourcroy, indeed, supposed that it is really the acetic acid, holding in solution a quantity of extractive matter and of the salts contained in whey, which disguise its ordinary properties.* But Berzelius contends that it is a distinct acid, and that it exists, either free or united with soda, in all animal fluids.†

V. The *saccholactic* or *mucous acid* is formed by pouring on powdered sugar of milk, in a stoppered retort, four times its weight of nitric acid, and distilling off a considerable portion of the liquor. On leaving it to crystallize, oxalic acid is obtained; but if, instead

* Nicholson's Journal, x. 264.

† Thomson's Annals, ii. 201, note. See also his investigation of the lactic acid, in Phil. Mag. xli. 241.

of this, the liquid be suddenly diluted with water, a white sediment forms, which may be separated by decantation and washing.

It may, also, be obtained by pouring on one part of gum arabic in a stoppered retort, two parts of nitric acid: applying heat a short time, till a little nitrous and carbonic acid gases have come over, and then allowing the mixture to cool. A white powder gradually separates, from which the liquid is to be decanted. The powder, after being washed several times with cold water, is saccholactic acid.*

This acid is about one fourth more soluble in hot than in cold water. Of the former it requires 60 parts. The solution is acid, and reddens the colour of litmus. At a boiling heat, it effervesces with alkaline carbonates; and unites readily with alkalis and earths, forming a genus of salts which are called *saccholactates*. With potash, it affords a salt soluble in eight times its weight of cold water, and crystallizable on cooling; and with soda a salt equally soluble, and requiring only five parts of water for solution.

The saccholactic acid is decomposed, when distilled at a red-heat, and yields an acid liquor, which deposits needle-shaped crystals. An empyreumatic oil is also formed, and a considerable quantity of carbonic acid and hydro-carburet gases. A considerable proportion of charcoal remains in the retort. Gay Lussac and Thénard have determined its composition to be

Carbon	.	.	.	.	.	33.69
Oxygen	.	.	.	.	.	62.69
Hydrogen	.	.	.	.	.	3.62
						<hr/>
						100.

There are, therefore, 36 parts of oxygen more than sufficient to saturate the hydrogen.

VI. The *sebacic acid* may be obtained from various species of animal fat. The simplest process for separating it is that of Guyton. To hogs'-lard, melted in an iron kettle, add pulverized quicklime, and stir the mixture for a few minutes, raising the heat towards the end of the process. When cold, the lard will be found to have less solidity. Pour on it a large quantity of water; boil them together, and filter the liquid. A brown acid salt will separate on cooling, consisting of lime, united with sebacic acid. This salt is contaminated with an admixture of oil, from which it may be separated by a degree of heat barely sufficient to decompose the oil. Re-dissolve and crystallize the residue; and, when again dry, distil it with one third its weight of sulphuric acid, diluted with water.

* From the greater facility of procuring this acid from gum, it appears to be the most appropriate base, from which to derive its name. The term is more easy, and its compounds especially are much more readily and harmoniously recognised as gummats, than as saccholactats. The acid I should therefore prefer to designate by the name of gummic acid. C.

Its purity from the latter acid may be ascertained by its affording, with a solution of acetate of lead, a precipitate soluble in nitric acid.

1. The sebacic acid is liquid, white, and has a penetrating smell. It reddens vegetable colours.

2. By distillation it becomes yellow, gives carbonic acid, and is partly decomposed.

3. It unites with alkalis; and, when mingled with nitric acid, dissolves gold.

4. Nitrate and acetate of lead give a precipitate, soluble in acetic acid. It decomposes the muriate of mercury.

According to Thenard, the acid which has been described is merely acetic acid, disguised by a little sulphurous acid. Besides this, however, there is a different acid not before observed, and which is really sebacic acid. It may be obtained by first distilling hogs'-lard, and washing the product with hot water. The watery solution, poured into one of acetate of lead, gives a flaky precipitate, which is to be heated, along with sulphuric acid, in a retort. No acid is distilled over; but on the surface of the matter in the retort, there floats a substance resembling fat, which may be separated, and washed with boiling water. The water entirely dissolves it, and becomes concrete on cooling.

The sebacic acid, thus procured, has a white colour; is without smell; has a slightly acid taste, and reddens infusion of litmus. When heated, it melts like a sort of fat; boiling water saturated with it becomes solid on cooling. Alcohol dissolves it copiously. It precipitates acetates and nitrates of mercury and lead, and nitrate of silver. The alkalis are neutralized by it, and form soluble salts, which do not decompose the solutions of lime, barytes, or strontites. It may be volatilized; but requires a higher temperature than benzoic acid, which, in several particulars, it resembles. Berzelius, indeed, considers it as merely benzoic acid, impregnated with other products of the distillation by which it has been obtained.

VII. The *prussic acid* is formed, chiefly during the decomposition of animal substances, at high temperatures. Three parts of blood, evaporated to dryness in an iron dish are to be mixed with one part of sub-carbonate of potash (common pearlash), and calcined in a crucible, which should be only two thirds filled by the materials, and loosely covered with a lid. The calcination must be continued with a moderate heat, as long as a blue flame issues from the crucible; and when it becomes faint, and likely to be extinguished, the process must be stopped. Throw the mass, when cold, into 10 or 12 parts of water; allow it to soak a few hours; and then boil them together in an iron kettle. Filter the liquor, and continue pouring hot water on the mass, as long as it acquires any taste. To this solution, add another, composed of two parts of alum and one of sulphate of iron, in 8 or 10 of boiling water; and continue the mixture as long as any effervescence or precipitation ensues. Wash the precipitate several times with boiling water. It will have a green colour; but, on the addition of a quantity of

muriatic acid, equal in weight to twice that of the sulphate of iron which has been used, it will assume a beautiful blue colour. Wash it again with water, and dry it in a gentle heat. In this state it is the pigment called Prussian blue, which consists of a mixture of prussiate of iron, with alumine. Its properties have already been described. (Chap. xix. sect. 8. v.)

From prussiate of iron, the prussic acid may be separated by the following process, invented by Scheele.

Mix two ounces of red oxide of mercury, prepared by nitric acid, with four ounces of finely-powdered Prussian blue, and boil the mixture with twelve ounces of water in a glass vessel, shaking frequently. Filter the solution, which is a prussiate of mercury, while hot; and, when cool, add to it, in a bottle, two ounces of iron filings, and six or seven drachms of sulphuric acid; shake these together, decant the clear liquor into a retort, and distil off one fourth of the liquor.

The distilled liquor is the prussic acid, which does not, like most other acids, redden vegetable blue colours, though it combines with alkaline and earthy bases.

Prussic acid has the following properties:

1. It is capable of assuming a gaseous form, and may be collected in that state over mercury, by heating, in a retort, the crystallized ferro-prussiate of potash with dilute sulphuric acid. This gas is absorbed by alcohol, and forms a permanent combination with it; but its solution in water undergoes spontaneous decomposition, becomes yellow in a few months, and deposits charcoal. The gas has, also, a constant tendency to escape from its watery solution.

2. Prussic acid gas is inflammable, and is instantly decomposed by contact with chlorine gas.

3. When received into the lungs of small animals, it is speedily fatal; and its watery solution, when taken into the stomach, proves almost instantly poisonous.*

4. In its pure state, it becomes a liquid at ordinary temperatures, as Gay Lussac has shown. To obtain it in this state, prussic acid gas was disengaged from prussiate of mercury by muriatic acid, and after passing through two bottles containing dry muriate of lime and chalk, was condensed in a third, which was surrounded by a freezing mixture.

5. Liquid prussic acid, thus procured, is a limpid and colourless fluid. Its taste is at first cool, but soon becomes hot and acrid. Though rectified from chalk, it still reddens litmus paper slightly. Its specific gravity at 45° Faht. is .7058. It is highly volatile, and boils at 79° Faht.; at 68° it supports a column of mercury at very nearly 15 inches; and it increases, five fold, the bulk of any gas with which it is mixed. It congeals at the temperature produced by snow and salt, and liquefies at 5° Faht. A drop of it placed on paper becomes solid instantly, because the cold, produced by the

* Robert, 92 Ann. de Chim. 52.

evaporation of one portion, reduces the temperature of the remainder below its freezing point.

6. It does not appear to have a strong affinity for alkalis; nor does it take them from carbonic acid; for no effervescence arises on adding it to a solution of alkaline carbonates. On the contrary, its combinations with alkalis and earths are decomposed by exposure to carbonic acid, even when highly diluted, as in atmospheric air. It readily combines, however, with pure alkalis; and forms crystallizable salts, which have an excess of alkali, are soluble in alcohol; and are incapable of forming Prussian blue with salts containing the peroxide of iron. But these simple prussiates, by combination with protoxide of iron, acquire all the characters of triple prussiates.

A new and ingenious view of the nature of the triple prussiates has lately been taken by Mr. Porrett, in the Philosophical Transactions for 1814. He considers them, indeed, not as *triple* salts, but as *binary* compounds of the respective bases with an acid, which is constituted of the elements of prussic acid, united with the protoxide of iron. That this oxide is really an element of the acid, and not a base, he has rendered highly probable by determining, that when prussiate of soda in solution is exposed to the agency of galvanic electricity, the black oxide of iron is carried along with the elements of the prussic acid, to the positive pole; whereas, if it had existed in the salt as a base, it would have appeared at the negative pole.

This compound acid he obtained in a state of watery solution, by adding, to a solution of triple prussiate of barytes, just sulphuric acid enough to precipitate the barytic earth. Its characters he describes as follows:

It has a pale lemon yellow colour; has no smell; is decomposed by a gentle heat, or by exposure to a strong light; in which case prussic acid is formed, and white triple prussiate of iron which, by absorbing oxygen, becomes Prussian blue. With alkalis, earths, and oxides, it forms, directly, the salts called triple prussiates. It displaces the acetic acid from all its combinations; and also detaches, from other acids, those bases, with which it is susceptible of forming compounds, that are insoluble in acids. As it is decomposed by heat, this acid can never be obtained by distillation. In that case, prussic acid and triple prussiate of iron are always formed.

This view of the subject explains why the iron, in triple prussiates, is not discovered by the most delicate tests; for it can no more be affected by them, than sulphur can be indicated by its appropriate tests, when existing in sulphuric acid.

In the nomenclature of prussic acid and its compounds, Mr. Porrett has not proposed any change; but for the peculiar acid, which it affords when combined with protoxide of iron, he suggests the name of *ferruretted chyazic acid*; and its compounds he terms *ferruretted chyazates*. It would, perhaps, have been preferable to have designated these bodies by the names *ferro-prussic acid*, and *ferro-prussiates*; at least these names have the advantage of greater brevity; and, for that reason, I shall employ them.

Beside the protoxide of iron, Mr. Porrett finds that there are other substances, which are capable of forming, with the elements of prussic acid, peculiar acids, characterized by a distinct train of properties. Sulphur is one of these bodies.

Sulphuretted chyazic, or sulphuretted prussic acid, was first obtained by Mr. Porrett, by decomposing Prussian blue with sulphuret of potash. To a heated solution of one part of the latter, three or four parts of Prussian blue in powder are to be added at distant intervals; and the liquid, which contains the compound in question, along with several neutral salts, is to be filtered: Or a solution of prussiate of mercury may be decomposed by hydroguretted sulphuret of potash: Or, lastly, a mixture of animal charcoal and sulphuret of potash may be calcined, in a red heat, for some hours, and the product lixiviated. The clear liquor (however obtained) is to be supersaturated with sulphuric acid; and kept, for a short time, at nearly the boiling point. A little finely powdered oxide of manganese, added when cold, turns the liquid a beautiful crimson. A solution of two parts sulphate of copper, and three of green sulphate of iron, is to be added, till this colour disappears. A white precipitate falls, which is a compound of protoxide of copper with sulphuretted prussic acid. The acid may then be transferred to potash, by boiling the precipitate with that alkali; and it may be obtained separate, by distilling the liquid with sulphuric acid.

The sulphuretted chyazic or prussic acid is generally colourless, but sometimes pinkish; it has the specific gravity 1.022; and it has a smell, resembling that of strong acetic acid. It dissolves sulphur when boiling, but lets the greater part fall again on cooling. It forms, with nitrate of silver and pro-nitrate of mercury, white precipitates. With alkaline and earthy bases, it composes a distinct genus of neutral salts.*

VIII. The *zoonic* acid has been shown by Thenard to be merely the acetous, holding some animal matter in solution. The *formic* acid, or acid of ants, was submitted to a course of experiments by Fourcroy and Vauquelin, who inferred that it is merely a mixture of acetic and malic acids. This conclusion was opposed by the experiments of Suersen, who endeavoured to prove that the formic is really a peculiar acid; but its identity with the acetic has since been confirmed.† Gehlen, however, has lately published a series of experiments, the object of which is to prove that the formic is really a peculiar acid. Its smell and taste differ, he alleges, entirely from those of acetic acid. When sufficiently cooled, it becomes solid, but does not crystallize. Its specific gravity is 1.1168; when diluted with an equal weight of water, it becomes 1.060; and with twice its weight, 1.0296; in all which respects it differs from acetic acid.‡

* This view of the prussic acid and its compounds, is in a great measure destroyed by later experiments on the subject by Gay Lussac, who has given an entirely new set of names to the Acid and its Compounds. It remains however yet to be known which, or whether either opinion is to be adopted. C.

† Ann. de Chim. lxiv. 48.

‡ Thomson's Ann. v. 24.

CHAPTER XXIII.

OF THE MORE COMPLEX ANIMAL PRODUCTS.

ALL arrangements of the various substances, that compose the animal body, must, in the present state of our knowledge, be entirely arbitrary; and it can, therefore, be of little consequence which of them is adopted. The most obvious division is that which distributes them into fluids and solids, and this order I shall follow in the description of their individual properties. A minute history, however, of all the variety of animal compounds would be foreign to the purpose of this work, and could not be given without very long details. For this reason, I shall notice, at greatest length, those, which are most interesting from their connection with animal physiology.

SECTION I.

Of the Blood—Respiration, &c.

THE blood, when examined as soon as it has been drawn from the body, is a smooth and apparently homogeneous fluid; viscid to the touch; and of a specific gravity exceeding that of water, in the proportion of from 1053 or 1126 to 1000. A vapour presently exhales from it, which has a peculiar smell, but which does not, when condensed, afford a liquid differing essentially from water. In a few minutes, a thin film appears on the surface; and, after a short time, the whole mass becomes coherent. When it has remained some time in this gelatinous state, a more complete separation of its principles ensues. Drops of a yellowish liquid ooze out from beneath the surface of the mass; and, at length, the whole is resolved into two parts, a firm red substance called the cruor, crassamentum, or clot; and a yellowish liquid termed serum. The proportion of these parts varies considerably; the crassamentum being much more abundant in vigorous well fed animals, than in such as have been debilitated by disease or by poor living.

The period, at which coagulation begins, varies not only with the condition of the blood itself, but with the circumstances in which it is placed. It commences sooner as the vessel is more shallow; but, on an average, it may be said to begin in about 3½ minutes, and to be completed in seven. Fourcroy states that, during coagulation, caloric is evolved; and this fact, which required confirmation, has been placed beyond a doubt by the experiments of Dr. Gordon, who found the coagulating part of a quantity of blood warmer than the rest, by from 6° to 12° Faht.*

* Thomson's Annals, iv. 139.

The *serum* is an apparently homogeneous fluid, with a yellowish and sometimes slightly greenish tinge; is unctuous to the touch and saltish to the taste. Its specific gravity is very variable, but on the average is about 1029. When exposed to a heat of 160° , and still more readily in that of 212° , serum is converted into a pretty firm white mass. This, in fact, is merely coagulated albumen, the properties of which have been already described. When cut into slices, and subjected to gentle pressure, a small quantity of a slightly opaque liquor, of a saline taste and a peculiar odour, oozes from it, which is called the *serosity*. This fluid has generally been considered as holding gelatine in solution; but Dr. Bostock has found reason to doubt the accuracy of the opinion; in which conclusion he is supported by Brande and Berzelius.

Mr. Brande coagulated two fluid ounces of serum, and digested the coagulum, cut into slices, in four fluid ounces of distilled water, which was afterward separated by means of a filtre. The liquid, when evaporated to half an ounce, gelatinized on cooling, and was precipitated by an infusion of tan; but this effect might equally well be produced by the presence of albumen; and decisive evidence of the presence of the latter substance was obtained, by placing some of the fluid in the Voltaic circuit, when a rapid coagulation of albumen took place round the negative wire. After having coagulated, by galvanic electricity, all the albumen of a portion of serum, the residuary liquor gave no indications of gelatine. Mr. Brande, therefore, infers, that the serosity consists of albumen, in combination with a large proportion of alkali.*

The serosity, according to Berzelius, contains no sulphuric acid, and only a vestige of the phosphoric; but it consists of water, of pure soda holding albumen in solution, of muriates of soda and potash, of lactate of soda, and an animal matter, which always accompanies the lactate.† The solid contents of the serosity, Dr. Bostock finds to vary from $\frac{1}{46}$ th to $\frac{1}{70}$ th of its weight; but on an average, they may be stated at $\frac{1}{50}$ th. It has been a subject of controversy,‡ which of the mineral alkalis exists in serum in an uncombined form. Dr. Pearson maintains that it is potash; but Drs. Bostock, Berzelius, and Marcet, allege that it is soda; and the evidence preponderates in favour of the latter opinion.

When serum is evaporated, at a heat below that required for its coagulation, it yields a yellowish semi-transparent mass, resembling amber, that splits to pieces in drying, and amounts to about 95 grains from 1000 of serum. This substance softens in water, and becomes gelatinous; and about 36 per cent. of its weight are dissolved, and may be passed through a filtre. The insoluble part is albumen; and much of this exists, also, in the filtered liquor, beside the neutral salts, which have already been mentioned.

The mineral acids coagulate serum, and so completely, that no albumen remains in the serosity. The insoluble compounds, which

* Phil. Trans. 1812.

† Thomson's Annals, ii. 201.

‡ See Medico-Chir. Trans. ii. 356, 368; and Nicholson's Journal, vols. 30, 31, 33.

are produced, exactly resemble those of the same acids with fibrin; and the action of alcohol is the same in both cases. Hence Berzelius contends, that there is very little difference between albumen and fibrin. The only character of distinction between them appears to be, that albumen does not coagulate spontaneously, but requires a high temperature; and from this circumstance, it is less rapidly soluble than fibrin in acetic acid.

The serum of human blood is composed, according to Berzelius, of

Water	905.0
Albumen	80.0
Substances soluble in alcohol, viz.	
Muriates of potash and soda 6 }	10.0
Lactate of soda and animal matter 4 }	
Substances soluble in water only.	
Soda, phosphate of soda, and a little animal matter	4.1
Loss	0.9
	<hr/> 1000.

This analysis agrees very remarkably with one of Dr. Marcet, who obtained the following ingredients. The substance, termed by him *muco-extractive matter*, is doubtless impure lactate of soda; and the sulphate of potash, and earthy phosphates, were probably formed by the combustion.

A thousand parts of human serum contain,

Water	900.00
Albumen	86.80
Muriates of potash and soda	6.60
Muco-extractive matter	4.00
Subcarbonate of soda	1.65
Sulphate of potash	0.35
Earthy phosphates	0.60
	<hr/> 1000.

Vogel considers sulphur as another constituent of serum; for he finds that when serum is kept for some days, at the temperature of between 75 and 90° Fahrenheit, a gas exhales from it, which renders legible characters written on paper with acetate of lead.* The same experiment was found to answer with the bile and urine; but it can scarcely be regarded as a proof, that the blood contains sulphur *as such*, or in any state but that of intimate combination.

* Ann. de Chim. vol. 87.

The *crassamentum* or clot is resolvable into two parts, viz. what has been called coagulable lymph or *fibrin* and *red globules*. The separation may be accomplished by long continued washing with water, which dissolves the red globules only, and leaves the fibrin. Its properties differ scarcely at all from those of fibrin obtained by the long boiling of muscular flesh.

Fibrin, as it is contained in the blood, is held in a state of solution; and it is still a question to what cause its spontaneous coagulation is owing. That it does not arise from the absorption of oxygen, is plain from the fact that blood, by exposure to oxygen gas, has its coagulation retarded. Hydrogen gas, also, delays its coagulation; but carbonic acid, nitrous, and nitrogen gases accelerate it. *In vacuo*, Mr. Hunter states that it occurs at the usual period; but it is not easy to conceive under what circumstances such an experiment could be fairly made. When intercepted in a living vessel, as by placing ligatures on a vein, Mr. Hewson found that blood remained imperfectly fluid for several hours. That mere rest is not sufficient to produce its coagulation appears, also, from the fact, that the blood continues fluid in cases where the circulation is suspended throughout the whole system; as in fainting, and in suffocation from drowning, and other causes. The coagulability of fibrin is destroyed, also, without our being able to explain the fact, in animals killed by electricity and lightning; by a blow on the stomach; by the poison of the viper; or by violent passions of the mind. In some diseases, on the contrary, its tendency to coagulation is greatly increased.

The *red globules of the blood* (that part to which its peculiar colour is owing) were first attentively observed and accurately described by Mr. Hewson. As their name imports, they have a globular figure, which is sufficiently visible with the aid of the microscope. They appear to dissolve readily in water, and tinge it with their own peculiar colour; but Dr. Young finds that the globule remains entire, though colourless. They are soluble in alkalis, acids, and alcohol, but not in the serum. The watery liquid turns syrup of violets green; and, after some time, deposits a flocculent precipitate, doubtless from the coagulation of albumen, the presence of which is indicated, also, by the effect of boiling the solution. It seems to consist of albumen, dissolved by an excess of pure soda. When evaporated and calcined in a crucible, a residuum is obtained, amounting to about $\frac{4}{1000}$ of the weight of solid matter, and composed, according to Fourcroy and Vauquelin, chiefly of subphosphate of iron.

It has been contended that the red colour of the blood is owing to the iron which it contains, but this opinion has been completely set aside by Prof. Berzelius and Mr. Brande. The former, indeed, admits that a small quantity of oxide of iron exists in the ashes of the colouring matter; while none, or at least an infinitely small portion, is afforded by the other ingredients of blood. He cut the *crassamentum* into thin slices, and placed them on blotting paper; and after this had ceased to draw out any moisture, he dried the slices. Four hundred grains of the dried substance left, after incineration,

five grains of ashes, which were composed (supposing 100 to have been operated on) of

Oxide of iron	50.0
Sub-phosphate of iron	7.5
Phosphate of lime with a small quantity of magnesia	6.0
Pure lime	20.0
Carbonic acid and loss	16.5
	<hr/>
	100.

The iron in colouring matter is not, however, in such a state, as to admit of its being detected by the nicest tests of that metal, until the composition of the colouring matter is destroyed. Nor is there any truth in the synthetic proof alleged by Fourcroy, that *sub-phosphate* of iron dissolves in albumen, and imparts to it a bright red colour, resembling that of blood.

To procure the colouring matter of blood in a detached state, Mr. Brande employed venous blood, stirred during its coagulation. The fibrin is thus removed; and the colouring matter is diffused through the serum, from which it gradually subsides in a very concentrated form. It retains, indeed, some serum; but this does not interfere with the effects of various agents upon the colouring principle.

The aqueous solution has a bright red colour, and is not very prone to putrefaction. It is not altered by any temperature below 190° or 200° Fahrenheit; but at higher temperatures, it becomes turbid, and deposits a pale brown sediment. If the fluid be poured upon a filtre, water passes through colourless; so that exposure to heat destroys the solubility of colouring matter.

Diluted sulphuric and muriatic acids, and acetic, oxalic, citric, and tartaric acids, dissolve the colouring matter, and extract it from the crassamentum. The solution has more or less of a scarlet hue, according to the acid employed; but it is always green, when viewed, in narrow tubes, by transmitted light. Nitric acid destroys the red colour, and converts it to a brown.

The pure and carbonated alkalis dissolve the red matter, the colour of which remains unimpaired. The solution in liquid ammonia approaches nearest to scarlet. When these solutions are supersaturated with muriatic or sulphuric acids, the liquid acquires a colour, similar to the original solution of the colouring matter by those acids.

Alumine cannot be brought to form a permanent red compound with the colouring principle of the blood. But when the colouring matter is left to stand a few days, in contact with a solution of the crystallized muriate of tin, a bright red powder precipitates, which is a combination of the colouring matter with oxide of tin. When kept in water, it sustains no change of colour; but when dried by exposure to air, it loses its brilliant tint, and assumes a dull red hue.

The most effectual mordants, which Mr. Brande discovered for the colouring matter, are solutions of mercury (especially the nitrate) and corrosive sublimate. When either of those salts was added to a watery solution of the colouring matter, a deep red compound was deposited, and the liquid became colourless. Woollen cloth, also, first impregnated in these solutions, and then dipped into the aqueous solution of colouring matter, acquired a permanent red dye, unalterable by washing with soap.

It appears, therefore, that the colouring principle of the blood is an animal substance of a peculiar nature, susceptible, like the colouring matter from vegetables, of uniting with bases, and admitting, probably, of important use in the art of dyeing. On examining the colouring matter, distinctly from the crassamentum, Mr. Brande did not discover a greater proportion of iron, than in the other principles of blood; and the theory may, therefore, be considered as completely set aside, which accounts for the red colour of the blood by the presence of iron.

It is doubtless on the red globules of the blood that the different gases act, which produce such remarkable changes in the colour of the entire fluid. Nitrogen gas blackens arterial blood, and, according to Girtanner, venous blood also. In an experiment of Dr. Priestley, it appeared that the bulk of a quantity of nitrogen gas, to which arterial blood was exposed, sustained a diminution. Blood, which has had its colour thus impaired, it was found by the same philosopher, may be restored to its bright florid hue, by agitation with oxygen gas; and these changes may, at pleasure, be repeated alternately. Oxygen gas, to which blood is exposed, is diminished in volume, and contaminated by carbonic acid. Atmospheric air undergoes the same change in consequence of the oxygen which it contains, but in a less remarkable degree.

Similar alterations are, also, constantly going on in the blood, during its circulation through the living body. In the veins it is of a dark red colour, inclining to purple. In this state it arrives at the right ventricle of the heart, by the contraction of which it is driven into the pulmonary artery. This artery is distributed, by extremely minute ramifications, over the whole surface of the air-cells of the lungs; and, in these, the blood is exposed to the action of atmospherical air, through the slender coats of the blood vessels. Here it acquires a bright vermillion colour; and, returning to the left ventricle of the heart by the pulmonary veins, it is distributed, by the contraction of this ventricle, through the whole body. In its course it loses its florid colour, and, after traversing the system, returns to the lungs, to be once more fitted for the performance of its functions.

The function of RESPIRATION consists of two distinct actions, that of *inspiration*, by which the air is drawn into the lungs; and that of *expiration*, by which it is expelled, after having served the purpose for which it was inhaled. By an easy natural inspiration, about twenty cubic inches may, perhaps, on an average, be the quantity taken in. It appears, also, from the recent experiments

of Messrs. Allen and Pepys,* that the same quantity is expired, with little if any diminution. Atmospheric air, after being once only admitted into the lungs, returns charged with 8 or $8\frac{1}{2}$ *per cent.* of carbonic acid gas. If the same portion be breathed repeatedly, considerable uneasiness is experienced; but the quantity of carbonic acid cannot be increased beyond 10 *per cent.* When the state of the expired air is examined by eudiometrical tests, a quantity of oxygen is found to have disappeared, equal in volume, according to the experiments of the same accurate chemists, to the carbonic acid which has been formed. Now as carbonic acid has been proved to contain exactly its own bulk of oxygen gas, it follows that all the oxygen, which disappears in respiration, must have been expended in forming this acid; and that no portion of it has united with hydrogen to form water. It may still, however, be doubted, whether the oxygen is absorbed through the coats of the vessels, and displaces carbonic acid, which may be supposed to have pre-existed in the blood; or whether this acid be not rather generated by the union of the inspired oxygen with the carbon of that fluid. Of the two suppositions, the latter appears to be the most probable.

The only change, then, that has been satisfactorily proved to take place in respired atmospherical air, is the removal of a certain quantity of oxygen (its nitrogen being wholly untouched), and the substitution of a precisely equal volume of carbonic acid gas. When, however, pure oxygen gas is respired, by an herbivorous animal, Messrs. Allen and Pepys have found that it cannot all be traced into this combination; but that a portion of oxygen has disappeared, and has been replaced by a corresponding quantity of nitrogen.† The addition of nitrogen appears to be made also, when a mixture of hydrogen and oxygen gases is breathed, in which the latter is in the same proportion as in atmospherical air. This mixture, it was found, may be respired for an hour without inconvenience. The substitution of nitrogen for the oxygen originally inhaled is a fact of considerable importance, and in the present state of our knowledge altogether inexplicable.‡

Besides carbonic acid, a portion of watery vapour is emitted from the lungs, and in a quantity sufficient to be visible when the atmosphere is of a low temperature. From various experiments, it may be inferred to amount to about three grains in a minute. Until lately the water, thus exhaled, was supposed to be generated in the lungs, by the union of the inspired oxygen with the hydrogen of the blood; but this hypothesis is inconsistent with the experiments of Messrs. Allen and Pepys, which have traced the whole of the oxygen into combination with carbon. It is proba-

* Philosophical Transactions, 1808.

† Ditto, 1809.

‡ How to explain the origin of the nitrogen above mentioned in the case where pure oxygen gas is respired, I cannot surmise; I think, however, its appearance in the other case, in which hydrogen was substituted for nitrogen, gives some considerable support to the opinion of nitrogen being a compound of oxygen and hydrogen. C.

bly therefore nothing more than the condensed vapour of a portion of that fluid, which is ordinarily secreted into the bronchial cells.

An important purpose of the function of respiration is, that it contributes to that equable temperature, which the animal body preserves, amidst all the changes in the surrounding medium. This is peculiarly the property of living matter; for all other bodies have the same degree of heat with the substances that are in contact with them. In the human body, the temperature varies only a very few degrees from 96° , whether it be exposed to a cold of many degrees below the freezing point; or whether it be surrounded by an atmosphere, little short of the heat of boiling water. There must, then, be certain processes in the animal economy, by which, in the former case, caloric is reduced from a latent form to that of temperature; and, in the latter case, by which the great excess of caloric is absorbed, and prevented from becoming injurious by its accumulation.

We are ignorant of those precise differences, which constitute the distinction between venous and arterial blood, or in what way the function of respiration converts the former into the latter. A fact, however, of considerable importance, on this subject, has been discovered by Dr. Crawford. The capacity of arterial blood for caloric he found to be superior to that of venous blood, in the proportion of 1030 to 892. When, therefore, arterial blood is converted into venous, a considerable quantity of caloric must pass from a latent to a free state, and must prove an abundant source of temperature. Now this is precisely what is constantly taking place in the body. Caloric is evolved by the combination of the inspired oxygen with carbon; but as the capacity of blood for caloric is, at the same time, enlarged, its temperature is not raised by being thus arterialized. In its progress through the system, the blood again suffers a diminution of capacity; and the caloric, which it had carried in a latent form to the remotest extremities, is extricated, and applied to the support of animal temperature. This theory explains why the heat is not excessive in the lungs, but is equally distributed over the whole body.* In animals, placed in a high temperature, Dr. Crawford has added the important fact, that the change of arterial into venous blood does not go on; and no addition of temperature is, therefore, derived from this source. Another cause, limiting the heat of the body under such circumstances, is the excessive evaporation which takes place from the surface of the skin, and which is indicated by a loss of weight of no inconsiderable amount.†

It is not in the lungs only that the blood exerts an action on at-

* To this explanation of the evolution of caloric, must be added, that which takes place by secretion; the newly formed matter having a less capacity for heat than the blood from which it was produced, must necessarily set free a portion of caloric; and this cannot be inconsiderable when we take into account the quantity of secreted matter from all the glands of the body. C.

† Nicholson's Journal, xvii. 215.

mospherical air ; for a similar function, it appears, belongs to the skin throughout the whole body. If the hand be confined in a portion of atmospherical air or oxygen gas, it has been ascertained that the oxygen disappears, and is replaced by a portion of carbonic acid. At the same time, a considerable quantity of fluid transpires, and may be collected by a proper apparatus.

The blood is subservient to various important uses in the animal economy. It is a source, from which are constantly prepared a variety of other substances, both solid and fluid, that are essential to our well being, and even to our existence. From the blood is derived the solid matter of the bones themselves ; it does not, however, exist in the blood in the state of sub-phosphate of lime or bone earth ; but appears to be produced, from the *ultimate* elements of blood, on the very spot where its presence is required.* The muscles, which are affixed to the bones, and which, acting as levers, enable us to change our situation at pleasure, are referrible to the same source ; and so also is all the variety of animal fluids, which perform a necessary part in the economy of this complicated machine. The solids and fluids, thus produced, are sometimes elaborated by complicated organs called glands, and are then termed *secretions*. A sufficiently exact and comprehensive knowledge of the business of secretion would have been attained, if we were able to discover, in the secreted solids or fluids, substances analogous to those which are found in the blood, and no others. But in many secretions we find principles bearing no resemblance to albumen, fibrin, or any of those fluids that form the proximate elements of the blood. In these cases, nature must have gone farther in the work of separation ; and, after disuniting the ultimate principles of the blood, have re-combined them in a new manner and in different proportions. This is a species of synthesis, which we have hitherto not been able to imitate in substances of the animal kingdom, and in very few instances even in vegetable products.

SECTION II.

Of the Secretions subservient to Digestion ; viz. the Saliva, the Gastric and Pancreatic Juices, and the Bile.

SALIVA is a liquid secreted by certain glands, and poured into the mouth, for the purpose of being mixed with the food during mastication. It is a slightly viscid liquor, of a saltish taste, destitute of smell, and of a white colour, or with a slight tinge of blue. Its specific gravity, according to Haller, is as 1960 to 1875, or, according to Siebold, as 1080 to 1000. The latter author has compared its consistence to that of a solution of one part of gum in forty parts of water. It is neither acid nor alkaline, and has there-

* Berzelius's Animal Chemistry, p. 19.

fore no effect on blue vegetable colours. Its quantity varies considerably. Nuck has estimated it at eight or ten ounces daily; and, during a mercurial salivation, several pints flow in the same interval.*

Saliva, when evaporated by a gentle heat to dryness, yields only a very small proportion of dry extract in thin semi-transparent plates: or if the process be stopped when about a third only remains, crystals of muriate of soda are formed. Exposed to the air, it appears to absorb oxygen, and becomes of a thicker consistence, whitish flocculi at the same time separating from it.

There is some difficulty in effecting the diffusion of saliva through water; but this may be accomplished by rubbing the two fluids together in a mortar. The solution, which is thus obtained, was subjected to the action of tests by Dr. Bostock.† Oxymuriate of mercury produced no immediate effect; but, after some hours, a light flocculent coagulum separated, leaving the liquid nearly transparent. The same test produced a still less striking effect in the filtered portion of some saliva, which had been several days exposed to the atmosphere. Infusion of galls precipitated white flakes, from the recent but not from the filtered liquor. The filtered fluid was copiously precipitated by Goulard's extract, and by nitro-muriate of tin. From these experiments, Dr. Bostock infers, that saliva contains coagulated albumen, and also a quantity of mucus and muriate of soda, but no gelatine. To the quantities of each, he considers the following as an approximation:

Water	80
Coagulated albumen	8
Mucus	11
Saline substances	1
	<hr/>
	100

Berzelius has lately published a more exact analysis of saliva.‡ Its constituents are

Water	992.9
A peculiar animal matter	2.9
Mucus	1.4
Alkaline muriates	1.7
Lactate of soda and animal matter	0.9
Pure soda	0.2
	<hr/>
	1000

When exposed to the agency of galvanic electricity, Mr. Brande has found that saliva, even after being first boiled in water, gives

* Fourcroy, *Système*, 4to. v. 268.

† Nicholson's *Journal*, xiv. 147.

‡ Thomson's *Annals*, iii. 25.

an abundant coagulation, and a separation of alkali round the negative pole, though neither acids, nor any of the common agents, showed the presence of albumen. Hence it appears that this substance may form part of an animal fluid, and yet not be discoverable by the common tests. In saliva Mr. Brande supposes that it is united with an alkali (probably soda) which, in this state of combination, loses its property of affecting vegetable colours.*

The GASTRIC JUICE is a fluid which is poured out upon the inner surface of the stomach, and is possessed of very extraordinary powers as a solvent. One of the great obstacles to an accurate analysis of it is the difficulty of procuring it sufficiently pure, and free from admixture with the contents of the stomach. It has been generally collected from animals, which have been kept, for some time before being killed, without food. In this state, it is a transparent liquor, having a saline and somewhat bitter taste, and containing neither uncombined acid nor alkali. It precipitates nitrate of silver; and, when evaporated, gives a solid residuum, which is deliquescent, and has an unpleasant smell. By the action of acids, a small proportion of albumen is discovered in it, and gelatine or mucus remains in solution. Vauquelin always found phosphoric acid in the gastric juice of herbivorous animals, whilst, on the other hand, that of man and carnivorous animals seldom give any visible traces of free acid or alkali.

This imperfect account of the properties of the gastric juice affords, however, no explanation of the solvent power, which it exerts on all animal and vegetable substances. Even out of the body, it appears, from the experiments of Spallanzani, to retard the putrefaction of animal substances, and to reduce them to a state somewhat similar to that, in which they are found after having been some time in the stomach. On substances taken into that organ its solvent power is even still more remarkable. In Dr. Stevens's experiment, hollow silver spheres, perforated with small holes, and containing animal and vegetable food, were swallowed by a man who possessed the faculty of doing this without injury, and with the result that the food was always dissolved, and the vessel voided in an empty state. After death, it appears from the observations of Mr. Hunter, that the stomach itself is sometimes eroded by the gastric juice, large holes having been found in it from the action of that fluid. These facts, as well as the power of the gastric juice in coagulating milk, are quite inexplicable on any known principle.

The PANCREATIC JUICE has not been examined with any attention. The only observations which we possess respecting it, are those of Dr. Fordyce. He found it to be a colourless liquid, slightly saline to the taste. By evaporation, muriate of soda was obtained, and the same salt was indicated also by nitrate of silver. Hence we may conclude it to be analogous in composition to the saliva.

The BILE is one of those fluids, which has attracted peculiarly

* Philosophical Transactions, 1809.

the notice of chemists, and which is, therefore, better understood than most others. It is to the labours of Fourcroy, and still more recently of Thenard,* who has published two memoirs on the bile, that we are chiefly indebted for our knowledge of its composition.

The bile of the ox, from the greater quantity of it which may be procured, has been mostly the subject of experiment. Its colour is commonly yellowish green, and very rarely deep green. When mixed with syrup of violets or infusion of turnsole, it produces no other change than what any other liquid of the same colour would effect. Its taste is bitter and at the same time sweetish, and excessively nauseous. Its smell is peculiar; and something like that of melted fat. Its specific gravity is 1026; its consistence variable, from that of a thin mucilage to that of synovia. Sometimes it is limpid, and, at others, contains flocculi of a yellow matter, which may easily be separated by water.

When submitted to heat, ox-bile first deposits a portion of coagulated matter, and yields a liquid, which has the peculiar smell of bile, and which throws down a white precipitate from acetate of lead. The solid residuum has a yellowish green colour; is very bitter; somewhat deliquescent; and entirely soluble in water and in alcohol. It melts at a moderate heat, and is decomposed by a still stronger one, the products being more oil, and less carbonate of ammonia, than from animal matters in general. A very bulky coal containing several neutral salts remains in the retort. The salts extracted from this coal, taking them in the order of their quantities, are muriate of soda, phosphate of soda, phosphate of lime, and sulphate of soda. Traces, also, are discovered of oxide of iron.

The uncombined soda in bile does not exceed $\frac{1}{200}$ its weight; and as this very minute quantity of alkali must be quite incapable of dissolving the large proportion of resin, which exists in that fluid, Thenard was induced to turn his attention to the discovery of some other solvent of resin, existing as a component of bile. Acetate of lead (the common sugar of lead of commerce) precipitates, he found, not only the resin, but the peculiar substance of which he was in search, in union with oxide of lead. But an acetate with a larger proportion of base (formed from eight parts of sugar of lead and one of litharge) produced a different effect; and precipitated only the albumen and the resin. When the remaining liquid was filtered, and the lead separated by sulphuretted hydrogen gas, it gave, on evaporation, a residue having less bitterness and considerably sweeter. In this state, the solvent of the resin could not be considered as pure, since it retained in solution a quantity of acetate of soda, arising from the decomposition, by the acetate of lead, of the salts of soda existing in the bile. He again, therefore, precipitated the solution by acetate of lead saturated with oxide, and obtained an insoluble compound of the peculiar matter and oxide of lead. This was dissolved in vinegar,

* Mémoires d'Arcueil, vol. 1.

the oxide of lead separated by sulphuretted hydrogen, and the acid expelled by evaporation.

This substance, to which Thenard has given the name of *picromel*, possesses the property of rendering the resin of bile easily soluble in water. Three parts are sufficient to one of the resin. The characters of picromel are, that it is insoluble in water and alcohol, and incapable of being crystallized; that it precipitates nitrate of mercury and acetate of lead with excess of oxide; and that it forms, with resin and a minute quantity of soda, a triple compound, which is not decomposable by acids nor by alkaline or earthy salts.

The resin is to be considered as the cause of the smell, and, in great part, of the colour and taste of the bile. It is solid; very bitter; and, when pure, green, but when melted it passes to yellow. It is soluble in alcohol and in pure alkalis, and is precipitable from the former by water, and from the latter by acids.

The yellow matter appears to be peculiar to the bile, and to possess characters distinct from those of other animal substances. Its presence seems to render the bile putrescent; and it is, also, the source of the concretions, which form in the gall-bladders of oxen. Insoluble by itself, it becomes soluble by the intervention of soda, resin, and picromel; and, whatever be the solvent, it is precipitated by acids.—In the analysis of bile, the first step was to separate this yellow matter, by adding nitric acid, and to free it from the portion of resin which adheres to it. Into the remainder, acetate of lead with excess of oxide (prepared as already directed) was poured, and an insoluble compound was formed, consisting of oxide of lead and resin, from which nitric acid detached the latter in the state of soft green flakes. Sulphuretted hydrogen was then passed through the liquid, which was separated by filtration from the precipitate and evaporated to dryness. Deducting, from its weight, that of the acetate of soda formed by the decomposition of acetate of lead; the weight of picromel was obtained. The saline substances were determined by calcination, lixiviation, and other common processes.

In this way, the composition of ox-bile was determined as follows:

Water	700	<i>or a little more.</i>
Resin	24	
Picromel	60.5	
Yellow matter	<i>variable—in this case 4.</i>	
Soda	4	
Phosphate of soda . .	2	
Muriate of soda . . .	3.2	
Sulphate of soda . . .	0.8	
Phosphate of lime . .	1.2	
Oxide of iron	<i>a trace,</i>	

800

The bile of the dog, the sheep, the cat, and the calf was found on analysis to be precisely similar to that of the ox. The bile of the pig, on the contrary, contained neither albumen, yellow matter, nor picromel. It consisted merely of resin in great quantity, of soda, and of salts, the nature of which has not yet been ascertained. It was entirely decomposed by acids, and even by the weakest, the acetic.

Berzelius denies the presence of resin in bile,* and asserts that it is not possible to repeat the analysis of that fluid, by the processes, which Thenard has described. The substance, he alleges, which, in bile, resembles resin, is precipitable by acids; and the precipitate is a compound of the acid employed with the green colouring matter of bile. When we use sulphuric acid with heat, a green liquid is obtained resembling a resin; and after saturating the acid with carbonate of barytes, the green matter is soluble in water, to which it imparts its own colour and bitterness. This is the characteristic ingredient of bile, which Berzelius calls *biliary matter*. He finds bile composed of

Water	907.4
Biliary matter	80.0
Mucus of the gall bladder	3.0
Alkalis and salts common to all animal fluids	9.6

1000.

The bile of birds contains a large quantity of albuminous matter. The picromel, which is extracted from it, is not sensibly sweet; but on the contrary has a sharp and bitter taste. It contains a mere trace of soda, and does not precipitate the super-acetate of lead.

HUMAN BILE was, also, an object of Mr. Thenard's researches; and his experiments, he is of opinion, have led him to as accurate a knowledge of it, as of any other species.—Its colour varies considerably; sometimes it is green, almost always brownish yellow, and sometimes it is without colour. Its taste is not very bitter. It is seldom perfectly limpid; for it generally holds suspended in it a certain quantity of yellow matter, which is sometimes even present in such quantity, as to render the bile clotted. When it is filtered, and submitted to a boiling heat, it becomes thick and emits the smell of white of egg. Evaporated to dryness, it affords an extract, which is equal to $\frac{1}{11}$ th the weight of the bile. This extract, by calcination, affords precisely the same salts as are found in ox-bile, viz. uncombined soda; muriate, sulphate, and phosphate of soda; phosphate of lime; and oxide of iron.

All the acids decompose human bile, and precipitate from it a large quantity of albumen and of resin. These may be separated from each other by alcohol. By the application of acetate of lead, no picromel can be discovered; nor is any other ingredient found

in human bile than yellow matter, albumen, resin, and saline substances. The proportions, ascertained by Thenard, are the following :

Water	1000*
Yellow matter, insoluble and floating in the } bile, a variable quantity from 2 to . . . }	10
Yellow matter in solution	<i>a trace.</i>
Albumen	42
Resin	41
Soda	5.6
Phosphates of soda and lime, sulphate and } muriate of soda, and oxide of iron . . }	4.5
<hr/>	
	1100

The yellow matter appears to be, in every respect, similar to that of ox-bile. The resin is yellowish; very fusible; very bitter, but less so than that of ox-bile; soluble in alcohol, from which it is precipitated by water; and soluble in alkalis, from which it is thrown down by acids. In water it appears scarcely to dissolve; and yet sulphuric and nitric acids occasion a precipitate from water which has been digested on it.

If bile be submitted to the action of galvanism, Mr. Brande has found that coagulation takes place at the negative pole, where soda also appears. At the positive pole muriatic and phosphoric acids are evolved.

BILIARY CALCULI. The composition of biliary concretions differs in different animals. Those of the ox contain traces of bile, which is removable by the action of water; after which they are entirely destitute of taste and smell. Their colour is a yellow of so much beauty as to render them a valuable pigment. They undergo no change at a heat below redness; but at this temperature they melt and swell, and after yielding the usual animal products, give about one sixth their weight of a white matter which is phosphate of lime. They are nearly insoluble both in water and in alcohol; and with some difficulty in alkalis, from which they are precipitated, in green flocculi, by acids. Boiling muriatic acid takes up only a small quantity, and renders them green. Hence they appear to be homogeneous; and to possess properties identical with those of the yellow matter of the bile of oxen, and of human bile.

The calculi of the human gall-bladder have been more attentively examined than those of the ox. It had been long known that they enter into fusion at a low temperature, and that the alkalis, and the fixed and volatile oils effect their solution. One of their distinctive characters was first pointed out by Poulletier de la Salle, *viz.* that of being soluble in boiling alcohol, and precipita-

* These are the numbers given by Thenard (*Mémoires d'Arcueil*, i. 57;) but as their sum exceeds 1100, it is probable that the error will best be corrected by reducing the proportion of water.

ble, on cooling, in the form of shining scales. Fourcroy afterwards discovered several important facts respecting them, and especially their resemblance to the substance which has been already described under the name of *adipocire*.

Of the calculi examined by Thenard, only a small number were formed of white plates, crystalline and shining, and entirely adipocirous. Many consisted of yellow laminæ containing from 88 to 94 *per cent.* of adipocire, and six or twelve of a colouring substance. A few were greenish on the outside, and yellow in their interior; several were covered, in spots at least, with a blackish brown crust, containing very little adipocire, but internally were like the rest. In all, excepting the perfectly white, there were traces of bile, discoverable by the action of water.—Calculi from the intestines were found to be similar to those of the gall-bladder.

We may conclude, therefore, with Fourcroy, that some of the calculi of the human gall-bladder consist entirely of adipocire; and that others are composed of the same substance, with the addition of a quantity of colouring matter, which is either yellowish or dark brown. When of the former colour, it appears not to differ from the yellow matter of the bile; and when of the latter, to be the same substance with an excess of carbon.

SECTION III.

Of Milk.

THE milk is a fluid which is secreted, by animals of the class *Mammalia*, for the nourishment of their young. Though differing considerably in the different species of animals, yet it admits of the following general description:

It is an opaque liquid, of a white colour, with sometimes a slight tinge of blue or yellow. Its taste is sweetish and grateful; but varies occasionally, as does its colour also, with the food of the animal. Its specific gravity is variable; that of cows' milk, according to Brisson, being about 1020, and that of ewes' milk 1040.

The milk may be resolved, partly by standing, and partly by agents that do not essentially alter the nature of its components, into three proximate ingredients, the cream, curd and whey.

1. The cream rises, as is well known, to the surface of milk after it has stood for some hours. It has many of the properties of an oil; is smooth and unctuous to the touch; and stains cloth in the same manner as other fat substances. By standing for some days, it becomes gradually thicker, and at length forms a soft solid, in which the flavour of cream is no longer perceived, and that of cheese is substituted in its place. Cream, of the specific gravity 1.0244, is composed, according to Berzelius, of

Butter . . .	4.5
Cheese . . .	3.5
Whey . . .	92.0
	<hr/>
	100.

But as 92 parts of whey contain 4.4 of sugar of milk and salts, it follows that cream contains 12.5 per cent. of solid matter.

When cream is agitated, as is done by the common process of churning, it separates into two parts, a thick animal oil, well known by the name of butter, and a fluid which possesses exactly the same properties as milk that has been deprived of its cream. This change has been supposed to be owing to the combination of the cream with the oxygen of the atmosphere; but it takes place, though perhaps not equally well, in vessels from which the air is excluded.

Butter has generally a yellow colour and a soft consistence. At the temperature of 96° or 98°, it melts, and when kept in this state for some time, a portion both of whey and curd separate from it. Its transparency is thus increased, but its taste, at the same time, rendered less agreeable. In this state, however, it may be kept longer without becoming rancid; and it is not improbable that it is in part by combination with the whey, that salt contributes to the preservation of butter. Butter, therefore, may be considered as an animal oil, united with a portion of whey and of curd.

When milk, either deprived or not of its cream, is mixed with certain substances, or even allowed to stand till it becomes sour, it undergoes a change which is called coagulation, consisting in its separation into a solid substance termed curd, and a fluid called whey. This change may be effected by several agents; by all acids, and by many neutral salts; by gum, sugar, and certain vegetable juices; by the gastric fluid; and especially by the infusion of the inner coat of a calf's stomach called *rennet*. The precipitation by acids, Scheele has explained, by supposing that they form, with the curd, a combination which requires more water for solution than milk contains;* and accordingly the curd is found always to contain a portion of that acid by which coagulation has been produced. But, in other cases, the coagulation cannot be thus accounted for; and is, indeed, altogether inexplicable. Thus the infusion of a piece of calf's stomach, not larger than half a crown, coagulates a quantity of milk sufficient for making a cheese of sixty pounds weight;† although the quantity of coagulating matter cannot in this case exceed a few grains.

The curd of milk, when pressed, salted, and partly dried, composes cheese. In good cheese, however, there is always a large proportion of butter, which is enveloped in the curd, and is not afterwards easily separable. Curd, therefore, for exhibiting its chemical properties, should be prepared from milk, which has been

* Essays, p. 267.

† Holland's Cheshire Report, p. 268.

deprived of cream, and should be made by the intervention of rennet. It is a white solid substance, insoluble in water and in alcohol, but readily soluble in pure alkalis, and precipitable therefrom by acids, though in a state more like tallow than the original curd. During solution in alkalis, a strong smell of ammonia is produced; and hence curd appears to be converted, by their action, into volatile alkali and fat. Liquid ammonia also dissolves curd; and it appears to be soluble by the pure alkaline earths. From the resemblance of its properties to those of the coagulated white of an egg, Scheele was induced to regard cheese as identical with albumen; and it is not improbable that if the curd could be obtained perfectly pure, their properties would exactly agree. By the combustion and calcination of curd, it appears, however, to afford a larger proportion of phosphate of lime and other saline substances, than is obtained from the coagulated white of an egg.

Berzelius found that the ashes, obtained by incinerating cheese, amount to 6.5 per cent. of its weight. The ash consists chiefly of earthy phosphates, with a little pure lime; but contains neither alkali nor oxide of iron. Cheese, digested with muriatic acid, loses its earthy phosphates, and afterwards burns without leaving any ash. The presence of so large a quantity of the earthy phosphates, in the most nutritious part of milk, may be regarded, Berzelius justly observes, as a wise provision of nature; and peculiarly adapts milk to the nutrition of young animals, in whose economy there exists the greatest demand for the earthy phosphates, for the purpose of ossification.

Cheese is generally considered as insoluble in water; but if it be precipitated from milk by sulphuric acid, then well pressed, and digested with carbonate of barytes, cheese affords with water a yellowish solution resembling a solution of gum. The solution boiled in an open vessel becomes covered with a white pellicle, precisely as milk does, and acquires the smell of boiled milk.

Cheese produces, with the mineral acids, the same combinations as albumen and fibrin, though its neutral compounds are less soluble than those of fibrin. A great excess of acetic acid is required to dissolve cheese, and the neutral compound formed with this acid appears to be insoluble. When it has not been completely separated from butter, this floats upon the surface of its solution in acetic acid. Alcohol converts cheese into an adipocirous and foetid substance.

The whey, or liquid which remains after the separation of all the curd, is a thin and almost transparent fluid, of a yellowish green colour and a pleasant sweetish taste. It still contains, generally, a portion both of curd and of butter; the former of which may be separated by a boiling heat, in the form of a coagulum. The buttery matter, also, separates by heat, especially if the whey be previously allowed to become sour.* Whey contains, indeed, in its recent state, some uncombined acetic acid.

* Cheshire Report, page 262.

When whey which has been deprived, as much as possible, of the butter and curd, is slowly evaporated, it yields the substance, already described under the name of sugar of milk. Besides this substance, it contains, also, several saline bodies, viz. muriate of potash, phosphates of lime and of iron, and sulphate of potash; and a peculiar animal matter, which gives a precipitate, with infusion of galls, and affords carbonate of ammonia by distillation. Sour whey contains also a peculiar acid called *the lactic*.

From this account of the composition of milk, several properties of the entire fluid may be understood. When fresh milk is boiled, its albuminous part is not coagulated into a mass like the white of an egg, on account of the large quantity of water, through which it is diffused; but a thin pellicle forms on the surface, which, if removed, is immediately replaced by another; and thus the whole of the albumen may be separated in successive portions. If the pellicle fall to the bottom, it becomes burnt, and gives the milk a peculiar flavour.

In order to procure butter from milk, it is not necessary, in the first place, to separate the cream; for butter may be obtained at once by the churning of milk, and has then the name of milk-butter. It is inferior, however, to butter made from cream, in consequence of its containing a larger proportion both of whey and of curd.

Milk is susceptible of the vinous fermentation, and is employed, by the Tartars, in making a sort of wine, which they call *Koumiss*.* It is prepared chiefly from mares' milk, and has an agreeable sweetish taste. By distillation, it yields a considerable quantity of alcohol. What is most remarkable with respect to this fermented liquor is, that it does not appear to owe its origin to the saccharine part of the fluid; for Fourcroy and Vauquelin have found that milk, after fermentation, yields as much sugar of milk as before.

There appears to be a considerable difference in the quality of the milk of different animals. Human milk is sweeter than that of cows; and yields a larger proportion of cream; but from this the butter cannot be separated by agitation. It deposits, also, a part of its curd by mere repose. Asses' milk bears a stronger resemblance to human milk than to any other. The cream is but in small quantity, and yields a soft white and nearly tasteless butter. The curd is so abundant, as even to separate on standing, before the milk becomes sour. Goats' milk yields a remarkably thick and unctuous cream, and abounds also in curd. The milk of sheep bears a strong resemblance to that of cows, and yields a large proportion of curd of a fat and unctuous kind. Mares' milk is thin, insipid, and affords very little cream, from which it is very difficult to separate any butter by agitation.

The constituents of skimmed cows' milk are stated by Berzelius as follows:†

* 37 Phil. Mag. 6.

† Thomson's Ann. iii. 27.

Water	928.75
Cheese, with a trace of butter	28.00
Sugar of milk	35.00
Muriate of potash	1.70
Phosphate of potash	0.25
Lactic acid, lactate of potash and a } trace of lactate of iron }	6.00
Earthy phosphates	0.30
	<hr/> 1000.

Of Chyle.

The chyle has been lately examined by Mr. Brande, who obtained it from the thoracic duct of an animal, about four hours after taking food. If taken at a longer interval, it is mixed with a greater or less proportion of lymph. When unmixed with blood, it has the following properties.

1. It is an opake fluid of a perfectly white colour, without smell, and having a slightly salt taste, accompanied by some degree of sweetness.

2. It does not affect the colour of litmus or turmeric, but it slowly changes violet paper to green.

3. Its specific gravity somewhat exceeds that of water, but is less than that of blood.

4. In about ten minutes after being taken from the duct, it assumes the appearance of a stiff jelly, which in the course of 24 hours, separates into two parts, producing a firm and contracted coagulum, surrounded by a transparent colourless fluid. Its spontaneous changes, indeed, bear a striking resemblance to those which take place in blood.

The coagulated portion has a closer resemblance to the cheese of milk, than to fibrin. It is rapidly dissolved both by pure and subcarbonated alkalis, forming pale brown compounds. Its solution in liquid ammonia is of a reddish hue. The acids throw down a substance intermediate between fat and albumen, which an excess of nitric acid redissolves in the cold; and sulphuric, muriatic, and acetic acids, by boiling for a short time.

Sulphuric acid, diluted, dissolves the coagulum, unless the water be increased to six times the weight of the acid. Alkalis do not precipitate the solution. It is transparent, of a pale brown colour, and, after the addition of alkali, is decomposed by infusions of tan.

When the coagulum is kept some weeks in one part of nitric acid, and 15 of water, it is converted into *adipocire*. Muriatic, acetic, and oxalic acids dissolve the coagulum; but neither citric nor tartaric have any action on it.

The serous part of the chyle, when heated, becomes slightly turbid, and deposits flakes of albumen. The clear liquid, by evaporation to half its bulk, deposits crystals, bearing a strong resemblance to sugar of milk. They are soluble in 20 parts of water at 60° Fahrenheit, or in four of boiling water, and the taste of the so-

lution is extremely sweet. By nitric acid, they are converted into a white powder, having the properties of *saccholactic acid*, as described by Scheele.

The destructive distillation of the serous part of chyle afforded a minute quantity of charcoal, with traces of phosphate of lime, and of muriate and carbonate of soda.

From these experiments, it appears that chyle bears a striking analogy to milk, not only in its external appearance, but in chemical properties and composition. It must be acknowledged, however, that the results, which have been described, are not perfectly coincident with those obtained by Emmert and Vauquelin, each of whom submitted to analysis the chyle of the horse. Emmert was unable to discover the smallest trace of sugar of milk;* and Vauquelin found also, 1st, a large proportion of albumen; 2d, a smaller one of fibrin; 3d, a fatty substance, which gives to the chyle the appearance of milk; and 4thly, several salts, such as potash, muriate of potash, and pro-phosphate of iron.† Berzelius, also, appears to distrust the analogy between chyle and milk.‡

SECTION IV.

Of the Mucus of the Nose; the Tears; the Humours of the Eye; and the Liquor of Surfaces and of Cavities.

1. *The mucus of the nose* was examined by Fourcroy and Vauquelin, in the state in which it is discharged during catarrh. Its principal qualities appear to be owing to the large proportion, which it contains, of the substance termed by Dr. Bostock animal mucus. By exposure to the air, this substance becomes viscid; but, when recently secreted, its consistence does not appear to be thicker than that of tears. It contains, besides other neutral salts, a small proportion of carbonate of soda; and hence it precipitates the solutions of barytes and of lime. Water does not dissolve it, and it can only be brought into a state of diffusion by agitation. The acids thicken it, when used in small quantity; but in a larger proportion they dissolve it. Pure liquid alkalis decompose it, and extricate ammonia. Oxymuriatic acid renders it thick and dry; and reduces it to a state almost resembling parchment.

Berzelius found the mucus of the nose to consist of

Water	933.7
Mucous matter	53.3
Muriates of potash and soda	5.6
Impure lactate of soda	0.9
Albumen and animal matter, insoluble in water, but soluble in alcohol }	3.5

1000.

* 80 Ann. de Chimie, 81. † 81 Ibid. 113. ‡ View of Animal Chemistry, p. 74.

2. The *tears* appear to differ from the mucus of the nose in no respect, except in being of a more fluid consistence. They are perfectly pellucid, have a saline taste, and a specific gravity rather greater than that of water. They change the colour of syrup of violets to green, owing to their containing a portion of uncombined soda. Mr. Hunter found that when tears are exposed to a temperature of 160° , a coagulum is formed; and that a substance still remains in solution, which is coagulable by Goulard's extract of lead. These properties indicate the presence both of albumen and of mucus. By evaporation, the tears afford a yellow extract, which is insoluble in water, but is readily soluble in alkalis. Sulphuric acid disengages from this extract both carbonic acid and muriatic acid gases. After its combustion, phosphate of soda and phosphate of lime are also discovered in it. Fresh tears are decomposed by oxymuriatic acid, and a precipitate is thrown down in flakes, which resembles the matter obtained by evaporation. Tears, therefore, are composed of water; an animal fluid resembling albumen; another fluid which is probably mucus; and various neutral salts.

3. *The humours of the eye.* The aqueous humour is a clear transparent liquid, of the specific gravity of 1009. It has little smell or taste, and scarcely affects blue vegetable colours. By evaporation it leaves a residuum, amounting to about 8 *per cent.* Boiling occasions a slight coagulation; and tan precipitates it, both before and after being heated. Nitrate of silver precipitates muriate of silver from it, but no other metallic salts affect it. Hence it may be inferred, that the aqueous humour consists of a large proportion of water; and of albumen, gelatine, and several neutral salts.

The vitreous humour agrees with the aqueous as to the nature of its ingredients, and differs only in their proportion. In the crystalline lens, both albumen and gelatine are present in considerably larger quantity. It is soluble in cold water; but the solution is coagulated by heat, and by the addition of tan. Its specific gravity is nearly 1100.—It appears, therefore, that all the humours of the eye are composed of the same ingredients, and differ only in the proportion which they bear to each other.

A recent analysis of the humours of the eye by Berzelius, has determined their composition as follows.

	Aqueous Humour.	Vitreous Humour.
Water	98.10	98.40
Albumen	a trace	0.16
Muriates and lactates . .	1.15	1.42
Soda with animal matter } soluble in water . . . }	0.75	0.02
	<hr/> 100.	<hr/> 100.

The lens of the eye was found to be composed of

Water	58
Peculiar matter	35.9
Muriates, lactates, and animal matter soluble in alcohol	} 2.4
Animal matter soluble only in water	
Insoluble membrane	2.4
	<hr/> 100.

4. *Liquor of surfaces.* On the surface of every cavity throughout the body a fluid is constantly poured out, in sufficient quantity to lubricate the parts; and occasionally, also, to keep certain cavities in a state of distension. To this head may be referred the fluid which moistens the pleura and the peritonæum, and the contents of the pericardium, of the ventricles of the brain, and of the amnios. It is only a part of these, however, that have been accurately examined.

The liquor of the pericardium has been analyzed by Dr. Bostock. It had the appearance of the serum of the blood; and when exposed to the heat of boiling water, became opaque and gelatinous. By slow evaporation it left a residuum equal to $\frac{1}{13}$ of the whole. It was precipitated by oxy-muriate of mercury; after the action of which infusion of galls had no effect, but a copious sediment was produced by Goulard's extract. From these characters Dr. Bostock is disposed to consider it as a compound of albumen and mucus with muriate of soda and water, but without any gelatine. The following proportions he assigns as approximations:

Water	92
Albumen	5.5
Mucus	2
Muriate of soda	0.5
	<hr/> 100*

The liquor of the amnios, or the fluid which surrounds the fœtus, is stated by Vauquelin and Buniva to be remarkable, in the cow, for affording a peculiar acid, already described under the name of the amniotic; but Dr. Prout, who has lately examined this liquor with much attention, was not able to detect any such principle.† The liquor, on which he made his experiments, had the sp. gr. 1.013. Its taste was bland and sweetish like fresh whey; and, when concentrated by evaporation, it yielded crystals of sugar of milk. It consisted of

Water	977
Albumen	2.6
Substance soluble in alcohol	16.6
Saline substances and sugar of milk	3.8
	<hr/> 1000

* Nicholson's Journal, xiv. 147.

† Thomson's Ann. v. 417.

In the human subject, the composition of the liquor of the amnios is entirely different; none of the amniotic acid appearing to exist in it. The only ingredients, that are found in it, are albumen, gelatine, with a portion of muriate and carbonate of soda and some phosphate of lime. It is precipitated by heat, by acids, by alcohol, and by infusion of galls.

5. *Lymph.* The fluid found in the thoracic duct of animals that have been kept 24 hours without food, is perfectly transparent and colourless, and seems to differ, in no respect, from that which is contained in the lymphatic vessels. Its properties are described by Mr. Brande as follows:

1. It is miscible in every proportion with water.
2. It produces no change in vegetable colours.
3. It is neither coagulated by heat, by acids, nor by alcohol, but is rendered slightly turbid by the last-mentioned agent.

4. It gives, on evaporation, a very sparing residuum, which turns the colour of violet paper green. By incineration, this matter gives a very little muriate of soda, but no iron.

5. When submitted to electrical action, there was an evolution of alkali, and a separation of albumen, at the negative pole. At the positive wire, muriatic acid only seemed to be evolved.

6. *Synovia.* This fluid which is found in the cavities of the joints, may, from its office in lubricating the parts in which it is found, be described in this place, though in composition it differs considerably from the liquor of surfaces. It is at first a viscid liquid, but soon becomes gelatinous; and, after remaining some time in this state, again assumes a fluid form and deposits a fibrous matter. Alcohol separates from it a portion of albumen, but the remaining liquid remains viscid. Acetic acid destroys its viscidly, and precipitates a quantity of white threads, which have a striking resemblance to vegetable gluten. The same substance is precipitated by the mineral acids, but not unless they are diluted with a large quantity of water; for in their concentrated form, they have the power of dissolving it. By continuing the analysis, several neutral salts may be obtained, and the proportions of the entire fluid have thus been stated by Margueron.*

Fibrous matter	11.86
Albumen	4.52
Muriate of soda	1.75
Soda	0.71
Phosphate of lime	0.70
Water	80.46

100

7. *The fluid of perspiration* has been examined by Berzelius; but under the disadvantage of operating in a very small quantity. A few drops, collected and evaporated on a watch glass, left a yellowish residue, having all the appearance, under the micro-

* *Annales de Chimie*, xiv.

scope, of the usual mixture of muriates of potash and soda with lactic acid, lactate of soda, and its accompanying animal matter. It reddened litmus, and dissolved in alcohol; and was, without doubt, of the same nature as the analogous matter found in other animal fluids. The acetic acid, which Thenard supposed he had discovered in the fluid of perspiration, was most probably a product of his mode of operating.

SECTION V.

Of the Urine and Urinary Calculi.

THE urine, though one of the most complicated fluids of the animal body, containing at least a dozen different substances, is perhaps one of those, the composition of which is now best understood. For a long period of time, the attention of chemists seems to have been limited to the extraction of phosphorus and neutral salts from urine; but a new direction was given to their labours, by the valuable discoveries of Fourcroy and Vauquelin.* The analysis of the urine has been prosecuted, also, with great success in this country by Cruickshank;† in Spain by Proust;‡ and recently by that indefatigable philosopher, Professor Berzelius of Stockholm.§ And though some important facts have been contributed by other persons, yet it is chiefly to these writers that we are indebted for the materials of its chemical history.

The external properties of the urine need no description; and indeed none would apply universally to a fluid, which is constantly varying, not only in the diseased but in the healthy state of the body. The following account of its chemical properties is to be understood as applying to the urine which is voided early in the morning, or at least several hours after a meal. In this state it has a deep yellow colour, and an intensely bitter taste. Its specific gravity is variable. Dr. Bryan Robinson fixes it at 1030, water being 1000; and Mr. Cruickshank found it to vary from 1005 to 1033. From my own experiments, I am disposed to consider the number stated by Dr. Robinson as a fair general average.

The substances, which appear to me to have been satisfactorily proved to exist in healthy urine, are the following:

- | | |
|---------------------------|---------------------------|
| 1. Water. | 11. Albumen. |
| 2. Free phosphoric acid. | 12. Lactate of ammonia. |
| 3. Phosphate of lime. | 13. Sulphate of potash. |
| 4. Phosphate of magnesia. | 14. Sulphate of soda. |
| 5. Fluoric acid. | 15. Fluuate of lime. |
| 6. Uric acid. | 16. Muriate of soda. |
| 7. Benzoic acid. | 17. Phosphate of soda. |
| 8. Lactic acid. | 18. Phosphate of ammonia. |
| 9. Urea. | 19. Sulphur. |
| 10. Gelatine. | 20. Silix. |

* Annales de Chimie, xxxi. 48.

† Annales de Chimie, xxxvi. 258.

‡ Phil. Mag. ii. 240.

§ Thomson's Annals, ii. 416.

The presence of an uncombined acid in urine is shown by its invariably, when recently voided, reddening blue vegetable colours. This effect is owing partly to the phosphoric, and partly to the lactic and uric acids, which urine contains. The lactic and phosphoric acids form the solvent, by which the phosphate of lime is retained in solution; and, if this portion of acid be saturated, the earthy salt is precipitated. Hence a few drops of pure ammonia, added to recent urine, occasion a white cloud, and a sediment of neutral phosphate of lime falls, in the proportion of about two grains from four ounces of urine. If lime-water be mixed with urine, a still larger quantity of phosphate of lime is deposited; for the newly added earth unites with the free phosphoric acid, and a quantity of phosphate of lime is generated, in addition to that which before existed in solution. In the precipitate, formed by either of these processes, a small proportion of magnesia is discoverable, which existed, no doubt, in combination with phosphoric acid. The sediment contains, also, according to Berzelius,* fluat of lime. The presence of the last-mentioned substance was ascertained by adding sulphuric acid, which set at liberty vapours of fluoric acid, in sufficient quantity to corrode glass.

When the urine had stood for about 24 hours at a mean temperature, the uric acid and phosphate of lime are in a great measure deposited; and still more speedily and completely, if the urine be first evaporated to half its bulk. They may be separated from each other, either by diluted nitric acid, which leaves the uric acid, and takes up only the phosphate of lime; or by calcining the mixture in a red-heat, which destroys the uric acid, but not the calcareous phosphate. By this operation, the uric acid is found to vary considerably; but the phosphate of lime is pretty constantly in the proportion of a grain from two ounces of urine. The quantity of uric acid, obtained from urine, is greatly increased by adding to that fluid almost any other acid, and allowing it to stand for some days; at the end of which time small crystalline grains will be found lining the inner surface of the vessel.†

The existence of salts, containing sulphuric acid, in urine, is proved by adding muriate of barytes, to urine acidulated with muriatic acid. This excess of acid prevents the precipitation of the phosphates, which would otherwise be decomposed by the barytic salt. From the weight of the precipitate, Berzelius computes that the proportion of sulphuric acid in urine exceeds that of phosphoric acid.—If nitrate of barytes, with an excess of nitric acid, be employed, and if the urine, after depositing the sulphate of barytes, be evaporated, a further portion of sulphate of barytes is deposited in small hard crystals. Now the sulphuric acid, which occasions this *second* production of the barytic sulphate, must have been *formed* during evaporation; and can only be accounted for by supposing, that a portion of sulphur, existing in the urine, has been acidified by the excess of nitric acid.

* Annales de Chimie, lxi. 256, and Thomson's Annals, ii. 416.

† Egan, Philosophical Magazine, xxiii. 298.

When urine, which has deposited its phosphate of lime and uric acid, is submitted to distillation, a liquid condenses in the receiver, which has a very peculiar and nauseous smell, and effervesces strongly with acids, in consequence of its containing carbonate of ammonia. In the retort there remains a residuum, which, if evaporated to the consistence of honey, composes from $\frac{1}{24}$ to $\frac{1}{36}$ the weight of the urine. When a little of this extract is added to a quantity of nitric acid, diluted with an equal weight of water, a number of shining white or yellowish scales are deposited, resembling the boracic acid, and in the proportion of $\frac{5}{8}$ or $\frac{7}{8}$ the weight of the extract. This precipitate is occasioned by the action of the nitric acid on the urea, which is contained in urine; and to the decomposition of the same substance is owing the carbonate of ammonia, obtained from urine by distillation. (See the section on Urea.)

From the extract of urine, the peculiar substance, called urea, may be separated by digesting the extract repeatedly with alcohol, and decanting the solutions, which are to be gently evaporated. Its proportion varies very considerably; but it has been stated, by Mr. Cruickshank, at about $\frac{1}{76}$ the weight of the urine, or one half the inspissated extract. The undissolved residue contains lactic acid and a number of neutral salts, consisting of muriate of potash, muriate of soda, phosphate of soda, and phosphate and lactate of ammonia. Muriate of ammonia is, also, occasionally found, and is dissolved, along with the urea, by the alcohol. These salts admit of being separated from each other by solution and evaporation. The muriates, at a certain degree of concentration, form a pellicle, which is to be removed while the liquor is hot. The solution, when cold, deposits two sets of crystals; rhomboidal prisms, which are the phosphate of ammonia; and rectangular tables, consisting of phosphate of soda.

Along with the urea, a portion of benzoic acid is, also, taken up by the alcohol. The presence of this acid in urine may be shown, by evaporating it to the consistence of syrup, and pouring in muriatic acid; when a precipitate appears, which consists of benzoic acid. In human urine its proportion is small, and Berzelius could not even discover a trace of it; but in that of herbivorous quadrupeds, so large a quantity exists as to be worth extraction. On the average, Vauquelin has shown that it forms about $\frac{1}{306}$ of the urine of this class of animals.*

If human urine be evaporated to the consistence of syrup only, and alcohol be added, the substance remaining undissolved is acid. The acid combines with ammonia, and the compound is soluble in alcohol. From this solution the ammonia is disengaged by lime; and from the new salt thus formed, the lime may be precipitated by oxalic acid, which leaves the *lactic acid* dissolved in water. By this process, a small part only of the lactic acid is obtained from urine; the greater portion of it being dissolved by the alcohol, together with the lactate of ammonia.

* Annales de Chimie, lxi. 311.

Albumen, gelatine, and mucus exist, also, in the urine, but in very variable proportion. When urine is heated nearly to the boiling temperature, a white flocculent precipitate often forms in it. This is in part phosphate of lime, thrown down by the ammonia resulting from the decomposition of urea; but it also contains coagulated albumen, which remains after adding muriatic acid to dissolve the calcareous phosphate. In dropsy, the proportion of albumen is often sufficient to produce a distinct coagulation, both by heat and acids. Gelatine is discovered, on adding infusion of galls, by a precipitate which amounts, according to Mr. Cruickshank, to one $\frac{1}{248}$ part the weight of the urine.

Mucus, also, is suspended in all newly evacuated urine, and affects its perfect transparency. If the urine be voided in different portions, the mucus, which naturally lines the urinary passages, is most abundant in the first, and less so in the subsequent portions. When recent urine is filtered, the mucus remains on the filter, in the form of transparent and colourless flocculi. The cloud, which appears in the urine during fever, is merely this mucus, which subsides more slowly than usual, in consequence of the increased specific gravity of the urine. From urine filtered when warm, a greyish white sediment falls in cooling, which gradually acquires a reddish hue and a crystalline form. The greyish powder is soluble in caustic potash, without any evolution of ammonia; but, as it becomes red and crystallized, potash disengages ammonia from it in abundance. Berzelius considers it, therefore, as urate of ammonia with excess of acid. The deposit is partly soluble, also, in acetic acid, which extracts a substance having the characters of mucus. There appears, indeed, to be an affinity between uric acid and mucus; for that acid separates most abundantly from urine, which has not been deprived of mucus by filtration. In some diseases of the bladder, its mucous secretion appears to undergo a considerable change, and to assume a purulent appearance.*

Sulphur was first discovered in urine by Proust. This fluid, he observes, blackens silver vessels in which it is evaporated, and scales are detached which consist of sulphuret of silver. Sulphuretted hydrogen gas, he finds also, is disengaged from urine which has been kept about fifteen days; a remark, which has since been made, also, by Vogel.

The same distinguished chemist supposed that he had discovered carbonic acid in urine, by examining the air bubbles which arise from this fluid during ebullition. There can be little doubt, however, that the carbonic acid, thus detected, arises from the decomposition of urea by the increased temperature. To the same source, also, (urea) may be referred the carbonate of lime, found by Proust on the surface of casks in which urine had been kept. By the decomposition of urea, carbonate of ammonia is formed; and this, re-acting on the phosphate of lime contained in urine, would doubtless compose carbonate of lime. The occasional presence of the sulphate of soda rests on better evidence; for it fre-

* Berzelius in Thomson's Annals, ii. 420.

quently happens that only a part of the precipitate, formed by adding muriate of barytes to urine, is dissolved by muriatic acid; thus indicating the formation of barytes.

The acetic acid and resinous matter, which Proust imagined he had discovered in urine, may be accounted for by supposing, that they were produced, rather than separated, by the processes which he employed. At least their existence in healthy urine is equivocal; and it is not improbable that this excellent chemist mistook the lactic for acetic acid. The acetic acid he obtained by distilling a fresh extract of urine with sulphuric acid; and the resinous matter by diluting the residue of this distillation when beginning to grow thick, with a large quantity of cold water; the excess of acid being afterwards removed by a little alkali. The resin thus produced he found to bear a striking resemblance to castor.

Berzelius discovered siliceous earth in urine by treating extract of urine, first with alcohol, then with water, and finally with muriatic acid. The silex remained in the form of a grey powder, which, by fusion with soda, became glass. Its source he apprehends to be in the water, which we drink, which almost universally contains silex.

With regard to the proportion of the different ingredients of urine, Berzelius finds that it differs essentially in the same individual, even from causes which have little influence on health. The following Table may be considered as shewing its average composition.

Water	. . . . .	933.00
Urea	. . . . .	30.10
Sulphate of potash	. . . . .	3.71
————— soda	. . . . .	3.16
Phosphate of soda	. . . . .	2.94
————— ammonia	. . . . .	1.65
Muriate of soda	. . . . .	4.45
————— ammonia	. . . . .	1.50
Free Lactic acid	. . . . .	} 17.14
Lactate of ammonia	
Animal matter soluble in alcohol and accompanying the lactates	
Animal matter insoluble in alcohol	
Urea not separable from the above	. . . . .	} 1.00
Earthy phosphates with a trace of Fluete of Lime	
Uric acid	. . . . .	1.00
Mucus of the Bladder	. . . . .	0.32
Silex	. . . . .	0.03
		1000.

The 17.14 parts of lactic acid, &c. contain a quantity of water, which cannot be abstracted without decomposing those bodies.

The uric acid is extremely variable; but in the particular instance, which furnished the above results, it was deposited on cooling. The earthy phosphates contain 11 per cent more magnesia, than exists in the earth of bones, or in the ashes of blood. Much more potash is discoverable, also, in urine and in milk, than in blood.

The putrefaction of urine is attended with a series of changes, somewhat analogous to those accompanying its distillation. The urea, which it contains, is decomposed and converted into carbonate of ammonia, which neutralizes all the redundant acids, and precipitates phosphate of lime. At the same time, the ammonia, uniting with the phosphate of magnesia, composes a salt, which settles in white crystals on the inner surface of the vessel. This salt is the ammoniaco-magnesian phosphate, which constitutes so large a part of some urinary calculi. The albumen and gelatine contained in the urine also undergo decomposition, and flakes are deposited, which consist of both these substances. Acetic acid is generated, and becomes saturated with ammonia. Acetate and carbonate of ammonia, and the ammoniaco-magnesian phosphate appear, therefore, to be the principal substances generated by the putrefaction of urine.

Some important facts have been ascertained by Mr. Crucikshank, respecting the changes that the urine undergoes in different diseases. In dropsy, the urine was coagulated so completely by heat and by acids, as to differ but little from the serum of the blood. When this disease, however, arose from a morbid state of the liver, the urine was not coagulable; but was observed to be small in quantity, high coloured, and to deposit a considerable portion of pink sediment (probably the *substance rosacée* of Proust.) In inflammatory affections, the urine was found to be loaded with albumen. In gout, towards the end of the paroxysm, the urine deposited a lateritious sediment, which consisted of a very minute quantity of uric acid, a larger quantity of phosphate of lime, and some peculiar animal fluid not soluble in water. The urine of jaundiced persons contained a small quantity of bile, which was discoverable by the addition of muriatic acid. Hysterical urine was remarkable for a large proportion of saline ingredients, but had scarcely any animalized matter.

The composition of the urine differs essentially in the different classes of animals. Urea appears to be a constituent of the urine of all animals, so far as it has hitherto been examined; but the uric acid is not found in herbivorous quadrupeds, the urine of which contains, instead of it, a large proportion of benzoic acid. That of the horse and of the rabbit are remarkable for becoming milky after being voided, in consequence of the deposition of carbonate of lime. The urine of the rabbit contains, also, carbonates of magnesia and potash, and sulphates of potash and lime. The urine of the cow, besides a larger proportion of benzoic acid, holds in solution carbonate and sulphate of potash and muriate of potash.—The urine of domestic fowls, which is voided through the same passage as the excrement, was found by Fourcroy and Vauquelin, and more lately by Chevreul, to contain uric acid. And

Dr. Wollaston has determined the proportion of uric acid to be greatest, in the urine of birds that feed on animal food. In the hawk, fed on flesh only, it was remarkably abundant; and the gannet, feeding solely on fish, discharged no solid matter except uric acid.* The uric acid has been found, also, by Dr. Prout† to constitute upwards of 90 per cent. of the excrement of an animal, belonging to a different class, the serpent called *boa constrictor*. Mr. Brande, some years ago, discovered it in the urine of the camel. But, on the other hand, Vauquelin has proved that it is entirely absent from the urine of the lion and tiger, though fed on flesh, and though their urine abounds in urea.‡

URINARY CALCULI. Connected with the analysis of urine is that of the concretions, which are found in the bladder, and which occasion a disease, equally formidable from its symptoms and its remedy. Little was known respecting their chemical composition, till the time of Scheele; to whom we owe on this, as on many other subjects, the first, and therefore the most difficult steps towards accurate analysis. By the discovery of the uric acid in one of the most common varieties of calculus, and in the ordinary urine, he paved the way to every thing that has been since ascertained, respecting other varieties; and his experiments have been most ably followed up by those of Dr. Wollaston, and of Fourcroy and Vauquelin. It is but justice to Dr. Wollaston, however, to state that the principal distinctions of the several species of calculus were pointed out by him in the year 1797,§ in a memoir not less distinguished by the importance of its facts, than by the simplicity with which they are narrated. Two years afterwards the experiments of Fourcroy and his associate were communicated to the National Institute; so that the title to priority unquestionably belongs to our own countryman.

The ingredients of urinary calculi are much less numerous than those of the urine. The following appear to be the only substances, the existence of which, in concretions of this sort, is sufficiently established; viz. uric acid; phosphate of lime; ammoniaco-magnesian phosphate; oxalate of lime; silex; and an animal matter, which serves the purpose of a cement to the earthy ingredients. To these, Proust has added the carbonate of lime;|| but, in this instance, there is reason to doubt of an authority which is in most cases unquestionable. It is scarcely ever that any of these substances is found singly. Nevertheless, the predominance of some one of them gives to the concretion its peculiar characters; and determines the genus to which it should be assigned. Several arrangements of urinary calculi have been contrived. Fourcroy and Vauquelin have enumerated three genera, which they have divided again into no less than twelve species. In these subdivisions, however, several minute differences have been attended to, which

* Phil. Trans. 1810.

† Thomson's Annals, v. 413.

‡ 82 Ann. de Chim. 199.

§ See the Philosophical Transactions for that year.

|| Ann. de Chim. xxxvi.

are scarcely sufficient grounds for specific distinctions ; and it appears to me sufficient for every purpose of arrangement to class them under the four following heads.

I. Calculi which are chiefly composed of uric acid :

II. Calculi principally composed of the ammoniaco-magnesian phosphate :

III. Calculi consisting, for the most part, of phosphate of lime :

IV. Calculi which derive their characteristic property from oxalate of lime ; and

V. Calculi composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide*.

I. The calculi composed entirely of uric acid are of very rare occurrence ; but those, in which it prevails, and gives the character of the species, form a very considerable proportion. Calculi of this kind are of various sizes, from that of a bean to that of a large egg. Their shape is most commonly a flattened oval ; but when more than one are found, they acquire, by friction against each other, several sides and angles. The best view of their internal structure is obtained by sawing them through their longest and widest diameter, when they exhibit generally a central nucleus, of more compact texture, and greater hardness and lustre, than the rest of the stone ; but generally of the same figure. From this to the circumference, a number of distinct layers are perceived ; and these layers, when the calculus is broken, exhibit a radiated structure, the radii converging towards the centre. The harder varieties, when divided by the saw, admit of some degree of polish, and bear a considerable resemblance to wood. Their colour is various, but generally of different shades of yellow, from pale straw yellow to a deep shade of that colour, approaching brown, or sometimes brown with a mixture of red. Their specific gravity, according to Fourcroy, varies from 1.276 to 1.786 ; but generally exceeds 1.500.

The chemical characters of calculi of this kind resemble those of the uric acid. When burned in a crucible, they emit the smell of horn, and are almost entirely consumed ; a black dense coal remaining which amounts to about one fifth the weight of the calculus. They dissolve, either wholly or in great measure, in solutions of pure potash and pure soda, and are precipitated again by acids. A very striking property of this sort of concretions is, that when a few grains are heated with a small quantity of nitric acid, and the mixture evaporated to dryness, a beautiful red substance remains, which dissolves in water and tinges the skin of the same colour.

II. The ammoniaco-magnesian phosphate is scarcely ever found without an admixture of some other substance, especially of a small proportion of phosphate of lime. Calculi of this sort are easily discriminated, from those of the first species, by their colour, which is white, and generally pure white. They attain a much greater size than uric acid calculi ; and, in one or two instances, have increased so as to fill the whole capacity of the bladder. The layers are distinguishable only by different degrees of hardness and density ; and small cells are often formed by the interrupted deposition of these layers, which are lined with sparkling crystals. The cal-

culi of this kind are soft, and their powder dissolves sufficiently in the mouth, to give a distinct sweetish taste.

Boiling water acts upon the ammoniaco-magnesian phosphate; and the calculus loses about four tenths of its weight, which is deposited, on cooling, in the form of shining crystals. When exposed to heat they first become black, emit a smell of ammonia, and a white powder is left, which fuses when the heat is more strongly urged. From this property, Dr. Wollaston gave them the name of *fusible calculi*. Most acids (even sulphuric acid of the specific gravity 1020) dissolve them rapidly, and deposit them again on the addition of alkalis. Pure alkalis do not dissolve them, but disengage ammonia. To extract the phosphoric acid, Dr. Wollaston dissolved the calculus in acetic acid, and precipitated the phosphoric acid by an excess of acetate of lead. To the clear liquor, sulphuric acid was added, which threw down the excess of lead, and, at the same time, formed sulphate of magnesia. Evaporation to dryness removed the acetic acid; and, by raising the heat, the sulphate of ammonia and excess of sulphuric acid were expelled; leaving the sulphate of magnesia pure, and capable of forming crystals by solution and evaporation.

III. The third species of calculus, composed chiefly of phosphate of lime, is usually, on its outer surface, of a pale brown colour, and so smooth as to appear polished. When sawed, it is found to be regularly laminated, and the layers adhere so slightly, as to be readily separated into concentric coats. Internally the colour is white, but not of that pure and brilliant kind, which distinguishes the ammoniaco-magnesian phosphate. The small crystals, also, which occur in the former variety, are never found in this; and its powder, when rubbed between the fingers, is considerably more harsh and rough.

The phosphate of lime calculus dissolves, though slowly, in diluted nitric, muriatic, and acetic acids (but not in sulphuric acid of the specific gravity 1020), and is precipitated unchanged by alkalis. A small fragment put into a drop of muriatic acid, on a piece of glass over a candle, is soon dissolved; and, when the acid is evaporated, crystallizes in needles, which make angles of 60° and 120° with each other. This property Dr. Wollaston considers as a very delicate test of the phosphate of lime.

IV. Calculi of the fourth kind, though their composition was not ascertained, have been long distinguished from others, by the peculiarities of their external characters, under the name of *mulberry calculi*. The epithet has been derived from their resemblance to the fruit of the mulberry. They are of a much darker colour than the other varieties, and are covered, generally, with a number of projecting tubercles. Their hardness greatly exceeds that of the other kinds; for it is not easy to reduce them to powder by scraping with a knife. They have also a greater degree of specific gravity, varying, according to Fourcroy, from 1428 to 1976.

Calculi of this species are soluble in muriatic and nitric acids; but not unless the acids are concentrated and heated. The solution by muriatic acid has a deep brown colour, but deposits white crys-

tals on cooling. Pure alkalies do not decompose this variety of calculus; but when it is digested with alkaline carbonates, the oxalic acid is separated, and replaced by carbonic acid. To exhibit the oxalic acid in a separate state, the oxalate of potash may be decomposed by acetate of barytes or super-acetate of lead, and the oxalate of lead or barytes by sulphuric acid. This is the process of Fourcroy; but Dr. Wollaston disengaged the oxalic acid by the direct addition of sulphuric acid to the pulverized calculus, and the crystallization of the acid which was thus detached.

The presence of lime, in this variety of calculus, is demonstrated, in a very simple manner, by burning it in a crucible, and strongly calcining the residuum. By the addition of water, we obtain lime-water. *Silex* is a very rare ingredient, and has been discovered in calculi, in one or two instances only.

V. A new species of calculus from the human bladder was discovered by Dr. Wollaston, about the year 1805. It appears to be extremely rare; for in 1810, when its properties were first described in the *Philosophical Transactions*, only two instances of it had occurred to its discoverer. With the assistance of Dr. Wollaston's clear and accurate description, and of the proper experiments, I have recognized two other examples, in a collection of calculi now in my possession; and these four are, I believe, the only specimens of it, that have hitherto been met with.

In external appearance, these calculi resemble more nearly the triple phosphate of magnesia than any other sort of calculus; but they are more compact, and do not consist of distinct laminæ, but appear as one mass, confusedly crystallized throughout its substance. They have a yellowish semi-transparency, and a peculiar glistening lustre, like that of a body having a high refractive density.

Under the blow pipe, the new calculus gives a peculiarly fœtid smell, quite distinct from that of uric acid. Distilled in close vessels, it yields fœtid carbonate of ammonia, partly solid and partly fluid, and a heavy fœtid oil; and there remains a black spongy coal, much smaller in proportion than from uric acid calculi.

It is so readily acted upon by chemical agents, that its characters are best taken from an enumeration of the few feeble powers, which it can resist. These are water, alcohol, acetic, tartaric, and citric acids, and saturated carbonate of ammonia; all which are incapable of dissolving it, except in very minute proportion.

Its solvents, on the other hand, are far more numerous. It is abundantly dissolved by muriatic, nitric, sulphuric, phosphoric, and oxalic acids; by potash, soda, ammonia, and lime water; and even by fully saturated carbonates of potash and soda. When therefore, it is intended to separate it from acids, the carbonate of ammonia is best adapted to the purpose; and, for the same reason, the acetic and citric acids are best suited to precipitate it from alkalis.

Its combinations with acids crystallize in slender spiculæ, radiating from a centre, which readily dissolve again in water. Its compounds with alkalis form small granular crystals.

As this substance does not affect vegetable colours, and has all the chemical habitudes of an oxide, Dr. Wollaston distinguishes it by the name of *cystic oxide*.

Such are the principle kinds of urinary concretions. If any addition were made to the five classes, under which they have been arranged, I would propose to add two others; the sixth comprehending those calculi, which contain several of the foregoing ingredients, in such a state of admixture as not to be distinguishable without chemical analysis; and the seventh those, in which the different substances are disposed in layers or in concentric strata. It may be proper, however, to give an outline of the classification, proposed by Fourcroy and Vauquelin, after the analysis of more than 600 of these concretions.

GENUS I.—CALCULI COMPOSED OF ONE INGREDIENT ONLY.

- Species* 1. Calculus of uric acid.
 2. ———— urate of ammonia.*
 3. ———— oxalate of lime.

GENUS II.—CALCULI COMPOSED OF TWO INGREDIENTS.

- Species* 1. Calculus of uric acid and earthy phosphates in distinct layers.
 2. ———— of uric acid and earthy phosphates intimately mixed.
 3. Calculus of urate of ammonia and the phosphates in layers.
 4. ———— of the same ingredients intimately mixed.
 5. ———— of earthy phosphates mixed or else in fine layers.
 6. ———— of oxalate of lime and uric acid in distinct layers.
 7. ———— of oxalate of lime and earthy phosphates in layers.

GENUS III.—CALCULI COMPOSED OF THREE OR FOUR INGREDIENTS.

- Species* 1. Calculus of uric acid or urate of ammonia, earthy phosphates, and oxalate of lime.
 2. ———— of uric acid, urate of ammonia, earthy phosphates, and silex.

The urinary concretions, which have been extracted from the bladders of inferior animals, differ from those of the human subject

* The existence of urate of ammonia, as an ingredient of calculi, has lately been rendered very questionable, to say the least, by Mr. Brande, with whose experience on this point my own entirely agrees.

in containing no uric acid, and in consisting chiefly of carbonate and phosphate of lime, cemented by animal matter.

SECTION VI.

Of Bones, Shells, Crusts, Horn, and Cartilage.

THE bones of animals are composed partly of earthy salts, which give them solidity and hardness, and partly of animal matter, which serves the purpose of a cement, and keeps the earthy ingredients in a state of union. By long continued boiling, a large part of the animal matter is extracted, and a solution is obtained, which concretes, on cooling, into a gelatinous mass. Hence bones contain gelatine as one of their ingredients. But besides this animalized substance, another is discovered by the slow action of diluted nitric or muriatic acid. Either of these acids dissolves both the earthy salts and gelatine; and a soft flexible substance remains, retaining, in a great measure, the shape of the original bone. This soft and spongy substance seems to be analogous to cartilage; and is essential to the constitution of all organized bones and shells. Its production appears to be the first step in the formation of bone, and of the other hard coverings of animals. In chemical composition, it has been found by Mr. Hatchett (to whom we owe its discovery) most to resemble coagulated albumen.

Besides the marrow, which is lodged in the hollow cavities of bones, they contain, in the most hard and solid part of their substance, a proportion of oil. This oil makes its appearance in a hard and suetty form, on the surface of the gelatinous mass extracted by boiling. It exudes, also, from the bones of recent anatomical preparations; and a portion of it passes over, in a separate but altered state, when bones are submitted to distillation. By this process, bones are deprived not only of their oily part, but the other animal substances which they contain are decomposed; a quantity of carbonate of ammonia is generated; and in the retort there remain the earthy ingredients blackened by charcoal. By a farther combustion in the open air, this charcoal is destroyed; and the earthy ingredients are left in a perfectly white state. In this way large quantities of bones are distilled for the sake of the carbonate of ammonia, which is afterwards applied in making the muriate of that alkali. The animal oil (formerly used in medicine, under the name of *Dippel's oil*) is now, on account of its offensive smell, which unfits it for most other purposes, chiefly converted into lamp-black.

When diluted muriatic or nitric acid is poured upon the white ashes of bones, an effervescence takes place, and nearly the whole is dissolved. Solution of pure ammonia added to the filtered liquid, precipitates a white earth in great abundance; but after it

has ceased to produce any effect, the addition of carbonate of ammonia occasions a fresh precipitation. What is thrown down by the pure alkali is composed of phosphate of lime and a small quantity of phosphate of magnesia; and the precipitate by the mild alkali is the carbonate of lime. The proportions, deduced from the analysis of ox-bones by Fourcroy and Vauquelin, are the following:

Animal matter	51
Phosphate of lime	37.7
Carbonate of lime	10
Phosphate of magnesia . .	1.3
	<hr/>
	100

Human bones were found by Fourcroy and Vauquelin (who have given a good general formula for the analysis of bones*) to contain some iron and manganese, and a larger proportion of magnesia than exists in the bones of herbivorous quadrupeds. This, indeed, might have been expected from the large quantity of magnesia, which is constantly passing off in human urine, but not in that of other animals. Alumine and silex were, also, found, by the same chemists, in human bones. Hildebrandt, however, has lately analyzed human bones, without being able to discover magnesia in them.†

Besides the above ingredients, Mr. Hatchett discovered in bones a minute quantity of sulphate of lime; and Berzelius has detected a combination of fluoric acid with the same earth, which Morochini had previously found in enamel. Berzelius has given the following tabular view of the results of his analysis.‡

	Dry Human Bones.	Enamel of Hu- man Teeth.	Dry Ox Bones.	Enamel of Ox Teeth.
Cartilage	32.17		33.30	3.56
Blood vessels	1.13			
Fluate of lime	2.0	3.2	2.90	4.0
Phosphate of lime	51.04	85.3	55.45	81.0
Carbonate of lime	11.30	8.0	3.85	7.10
Phosphate of magnesia . . .	1.16	1.5	2.05	3.0
Soda, muriate of soda, } water, &c.	1.20	2.0	2.45	1.34
	<hr/>	<hr/>	<hr/>	<hr/>
	100	100	100	100

Human teeth are composed of the same ingredients as the enamel, and in the same proportion, except that, in addition to other ingredients, they contain cartilage. This cartilaginous basis Mr.

* 72 Ann. de Chim. 282.

† 88 Ann. de Chim. 199.

‡ Annales de Chimie, lxi. 257.

Hatchett found to remain, in the original shape of the tooth, after removing the other component parts by diluted nitric acid. The enamel, on the contrary, dissolves entirely in diluted nitric acid, and is, therefore, free from cartilage. But it probably contains gelatine, and to the solution of this animal substance (which is not afterwards precipitable by alkalis) may perhaps be ascribed the loss, which forms part of the following results of the analysis of enamel obtained by Mr. Pepys. He found the enamel of human teeth to consist of

Phosphate of lime	78
Carbonate of lime	6
Loss and water	16
	<hr/>
	100

The substance of the teeth Mr. Pepys found to be composed as follows :

	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
	<hr/>	<hr/>	<hr/>
	100	100	100

The shells, with which several marine and also some land animals are covered, have been divided by Mr. Hatchett into two classes. The first, from their resemblance to porcelain, he has termed porcellaneous shells. To this class belong the several species of *voluta*, *cypræa*, &c. The second class approach in their characters to mother of pearl. The shell of the fresh water muscle, and of the oyster, may be arranged under this head ; and pearl itself has the same characters and chemical composition. Comparing the experiments on both classes, Mr. Hatchett concludes that porcellaneous shells consist of carbonate of lime, cemented by a very small portion of animal matter ; and that mother of pearl and pearl do not differ from these, except in containing a smaller proportion of carbonate of lime. This, instead of being merely cemented by animal matter, is intermixed with and serves to harden a membranous or cartilaginous substance, which is capable of retaining its form, after the removal of the earthy ingredient.

The covering of crustaceous animals (as echini, star fish, lobsters, crabs, &c.) differs in composition from marine shells, and approaches that of the eggs of birds. The shells of eggs, Mr. Hatchett found, are composed of carbonate of lime, with a small proportion of phosphate of lime, cemented by animal matter.

Vauquelin has lately added to these ingredients of egg shells, carbonate of magnesia, iron, and sulphur.*

Horn differs essentially from all the substances, that have been described in this section. The proportion of earthy matter obtained by its combustion, scarcely amounts to $\frac{1}{300}$ part. It appears to consist principally of gelatine and coagulated albumen.

Of Cartilage.

Chevreul has analyzed the cartilage of the *squalus peregrinus*. He found it to be sparingly soluble in water; the solution was viscid, foamed on agitation; restored the colour of reddened litmus; and was precipitated by sulphuric, nitric, or muriatic acid, an excess of which redissolved the precipitate. Oxymuriatic acid occasioned a deposit, as did also the pro-nitrate of mercury and the sub-acetate of lead. Infusion of galls produced only a slight cloud.

When boiled with alcohol, the cartilage shrunk in bulk, and became opaque by losing water. The first washings had the colour of ammoniuret of copper, and deposited an animal matter. From the residue of the evaporation of these washings, hydrate of lime disengaged a large quantity of ammonia.

Cartilage dissolved in muriatic acid, and the solution was precipitated by infusion of galls. Nitric acid dissolved it, and when evaporated, gave oxalic acid, nitrate of soda, a yellow matter, different from that of Welther, and an odorous oil.

By destructive distillation, it gave the ordinary products of animal substances.

SECTION VII.

Of Muscle, Membrane, Tendon, Ligament.

THE *muscular flesh* of animal consists chiefly of the peculiar substance, which has been already described under the name of *Fibrin*. Though generally of a reddish colour; yet, essentially, muscular fibre is white, and may be obtained in this state, if all the soluble parts be first washed away by long continued affusions of water, which acquires a dark colour. The solution, if concentrated by boiling, gelatinates on cooling; and hence gelatine appears to be one of the constituents of muscle. Albumen is another ingredient, and makes its appearance by a deposition of coagulated flocculi in the heated watery solution. A portion of fat, also, frequently concretes on cooling; but this is to be considered rather as an accidental admixture. From the gelatine, when evaporated to dryness, alcohol removes a peculiar kind of extract, soluble in water and in alcohol, and first described by Thouvenel. The entire

* 81 Ann. de Chim. 304.

muscle, when calcined, leaves about 5 *per cent.* of its weight of saline matter, composed chiefly of phosphates of soda, ammonia and lime, and carbonate of lime.

Lean flesh, Berzelius finds, is composed of nearly three-fourths its weight of fluid. This fluid contains a free acid; and the extract, which Thouvenel described, is the same acid syrupy mass, which is met with in milk and urine, and which consists of lactic acid, an alkaline lactate, and the animal matter, that always accompanies the lactates. The fluids of muscle abound much more in this syrupy extract, and contain more phosphate of soda, than the blood. The solid fibre is interwoven with the cellular texture, and is furnished with minute veins and nerves. It agrees, in chemical properties, with the fibrin of the blood; and it is soluble, except the cellular texture of veins and nerves, in acetic acid. By boiling it becomes, like the fibrin of blood, insoluble in acetic acid, and imparts to the water, with which it has been boiled, a constituent part, which has a strong and pleasant taste of flesh, and cannot be gelatinized. When this is dissolved, and mixed with the uncoagulated part of the humours of the flesh, it forms what is called *broth*, the strength and taste of which depend, not only on the dissolved gelatine of the cellular texture, but also on the fibrin, the taste of which it retains. The taste does not depend on the extractive matter of Thouvenel; for flesh, from which this extract has been separated, still gives a palatable though colourless soup.

Considerable differences exist in the colour and other properties of the muscular flesh of different animals; but the cause of these differences is not well understood. It depends, most probably, on the proportion which the fibrin, albumen, and other principles bear to each other. Gelatine appears to be most abundant in the flesh of young animals; and albumen and extract in that of old ones.

The *tendons*, or *sinews* as they are commonly called, are the strong cords in which muscles terminate, and which connect them with the bones. They differ from muscle in the total absence of fibrin; and in being completely soluble in water by sufficiently long boiling. The solution has the properties of gelatine.

The *ligaments* are excessively strong bands, which tie the bones together at the different joints. They are in a great measure, but not completely, soluble by boiling water; and contain, therefore, beside gelatine, some other animal substance, probably coagulated albumen.

Membranes are thin semi-transparent substances which sometimes form bags for containing fluids, and sometimes line the different cavities of the body. They are for the most part, though not entirely, soluble in water; and are composed, therefore, chiefly of gelatine. Hence by the common process of tanning, membranes are convertible into leather. There is an essential difference, however, between cellular or serous membranes, and mucous membranes. The latter furnish no gelatine by boiling; and are sooner destroyed than any animal substance, the brain excepted; by maceration in water, or by the action of acids.

SECTION VIII.

Of the soft Coverings of Animals, viz. Nails, Scales, Skin, Hair, Feathers, and Wool.

THE *nails* and *hoofs* of animals most nearly resemble horn in chemical composition. Their basis seems to be a series of membranes composed of coagulated albumen, in which is deposited a quantity of gelatine. Long boiling does not entirely dissolve them. By calcination they have only a very small proportion of earthy matter.

The *scales* of serpents also resemble horn in their chemical composition and properties. The scales of fish, on the contrary, are more nearly analogous to mother of pearl, and are composed of alternate layers of membrane and phosphate of lime.

The *skin* consists of two distinct parts, a tough white membrane on the outside which is almost insensible, and an internal one, full of blood vessels and nerves, and distinguished by great sensibility. Between these two, in the human body, is a soft mucous substance called *rete mucosum*.

1. The external layer, called the *cuticle* or *epidermis*, is best separated from the parts beneath by the action of a blister. It is not soluble in water, nor in acids, unless they are sufficiently concentrated to decompose it. Hence it differs from gelatine. Alkalis however dissolve it; and, in this respect, it agrees with coagulated albumen, which it resembles, also, in receiving a yellow tinge from nitric acid.

2. The *cutis vera*, which lies beneath the cuticle, consists of a number of fibres crossing each other in various directions, and has considerable firmness and elasticity. Long continued boiling in water entirely dissolves it, and a solution is obtained which gelatinates on cooling, or by farther evaporation, may be wholly converted into glue.

The true skin is composed, therefore, almost entirely of gelatine; but under some modification which renders it insoluble in water. It is this substance that adapts the skins of animals for two important uses, that of being converted into leather by the reception of the tanning principle, and that of furnishing glue.

3. Of the *rete mucosum* very little is known. It is that part of the skin, on which its colour depends; and by the sufficiently long continued application of oxymuriatic acid, it has been found that in the negro it may be entirely deprived of its colour.

Hair has been examined with considerable attention by Vauquelin. He effected a complete solution of it in water by using a Papin's digester. The application of the proper temperature required, however, some caution; for if raised too high, the hair was decomposed and gave carbonate of ammonia, empyreumatic oil, and sulphuretted hydrogen. The solution always contained a sort of bituminous oil, the colour of which approached to that of the

hair which had been dissolved. After separating this oil, the solution was precipitated by infusion of galls and by oxymuriatic acid; but did not gelatinate on cooling. Acids occasioned a precipitate, which was re-dissolved by adding more acid. Silver was precipitated from its solutions of a black colour, and lead of a brown.

A diluted solution of potash dissolved hair, excepting a little oil, sulphur, and iron; and the compound was a sort of soap. The oil, if red hair was employed, had a yellow tinge. Alcohol, also, extracted from hair a portion of oil, the colour of which varied with that of the hair.

The coal, obtained by incinerating hair, afforded phosphate, sulphate, and carbonate of lime, muriate of soda, silex, magnesia, and oxides of iron and manganese. The whole of these substances bore a very small proportion to the hair, and varied in hair of different colours. Hair, therefore, appears to consist chiefly of an animal matter resembling coagulated albumen; of an oil of various colours; of sulphur, silex, carbonate and phosphate of lime; and oxides of iron, and manganese.

Feathers probably agree in composition with hair. The quill, Mr. Hatchett has shown, consists of coagulated albumen without any gelatine.

The composition of *wool* is not accurately known; but from its forming a soap with pure alkalis, it probably consists of coagulated albumen.

We are equally ignorant of the true nature of silk. It is insoluble both in water and in alcohol, but dissolves in pure alkalis and acids. By the action of nitric acid it affords the peculiar substance already described under the name of the bitter principle.

SECTION IX.

Of the Substance of the Brain.

THE medullary matter of the brain and nervous system appears to differ from all other organized substances. It was first examined by M. Thouret, with a view to explain why the brain was exempted from the change, observed in the bodies which were interred in the *Cimetière des Innocens*. Fourcroy afterwards added many important facts, and corrected M. Thouret in several particulars; and Vauquelin has lately published an elaborate set of experiments on the same subject.*

The medullary substance of the brain is of a soft consistence, and forms, when agitated with water, a sort of emulsion, that passes through the finest sieves. This fluid is coagulated by a temperature of 160°, and a quantity of a substance resembling albumen is separated. The same coagulation is produced by acids;

* Thomson's Annals, i. 332.

but the coagulum differs, in several respects, from that which takes place from the serum of the blood. On being boiled with alcohol, it loses about $\frac{6}{10}$ of its weight; but one third of the portion, which has been dissolved, is again deposited on cooling in the form of shining crystalline plates, resembling those which are obtained from biliary calculi, from spermaceti, or from adipocire; but differing from those substances in requiring a higher temperature for its fusion. It stains paper like a fixed oil, is soluble in 20 times its weight of boiling alcohol; and is miscible with water into a sort of emulsion, from which it does not separate on standing, and which is not acid. From the results of its combustion, both alone and with nitre, Vauquelin infers that it contains uncombined phosphorus.

Alcohol, by digesting with brain, acquires a greenish colour, which it retains even after filtration. By evaporation to one eighth its bulk, it deposits a yellowish oily fluid, and the liquor itself is yellowish. When repeated quantities of alcohol are digested on the same portion of brain, the alcohol is tinged a sapphire blue colour. These colours remain, till the whole alcohol is expelled by heat, when the residuary matter acquires a yellow tinge, of greater or less intensity. The latter portions of alcohol, do not, like the first, deposit oil on standing.

The liquid oil, after being washed with water, and evaporated to dryness at a gentle heat, has a reddish brown colour, and a smell resembling that of the brain itself, but stronger. Its taste is like that of rancid fat. It forms, with water, an emulsion, which is coagulated by the addition of acids, and by infusion of tan. It is soluble in hot alcohol; and the greater part separates on cooling. Though freed from all acid by washing, yet it furnishes phosphoric acid by being burnt either alone or with nitre; and hence we must admit the presence of phosphorus in this fatty matter, as well as in the crystalline substance. From the latter, indeed, it appears to differ only in containing a quantity of animal matter, which is separable by cold alcohol.

The alcohol, from which the fatty matter has separated, has a yellow colour, a taste of the juice of meat, and gives marks of acidity. It contains super-phosphate of potash, and a peculiar animal matter, which, by its solubility in cold alcohol and water; by its property of being precipitated by infusion of galls; by its reddish brown colour, its deliquescence, its taste and smell of the juice of meat, may be regarded as identical with the substance, which Rouelle formerly called saponaceous extract of meat, and to which Thenard has given the name of *Osmazome*. It is this substance, which tinges the fatty matter, extracted from brain by alcohol.

The portion of brain, which remains after the full action of alcohol, is a greyish white matter in the form of flocks, which resembles cheese externally. In drying, it assumes a grey colour, a semi-transparency, and a fracture similar to that of gum-arabic. It appears, as Fourcroy supposed, to be perfectly identical with albumen; and it is this ingredient, which occasions the coagulation of brain, when mixed with water, by heat, acids, metallic salts, &c.

The alkaline solution of this part of brain precipitates acetate of lead of a dark brown colour, showing obviously the presence of sulphur.

The medulla of the brain, when exposed to the air, soon undergoes spontaneous decomposition; and evolves an acid, before it passes to the putrid state; but under water it may be kept a long time without any change. Nitric acid does not produce the same effects upon it, as on other animal substances. No nitrogen is separated; but, when the temperature is raised, a large quantity of carbonate of ammonia is disengaged, and oxalic acid is found in the retort.

Diluted sulphuric acid partly dissolves brain, and coagulates another part. The acid solution becomes black when concentrated by evaporation; sulphurous acid is generated; and crystals are formed which consist of sulphate of ammonia. Besides this salt, sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia are found in the liquid.

When brain is dried at the temperature of boiling water, it coagulates, and some water separates from it. When distilled in close vessels, ammonia is disengaged; which, uniting with carbonic acid formed at the same time, composes carbonate of ammonia. A portion of oil is obtained also, and sulphuretted and carburetted hydrogen gases are formed. In the retort a coal remains, which affords traces of phosphates of lime and soda.

The mass of brain, as appears from the experiments of Vauquelin, is composed, therefore, of 1st, two fatty matters, which are probably identical; 2dly, albumen; 3dly, osmazome; 4thly, different salts; and, among others, phosphates of potash, lime, and magnesia, and a little common salt; 5thly, phosphorus; 6thly, sulphur. The following is to be considered merely as an approximation to their proportions.

1. Water	80.00
2. White fatty matter . .	4.53
3. Red fatty matter . .	0.70
4. Albumen	7.00
5. Osmazome	1.12
6. Phosphorus	1.50
7. Acids, salts, and sulphur	5.15

100.

ELEMENTS
OF
EXPERIMENTAL CHEMISTRY.

PART II.

DIRECTIONS FOR EXAMINING MINERAL WATERS, AND MINERAL
BODIES IN GENERAL.

CHAPTER I.

ANALYSIS OF MINERAL WATERS.

THE complete and accurate analysis of mineral waters, and of mineral bodies in general, is one of the most difficult subjects of chemical manipulation, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Long and attentive study of the science is therefore essential to qualify any one for undertaking exact and minute determinations of the proportion of the component parts of bodies. Such minuteness, however, is scarcely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of them. I shall not attempt, therefore, to lay down rules for accurate analysis, but shall only describe such experiments as are suited to afford an insight into the kind, but not to decide the exact proportion, of the constituent principles of natural waters, and of mineral substances in general.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The nature of the strata in the neighbourhood of the spring, will often furnish useful suggestions respecting the contents of the water; the period of the year should be stated at which the analysis was performed; and whether after a rainy or dry season. The temperature of the water must be carefully ob-

served, as it issues from the spring; and the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water may be found by weighing a bottle, which is capable of containing a known weight of distilled water, at a certain temperature, filled with the water, under examination, at the same temperature. It is proper, also, to examine, on the spot, the channel through which the water has flowed; to collect any deposit that may have been formed; and to investigate its nature.

The effects of heat on the water may be next tried. Many waters lose their transparency when their temperature is raised, and let fall a considerable deposit. The quality of this may, in some degree, be conjectured from its appearance. If its colour be brownish yellow, it consists, either wholly or chiefly, of oxide of iron; if white, or nearly white, it is composed principally of the earthy carbonates. A mineral water, containing iron, deposits that metal also, when exposed to the atmosphere; and a thin pellicle forms on its surface, whether stagnant in a natural reservoir, or collected in a separate vessel. By this exposure, iron may be sometimes discovered in a water, though not easily detected at first; because it becomes farther oxydized, and more sensible to the action of tests. Sulphuretted hydrogenous waters deposit a sediment, even when preserved in a well-closed phial; the hydrogen quitting the sulphur, which settles in the form of a white powder.

SECTION I.

Examination of Mineral Waters by Re-agents.

WATER is never presented by nature in a state of complete purity. Even when collected as it descends in the form of rain, chemical tests detect in it a minute proportion of foreign ingredients. And when it has been absorbed by the earth, has traversed its different strata, and is returned to us by springs, it is found to have acquired various impregnations. The readiest method of judging of the contents of natural waters, is by applying what are termed tests, or re-agents; *i. e.* substances which, on being added to a water, exhibit, by the phenomena they produce, the nature of the saline, or other ingredients.—For example, if, on adding infusion of litmus to any water, its colour is changed to red, we infer, that the water contains an uncombined acid: if this change ensues, even after the water has been boiled, we judge that the acid is a fixed, and not a volatile one: and if, on adding the muriated barytes, a precipitate falls down, we safely conclude that the peculiar acid, present in the water, is either entirely or in part, the sulphuric acid. I shall first enumerate the tests generally employed in examining waters, and describe their application; and, afterwards, point out by what particular tests the substances, generally found in waters, may be detected.

In many instances, however, a mineral water may contain a saline, or other ingredient, but in such small quantity as to escape discovery by tests. It is therefore advisable to apply the tests of fixed substances to the water, after reducing its bulk one half, or more, by evaporation, as well as in its natural state.

The use of tests, or re-agents, has been employed by Mr. Kirwan to ascertain by a careful examination of the precipitate not only the *kind*, but the *quantity*, of the ingredients of mineral waters. This will be best understood from an example. It is an established fact, that 100 parts of crystallized muriate of soda, when completely decomposed by nitrate of silver, yield, as nearly as possible, 240 of precipitated muriate of silver. From the weight of the precipitate, separated by nitrate of silver from a given quantity of any water, it is therefore easy, when no other muriatic salt is present, to infer, what quantity of muriate of soda was contained in the water; since every hundred grains of muriated silver indicate, pretty accurately, $41\frac{1}{2}$ of crystallized common salt. The same mode of estimation may be applied in various other instances; and the rule for each individual case will be stated in the following description of the use of the various re-agents.

When filters of paper are used for collecting precipitates, great caution is necessary that their weight should be the same, before and after the experiment. Even during the time of weighing, they acquire moisture from the atmosphere; and it is therefore necessary, before taking their weight correctly, to obtain an approximation to it; after which, less time is occupied in determining it within the fraction of a grain. The unsized paper, which accompanies Mr. Watt's copying machines, answers the purpose extremely well. It is this which was always employed by Berzelius, whenever he used filters at all; but their use, when the nature of the precipitate admits, he thinks should be avoided.*

I.—*Infusion of Litmus, Syrup of Violets, &c.*

The infusion of litmus is prepared by steeping this substance, first bruised in a mortar, and tied up in a linen rag, in distilled water, which extracts its blue colour.

If the colour of the infusion tends too much to purple, it may be amended by a drop or two of solution of pure ammonia; but of this no more must be added than is barely sufficient, lest the delicacy of the test should be impaired.

The syrup of violets is not easily obtained pure. The genuine syrup may be distinguished from the spurious by a solution of corrosive sublimate, which changes the former to green, while it reddens the latter. When it can be procured genuine, it is an excellent test of acids, and may be employed in the same manner as the infusion of litmus.†

* 78 Ann. de Chim. 31.

† The infusion of the common purple convolvulus, when in season, is a very delicate test both of acids and alkalis, so likewise is that of the purple or blue larkspur; but as most readily procured, none is superior to the common blue cabbage. C.

Paper stained with the juice of the March violet, or with that of the scrapings of radishes, answers a similar purpose. In staining paper for the purpose of a test, the paper must be used unsized; or, if sized, it must previously be well washed with warm water; because the alum, which enters into the composition of the size, will otherwise change the vegetable colour to red.

In the Philosophical Magazine, vol. i. page 180, may be found some recipes for other test liquors, invented by Mr. Watt.

Infusion of litmus is a test of most uncombined acids.

1. If the infusion redden the unboiled, but not the boiled water, under examination; or if the red colour, occasioned by adding the infusion to a recent water, return to blue, on boiling; we may infer, that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

2. To ascertain whether the change be produced by carbonic acid or by sulphuretted hydrogen, when experiment shows that the reddening cause is volatile, add a little lime-water, or, in preference, barytic water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little muriatic acid. Sulphuretted hydrogen may also be contained along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described.

3. Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying. The mineral and fixed acids redden it permanently. That these acids, however, may produce their effect, it is necessary that they should be present in a sufficient proportion.* The dark blue paper, which is generally wrapped round loaves of refined sugar, is not discoloured by carbonic acid or sulphuretted hydrogen, but only by the stronger acids.

II.—*Infusion of Litmus reddened by Vinegar,—Spirituous Tincture of Brazil-wood,—Tincture of Turmeric, and Paper stained with each of these three Substances,—Syrup of Violets.*

All these different tests have one and the same object.

1. Infusion of litmus reddened by vinegar, or litmus paper reddened by vinegar, has its blue colour restored by pure alkalis and pure earths, and by carbonated alkalis and earths.

2. Turmeric paper and tincture are changed to a reddish brown by alkalis, whether pure or carbonated, and by pure earths, but not by carbonated earths. Dr. Bostock finds that it is obviously affected by a solution, containing only $\frac{1}{2000}$ of its weight of potash.

3. The red infusion of Brazil-wood, and paper stained with it, become blue by alkalis and earths, and even by the latter when dissolved by an excess of carbonic acid. In the last mentioned case, however, the change will either cease to appear, or will be much less remarkable, when the water has been boiled.

* See Kirwan on Mineral Waters, page 40.

4. Syrup of violets, when pure, is, by the same causes, turned green;* as is also paper stained with the juice of the violet, or with the scrapings of radishes.

III.—*Tincture of Galls.*

Tincture of galls is the test generally employed for discovering iron; with all the combinations of which it produces a black tinge, more or less intense according to the quantity of iron. The iron, however, in order to be detected by this test, must be in the state of red oxide, or, if oxydized in a less degree, its effect will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation, or boiling, we may know whether the iron be held in solution by carbonic acid, or by a fixed acid; for,

1. If it produce its effect before the application of heat, and not afterwards, carbonic acid is the solvent.

2. If after, as well as before, a mineral acid is the solvent.

3. If, by the boiling, a yellowish powder be precipitated, and yet galls still continue to strike the water black, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid. A neat mode of applying the gall-test was used by M. Klaproth, in his analysis of the Carlsbad water; a slice of the gall-nut was suspended by a silken thread in a large bottle of the recent water, and so small was the quantity of iron, that it could only be discovered in water fresh from the spring, by a slowly-formed and dark cloud, surrounding the re-agent.†

IV.—*Sulphuric Acid.*

1. Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alkalis or earths.

2. If lime be present, whether pure or uncombined, the addition of sulphuric acid occasions, after a few days, a white precipitate. If from a mineral water, which has been well boiled, the addition of sulphuric acid extricates sulphuretted hydrogen gas, Mr. Westrumb infers the presence of hydro-sulphuret of lime. In this case, sulphate of lime is precipitated.‡

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric and muriatic salts, in a dry state, or dissolved in very little water, on adding sulphuric acid, and applying heat, are decom-

* According to Mr. Accum, syrup of violets, which has lost its colour by keeping, may be restored by agitation, during a few minutes, in contact with oxygen gas. In preference to the syrup, Mr. Descroizilles recommends as a test the *pickle* of violets, prepared by adding common salt to the expressed juice. (Annales de Chimie, lxxvii. 80; or Nicholson's Journal, xxv. 232.)

† Klaproth, vol. i. page 279.

‡ Nicholson's Journal, xviii. 40.

posed; and if a stopper, moistened with solution of pure ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

V.—*Nitric and Nitrous Acids.*

These acids, if they occasion effervescence, give the same indications as the sulphuric. The fuming red nitrous acid has been recommended as a test distinguishing between hepatic waters that contain hydro-sulphuret of potash, and those that contain only sulphuretted hydrogen gas. In the former case, a precipitate ensues on adding nitrous acid, and a very fetid smell arises; in the latter, a slight cloudiness only appears, and the smell of the water becomes less disagreeable. If a water, after boiling, gives a precipitate of sulphur, on adding nitrous acid, Westrumb concludes that this is owing to hydro-sulphuret of lime.

VI.—*Oxalic Acid and Oxalates.*

The oxalic acid is a most delicate test of lime, which it separates from all its combinations.

1. If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs, by means of a quill or glass tube, we may infer, that pure lime (or barytes, which has never yet been found pure in water) is present.

2. If the oxalic acid occasion a precipitate before, but not after boiling, the lime is dissolved by an excess of carbonic acid.

3. If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present; because some acids decompose the oxalic, and others, dissolving the oxalate of lime, prevent it from appearing.*

The oxalate of ammonia, or of potash (which may easily be formed by saturating the respective carbonates of these alkalis with a solution of oxalic acid), are not liable to the above objection, and are preferable, as re-agents, to the uncombined acid. Yet even these oxalates fail to detect lime when supersaturated with muriatic or nitric acid; and, if such an excess be present, it must be saturated, before adding the test, with pure ammonia. A precipitation will then be produced.

The quantity of lime contained in the precipitate may be known, by first calcining it with access of air, which converts the oxalate into a carbonate; and by expelling from this last its carbonic acid, by calcination, with a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit. The use of oxalate of am-

* See Kirwan on Waters, page 88.

monia, that excellent analyst finds, is in some degree limited by its property of precipitating the salts of iron.

The fluato of ammonia, recommended by Scheele, I find to be a most delicate test of lime. It may be prepared by adding carbonate of ammonia to diluted fluoric acid, in a leaden vessel, observing that there be a small excess of acid.

VII.—*Pure Alkalis and Carbonated Alkalis.*

1. The pure fixed alkalis precipitate all earths and metals, whether dissolved by volatile or fixed menstrua, but only in certain states of dilution; for example, sulphate of alumine may be present in water, in the proportion of four grains to 500, without being discovered by pure fixed alkalis. As the alkalis precipitate so many substances, it is evident that they cannot afford any very precise information, when employed as re-agents. From the colour of the precipitate, as it approaches to a pure white, or recedes from it, an experienced eye will judge, that the precipitated earth contains less or more of metallic admixture; and its precise composition must be ascertained by rules which will presently be given.

2. Pure fixed alkalis also decompose all salts with basis of ammonia, which becomes evident by its smell (unless the salts are dissolved in much water), and also by the white fumes it exhibits when a stopper, moistened with muriatic acid, is brought near.

3. Carbonates of potash and of soda have similar effects.

4. Pure ammonia precipitates all earthy and metallic salts. Besides this property, it also imparts a deep blue colour to any liquid that contains copper or nickel in a state of solution; the precipitated oxides of those metals being re-dissolved by an excess of the volatile alkali.

5. Carbonate of ammonia has the same properties, except that it does not precipitate magnesia from its combinations. Hence, to ascertain whether this earth be present in any solution, add the carbonate of ammonia till no farther precipitation ensues; filter the liquor; raise it nearly to 212° Fahrenheit; and then add pure ammonia. If any precipitation now occurs, we may infer the presence of magnesia. It must be acknowledged that zircon, yttria, and glucine, would escape discovery by this process; but they have never yet been found in mineral waters; and their presence can scarcely be expected.

VIII.—*Lime-Water.*

1. Lime-water is applied to the purposes of a test, chiefly for detecting carbonic acid. Let any liquor supposed to contain this acid be mixed with an equal bulk of lime-water. If carbonic acid be present, either free or combined, a precipitate will immediately appear, which, on adding a few drops of muriatic acid, will again be dissolved with effervescence.

2. Lime-water will also show the presence of corrosive sublimate

by a brick-dust coloured sediment. If arsenous acid (common arsenic) be contained in a liquid, lime-water, when added, will occasion a precipitate, consisting of lime and arsenous acid, which is very difficultly soluble in water. This precipitate, when mixed up with oil, and laid on hot coals, yields the well known garlic smell of arsenic.

IX.—*Pure Barytes, and its Solution in Water.*

1. A solution of pure barytes is even more effectual than lime-water in detecting the presence of carbonic acid, and is much more portable and convenient; since, from the crystals of this earth, the barytic solution may at any time be immediately prepared. In discovering carbonic acid, the solution of barytes is used similarly to lime-water, and, if this acid be present, gives, in like manner, a precipitate soluble with effervescence in dilute muriatic acid.

2. The barytic solution is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate not soluble in muriatic acid.—Pure strontites has similar effects as a test. The quantity of the precipitated substance, indicated by the weight of the precipitate, will be stated in No. XV.

X.—*Metals.*

1. Of the metals, silver and mercury are tests of the presence of hydro-sulphurets, and of sulphuretted hydrogen gas. If a little quicksilver be put into a bottle containing water impregnated with either of these substances, its surface soon acquires a black film, and, on shaking the bottle, a blackish powder separates from it. Silver is speedily tarnished by the same cause.

2. The metals may be used also as tests of each other, on the principle of elective affinity. Thus, for example, a polished iron plate, immersed in a solution of sulphate of copper, soon acquires a coat of this metal; and the same in other similar examples.

XI.—*Sulphate of Iron.*

This is the only one of the sulphates, except that of silver, applicable to the purposes of a test. When used with this view, it is generally employed for ascertaining the presence of oxygen gas, of which a natural water may contain a small quantity.

A water, suspected to contain this gas, may be mixed with a little recently-dissolved sulphate of iron, and kept corked up, in a phial completely filled by the mixture. If an oxide of iron be precipitated in the course of a few days, the water may be inferred to contain oxygen gas.

XII.—*Sulphate, Nitrate, and Acetate of Silver.*

These solutions are all in some measure applicable to similar purposes.

1. They are peculiarly adapted to the discovery of muriatic acid and of muriates. For the silver, quitting its solvent, combines with the muriatic acid, and forms a flaky precipitate, which, at first, is white, but on exposure to the sun's light, acquires a bluish, and finally a black colour. This precipitate, dried and fused by a gentle heat, Dr. Black states to contain, in 1000 parts, as much muriatic acid as would form $425\frac{1}{2}$ of crystallized muriate of soda, which estimate scarcely differs at all from that of Klaproth. The same quantity of muriate of silver (1000 parts) indicates, according to Kirwan, $454\frac{1}{2}$ of muriate of potash. Dr. Marcet's experiments and my own indicate a larger product of muriate of silver from the decomposition of dry muriate of soda, viz. not less than 240 grains from 100 of common salt. Hence 100 grains of fused muriate of silver denote 41.6 of muriate of soda, and about 19 grains of muriatic acid. A precipitation, however, may arise from other causes, which it may be proper to state.

2. The solutions of silver in acids are precipitated by carbonated alkalis and earths. The agency of the alkalis and earths may, however, be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved.

3. The nitrate and acetate of silver are decomposed by the sulphuric and sulphurous acids; but this may be prevented by adding, previously, a few drops of nitrate or acetate of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted, and the solution of silver added. Should a precipitation now take place, the presence of muriatic acid, or some one of its combinations, may be suspected. To remove uncertainty, whether a precipitation be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when no uncombined alkali or earth is present, is affected only by the latter acid. According to Professor Pfaff, one part of muriatic acid of the specific gravity 1.15, diluted with 70,000 parts of water, barely exhibits a slight opaline tinge, when tested with nitrate of silver: and, when diluted with 80,000 parts of water, it is not affected at all.* Mr. Meyer of Stettin assigns, however, a much more extensive power to nitrate of silver, as a test of muriatic acid.†

4. The solutions of silver are also precipitated by sulphuretted hydrogen, and by hydro-sulphurets; but the precipitate is then reddish, or brown, or black; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble, in great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

5. The solutions of silver are precipitated by extractive matter; but, in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

* Nicholson's Journal, xvii. 361.

† Thomson's Annals, v. 23.

XIII.—*Nitrate and Acetate of Lead.*

1. Acetate of lead, the most eligible of these two tests, is precipitated by sulphuric and muriatic acids; but, as of both these we have much better indicators, I do not enlarge on its application to this purpose.

2. The acetate is also a test of sulphuretted hydrogen and of hydro-sulphurets of alkalis, which occasion a black precipitate; and, if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hydrogen gas, they are soon rendered visible; especially when the water is a little warmed.

3. The acetate of lead is employed in the discovery of uncombined boracic acid, a very rare ingredient of waters. To ascertain whether this be present, some cautions are necessary. (a) The uncombined alkalis and earths (if any be suspected) must be saturated with acetic or acetous acid. (b) The sulphates must be decomposed by acetate or nitrate of barytes, and the muriates by acetate or nitrate of silver. The filtered liquor, if boracic acid be contained in it, will continue to give a precipitate, which is soluble in nitric acid of the specific gravity 1.3.

4. Acetate of lead is said, also, by Pfaff, to be a very delicate test of carbonic acid; and that it renders milky, water which contains the smallest possible quantity of this acid.

XIV.—*Nitrate of Mercury prepared with and without Heat.*

This solution, differently prepared, is sometimes employed as a test.

1. The solution of nitrate of mercury, prepared without heat,* has been found by Pfaff to be a much more sensible test of muriatic acid than nitrate of silver. Its sensibility, indeed, is so great, that one part of muriatic acid, of the specific gravity 1.50 diluted with 300,000 parts of water, is indicated by a slightly dull tint ensuing on the addition of the test.

2. It is, at the same time, the most sensible test of ammonia, one part of which, with 30,000 parts of water, is indicated by a slight blackish yellow tint, on adding the nitrate of mercury.

3. The nitrate of mercury is also precipitated by highly diluted phosphoric acid; but the precipitate is soluble in an excess of phosphoric or nitric acid, which is not the case if it has been occasioned by muriatic acid.

XV.—*Muriate, Nitrate, and Acetate of Barytes.*

1. These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate, insoluble in dilute muriatic acid. They are decomposed, however, by carbonates of alkali; but the precipitate occasioned by carbonates

* See chap. xix. sect. 4, vi.

is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding, previously, a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. i. page 168) about $45\frac{1}{2}$ of sulphuric acid of the specific gravity 1850; according to Clayfield (Nicholson's Journal, 4to. iii. 38), 33 of acid, of the specific gravity 2240; according to Thenard, after calcination, about 25; and, according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried sulphate of soda; while 136.36 of the same substance indicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

From Klaproth's experiments, it appears, that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallized salt. The same chemist has shown, that 100 grains of sulphate of barytes are produced by the precipitation of 71 grains of sulphate of lime, of ordinary dryness. The results of my own experiments are stated in page 274. From these it follows, that 100 grains of ignited sulphate of barytes denote 57 of calcined sulphate of lime; or 73 of the same sulphate, dried by a temperature of only 160° Fahrenheit. Desiccated sulphate of magnesia, when decomposed by muriate of barytes, affords twice its weight of the barytic sulphate.

2. Phosphoric salts occasion a precipitate also, which is soluble in muriatic acid without effervescence.

XVI.—*Prussiates of Potash and of Lime.**

Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily resume a blue colour on the addition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron, with the solutions of which in acids it produces a Prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alkalis or earths, which, if present, prevent the detection of very minute quantities of iron.

1. If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate of potash, the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

2. Should the precipitation ensue in the boiled water, the solvent is a fixed acid, the nature of which must be ascertained by other tests.

Doubts had been thrown, by several chemical writers, on the fitness of the ferro-prussiate of potash for determining the *quantity* of iron in solutions of that metal. But Mr. Porrett, in his able

* The triple prussiates are to be understood in this place.

inquiry into the nature of the triple prussiates, has shown that, with certain precautions, the ferro-prussiate of potash is fully adequate to this purpose.* It is necessary to observe,

1st. That if the ferro-prussiate, after being dissolved in water gives, immediately, a blue precipitate by the addition of muriatic acid, it is not pure, and will afford a fallacious result.

2dly. That if this salt, however pure, be added, *in excess*, to a solution of iron *containing an excess of acid*, and then heated, the Prussian blue thrown down will weigh more than it ought; because some is furnished by the decomposition of the ferro-prussic acid, contained in that part of the salt, which has been added in excess.

3dly. That Prussian blue, even after it has been formed, is materially acted upon by a mixture of nitric and muriatic acids, and, in some degree, by the muriatic acid alone at a boiling heat.

4thly. That Prussian blue, when precipitated, often carries with it sulphate of potash, derived from the liquid from which it is thrown down; and that this sulphate adheres to it so obstinately, that several washings with water, acidulated with sulphuric acid, are necessary to detach it.

5thly. That if the solution, to which the test is applied, contain not only iron, but alumine, oxide of copper, or any other substance, which the test is known to precipitate, *that substance should be removed*, by the usual means, previously to the application of the test.

Suppose then, for example, that we have barytes, alumine, magnesia, and oxides of iron and copper, in a state of solution by nitro-muriatic acid. The solution, if not already neutral, may first be rendered so by the cautious addition of ammonia. The barytic salt may next be decomposed by a solution of sulphate of soda, added till it ceases to occasion a precipitate. Ammonia, added to the residuary liquor, throws down the other earths and oxides, and an excess of it will re-dissolve the oxide of copper. From the insoluble part, consisting of alumine, magnesia, and oxide of iron, solution of pure potash will remove the alumine. The oxide of iron and magnesia may then be re-dissolved in any suitable acid; and to the solution, neutralized, or nearly so, by ammonia if necessary, the ferro-prussiate may be poured, till it ceases to produce any effect, taking care to add as little excess as possible. The precipitate washed, dried at a steam heat, and weighed, will indicate in every 100 grains, 34.235 grains of peroxide of iron.

Besides iron, the prussiated alkalies also precipitate muriate of alumine. No conclusion, therefore, can be deduced, respecting the non-existence of muriate of alumine, from any process, in which the prussic test has previously been used. It will, therefore, be proper, if a salt of alumine be indicated by other tests, to examine the precipitate effected by prussiate of potash. This may be done by repeatedly boiling it to dryness with muriatic acid, which takes up the alumine, and leaves the prussiate of iron. From the muriatic solution, the alumine may be precipitated by a solution of carbonate of potash.

* Phil. Trans. 1814, p. 538.

According to Klaproth (ii. 55), solutions of yttria (which earth, however, is not likely to be present in any mineral water) afford, with the Prussian test, a white precipitate, passing to pearl-grey, which consists of prussiate of yttria. This precipitate disappears on adding an acid, and hence may be separated from prussiated iron. The same accurate chemist states, that the Prussian test has no action on salts with base of glucine (ib.); but that it precipitates zircon from its solutions. (ii. 214.)

The prussiated alkalies decompose, also, all metallic solutions, excepting those of gold, platina, iridium, rhodium, osmium, and antimony.

XVII.—*Succinate of Soda and of Ammonia.*

1. The succinate of soda was first recommended by Gehlen, and afterwards employed by Klaproth (Contributions, ii. 48) for the discovery and separation of iron. The salt with base of ammonia has also been used for a similar purpose by Dr. Marcet, physician to Guy's Hospital, in a skilful analysis of the Brighton chalybeate, which is published in the new edition of Dr. Saunders's Treatise on Mineral Waters.

The succinic test is prepared by saturating carbonate of soda or ammonia with succinic acid. In applying the test, it is necessary not to use more than is sufficient for the purpose; because an excess of it re-dissolves the precipitate. The best mode of proceeding, is to heat the solution containing iron, and to add gradually the solution of succinate, until it ceases to produce any turbidness. A brownish precipitate is obtained, consisting of succinate of iron. This, when calcined with a little wax, in a low red-heat, gives an oxide of iron, containing about 70 *per cent.* of the metal. From Dr. Marcet's experiments, it appears that 100 grains of iron, dissolved in sulphuric acid, then precipitated by the succinate test, and afterwards burned with wax, give 148 of oxide of iron; that is, 100 grains of the oxide indicate about 67½ of metallic iron.

2. The succinates, however, it is stated by Dr. Marcet and Mr. Ekeberg, precipitate alumine, provided there be no considerable excess of acid in the aluminous salt. On magnesia it has no action, and hence may be successfully employed in the separation of these two earths. If 100 parts of octohedral crystals of alum be entirely decomposed by succinate of ammonia, they give precisely 12 parts of alumine calcined in a dull red-heat. The succinate of ammonia, it is stated by Mr. Ekeberg,* precipitates glucine; and the same test, according to Klaproth (ii. 214), throws down zircon from its solutions.

To separate all the iron and alumine from any water, long boiling is necessary with free access of air, in order that the iron may be completely oxidized; for the succinates have no action on salts containing the protoxide of iron.

* Journ. des Mines, No. 70.

XVIII.—*Phosphate of Soda.*

An easy and valuable method of precipitating magnesia has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses ; first to dissolve the carbonate of magnesia, formed when it is added to the solution of a magnesian salt, and afterwards to yield the earth to phosphoric acid, with which and ammonia it forms a triple salt. For this purpose, a solution of carbonate of ammonia, prepared with a portion of that salt which has been exposed, spread on a paper, for a few hours to the air, is to be added to the solution of the magnesian salt sufficiently concentrated ; or to a water suspected to contain magnesia, after being very much reduced by evaporation. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of pure magnesia ; about 66 of muriate of magnesia ; and 62 of desiccated, or double that quantity of crystallized, sulphate of magnesia. If, instead of drying the precipitate at a gentle heat, we calcine it, we may then reckon the calcined phosphate of magnesia to indicate, in every hundred grains, 38.5 of magnesia, or to be equivalent to 226 grains of the crystallized sulphate of that earth.

XIX.—*Muriate of Lime.*

Muriate of lime is principally of use in discovering the presence of alkaline carbonates, which, though they very rarely occur, have sometimes been found in mineral waters. Carbonate of potash exists in the waters of Aix-la-Chapelle ; that of soda, in the water of a few springs and lakes ; and the ammoniacal carbonate was detected by Mr. Cavendish in the waters of Rathbone-place. Of all the three carbonates, muriate of lime is a sufficient indicator ; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid.

With respect to the discrimination of the different alkalis, potash may be detected by the nitro-muriate of platina, which distinctly and immediately precipitates that alkali and its compounds, and is not affected by soda. Carbonate of ammonia may be discovered by its smell ; and by its precipitating a neutral salt of alumine, while it has no action apparently on magnesian salts.

XX.—*Solution of Soap in Alcohol.*

This solution may be employed to ascertain the comparative hardness of waters. With distilled water it may be mixed, without any change ensuing ; but if added to a hard water, it produces a milkiness, more considerable as the water is less pure ; and, from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is

owing to the alkali quitting the oil, whenever there is present in a water any substance, for which the alkali has a stronger affinity than it has for oil. Thus all uncombined acids, and all earthy and metallic salts, decompose soap, and occasion that property in waters, which is termed hardness.

XXI.—*Alcohol.*

Alcohol, when mixed with any water, in the proportion of about an equal bulk, precipitates all the salts which it is incapable of dissolving. (See Kirwan on Waters, page 263.)

XXII.—*Hydro-Sulphuret of Ammonia.*

This and other sulphurets, as well as water saturated with sulphuretted hydrogen, may be employed in detecting lead and arsenic; with the former of which they give a black, and with the latter a yellowish precipitate. As lead and arsenic, however, are never found in natural waters, I shall reserve, for another occasion, what I have to say of the application of these tests.

TABLE,

Showing the Substances that may be expected in Mineral Waters, and the Means of detecting them.

- Acids in general.* Infusion of litmus.—Syrup of violets, I.
Acid, boracic. Acetate of lead, XIII. 3.
Acid, carbonic. Infusion of litmus, I. 1, 2.—Lime water, VIII. 1.—Barytic water, IX. 1.
Acid, muriatic. Nitrate and acetate of silver, XII. Nitrate of mercury, XIV.
Acid, nitric. Sulphuric acid, IV. 4.
Acid, phosphoric. Solutions of barytes, XV. 2. Nitrate of mercury, XIV. 3.
Acid, sulphurous. By its smell,—and destroying the colour of litmus, and of infusion of red roses:—by the cessation of the smell a few hours after the addition of the black oxide of manganese.
Acid, sulphuric. Solution of pure barytes, IX. Barytic salts, XV. Acetate of lead, XII.
Alkalis in general. Vegetable colours, II. Muriate of lime, XIX.
Alumine dissolved by acids. Succinates, XVII.
Ammonia, by its smell, and tests, II. Nitrate of mercury, XIV. 2.
Barytes, and its compounds, by sulphuric acid, IV.
Carbonates in general. Effervesce on adding acids.
Earths dissolved by carbonic acid. By a precipitation on boiling; by pure alkalis, VII.

Hydro-sulphuret of lime. Sulphuric acid, IV. Nitrous acid, V.
Iron dissolved by carbonic acid. Tincture of galls, III. 1. Prussiate of potash, XVI. 1. Succinate of ammonia, XVII.

Iron dissolved by sulphuric acid. Same tests, III. 3. XVI. 2. XVII.

Lime in a pure state. Water saturated with carbonic acid. Blowing air from the lungs. Oxalic acid, VI.

Lime dissolved by carbonic acid. Precipitation on boiling.—Cautic alkalis, VII. Oxalic acid, VI.

Lime dissolved by sulphuric acid. Oxalate of ammonia, VI. Barytic solutions, IX. and XV.

Magnesia dissolved by carbonic acid. Precipitation on boiling,—the precipitate soluble in dilute sulphuric acid.

Magnesia dissolved by other acids. Precipitated by pure ammonia, not by the carbonate, VII. 5. Phosphate of soda, XVII.

Muriates of alkalis. Solutions of silver, XII.

———*of lime.* Solutions of silver, XII. Oxalic acid and oxalate of ammonia, VI.

Sulphates in general. Barytic solutions, IX. and XV.—Acetate of lead, XIII.

Sulphate of alumine. Barytic solutions, IX. and XV.—A precipitate by carbonate of ammonia not soluble in acetous acid, but soluble in pure fixed alkalis by boiling. Succinates, XVII. 2.

Sulphate of lime. Barytic solutions, IX. and XV.—Oxalic acid, and oxalates, VI.—A precipitate by alkalis not soluble in dilute sulphuric acid.

Sulphurets of alkalis. Polished metals, X. Smell on adding sulphuric or muriatic acid. Nitrous acid, V.

Sulphuretted hydrogen gas. By its smell. Infusion of litmus, I. Polished metals, X. Acetate of lead, XIII. 2.*

SECTION II.

Analysis of Waters by Evaporation.

BEFORE proceeding to the evaporation of any natural water, its gaseous contents must be collected. This may be done by filling with the water a large glass bottle, capable of holding about 50 cubical inches, and furnished with a ground stopper and bent tube. The bottle is to be placed, up to its neck, in a tin kettle filled with a saturated solution of common salt, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what is lost by evaporation. The disengaged gas is conveyed, by the bent tube, into a graduated jar, filled with, and inverted in, mercu-

* The vapour of putrefying animal or vegetable matter dissolved in water, according to Klaproth, vol. i. page 590, often gives a deceptive indication of sulphuretted hydrogen.

ry, where its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar, till the water has attained its maximum of temperature. This must be suffered to escape, and its quantity be deducted from that of the water submitted to experiment.

In determining, with precision, the quantity of gas, it is necessary to attend to the state of the barometer and thermometer, and to other circumstances already enumerated, page 92. Rules for reducing observations made under different states of the barometer and thermometer, to a mean standard, will be given in the Appendix. If a considerable proportion of gas be contained in a mineral water, the most commodious method of receiving it is into a small gazometer.

The gases, most commonly found in mineral waters, are *carbonic acid*; *sulphuretted hydrogen*; *nitrogen gas*; *oxygen gas*; and, in the neighbourhood of volcanoes only, *sulphurous acid gas*.

To determine the proportion of the gases, constituting any mixture obtained from any mineral water in the foregoing manner, the following experiments may be made. If the use of re-agents has not detected the presence of sulphuretted hydrogen, and there is reason to believe, from the same evidence, that carbonic acid forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver. Pass up a small portion of solution of potash, and agitate this in contact with the gas. The amount of the diminution will show how much carbonic acid has been absorbed; and, if the quantity submitted to experiment, was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxygen and azotic gases; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer. (See page 106.)

If sulphuretted hydrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hydrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hydrogen by oxymuriatic acid gas (obtained from muriatic acid and hyper-oxymuriate of potash); adding the latter gas very cautiously, as long as it produces any condensation. Or, perhaps a better plan of effecting the separation will be the following: Half fill a graduated phial with the mixed carbonic acid and sulphuretted hydrogen gases, and expel the rest of the water by oxy-muriatic acid gas. Let the mouth of the bottle be then closed with a well-ground stopper, and let the mixture be kept twenty-four hours. Then withdraw the stopper under water, a quantity of which fluid will immediately rush in. Allow the bottle to stand half an hour without agitation. The redundant oxymuriatic acid gas will thus be absorbed; and very little of the carbonic acid will

disappear. Supposing that, to ten cubic inches of the mixed gases, ten inches of oxymuriatic gas have been added, and that, after absorption by standing over water, five inches remain: the result of this experiment shows, that the mixture consisted of equal parts of sulphuretted hydrogen and carbonic acid gases.

Mr. Westrumb ascertains the proportion of sulphuretted hydrogen and carbonic acid gases, by the following method. He introduces a known quantity of the water under examination into a glass vessel, from which proceeds a curved tube, terminating in a long cylinder, filled with lime water. The gas is expelled by heat, and the precipitate collected. Every twenty grains indicate ten cubic inches of carbonic acid. To determine the quantity of sulphuretted hydrogen, the same experiment is repeated, substituting a solution of super-acetate of lead. Hydro-sulphuret of lead is formed, in the proportion of nineteen grains to ten cubic inches of gas. This method, for several reasons which it would take too much room to state, is perhaps inferior to the one which I have just proposed.

Whenever this complicated admixture of gases occurs, as in the case of the Harrowgate-water, it is advisable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphuretted hydrogen; and that of nitrogen and oxygen by the other. In the latter instance, remove both the absorbable gases by caustic potash; and examine the remainder in the manner already directed.

Nitrogen gas sometimes occurs in mineral waters, almost in an unmixed state. When this happens, the gas will be known by the characters already described as belonging to it, page 101. Sulphurous acid gas may be detected by its peculiar smell of burning brimstone, and by its discharging the colour of an infusion of roses, which has been reddened by the smallest quantity of any mineral acid adequate to the effect.

The vessels employed for EVAPORATION, should be of such materials as are not likely to be acted on by the contents of the water. I prefer those of unglazed biscuit ware, made by Messrs. Wedgwood; but, as their surface is not perfectly smooth, and the dry mass may adhere so strongly as not to be easily scraped off, the water, when reduced to about one tenth or less, may be transferred, with any deposit that may have taken place, into a smaller vessel of glass. Here let it be evaporated to dryness.

(a) The dry mass, when collected and accurately weighed, is to be put into a bottle, and alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol, and dry and weigh the remainder.

(b) To the undissolved residue, add eight times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

(c) Boil the residuum, for a quarter of an hour, in somewhat more than five hundred times its weight of water, and afterwards filter.

(d) The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

I. The solution in alcohol (a) may contain one or all of the following salts: Murates of lime, magnesia, or barytes; or nitrates of the same earths. Sometimes, also, the alcohol may take up a sulphate of iron, in which the metal is highly oxydized, as will appear from its reddish brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add above half its weight of strong sulphuric acid; and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes; the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis of the salts, let the heat be continued till no more fumes arise, and let it then be raised to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates may be separately decomposed, by boiling with three or four times their weight of carbonate of potash. The carbonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid, and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up. Lime and magnesia may also be separated by the use of the phosphate of soda, applied in the manner already described in the preceding section, No. XVIII.

The presence of barytes, which is very rarely to be expected, may be known by a precipitation ensuing on adding sulphuric acid to a portion of the alcoholic solution, which has been diluted with 50 or 60 times its bulk of pure water.

II. The watery solution (b) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallization. For this purpose, let one half be evaporated by a very gentle heat, not exceeding 80° or 90° . Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda or common salt. The remaining solution, on cooling very gradually, will, perhaps afford crystals distinguishable by their form and other qualities. When various salts, however, are contained in the same solution, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must, therefore, be examined by tests, or re-agents.

The presence of an uncombined alkali will be discovered by the stained papers (page 589), and of acids by the tests (p. 588, 589). The vegetable alkali, or potash, may be distinguished from the mineral, or soda, by saturation with sulphuric acid, and evaporation

to dryness; the sulphate of soda being much more soluble than that of potash; or, by supersaturation, with the tartarous acid, which gives a soluble salt with soda, but not with potash. Muriate of platina, also, is an excellent test of potash and its combinations; for, with the smallest portion of this alkali, or any of its salts, it forms a distinct and immediate precipitate; while it is not at all affected by the mineral alkali or its compounds.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and of the basis. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III. The solution by boiling water contains scarcely any thing beside sulphate of lime.

IV. The residuum (*d*) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly oxydized iron. Evaporate the solution to dryness. If it contain acetate of lime only, a substance will be obtained which does not attract moisture from the air; if magnesia be present, the mass will deliquesce. To separate the lime from the magnesia, proceed as in I.

The residue, insoluble in acetous acid, may contain alumine, iron, and silex. The two first may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterwards by a fixed alkali.

CHAPTER II.

EXAMINATION OF MINERALS.

SECTION I.

General Directions.

THE chemical analysis of minerals is attended even with greater difficulties than that of natural waters; and it would require not only a separate work, but one of considerable extent to comprehend rules for determining the proportions of all possible combinations. On the present occasion, I mean only to offer a few general directions for attaining such a knowledge of the composition of mineral bodies, as may enable the chemical student to refer them to their proper place in a mineral arrangement, and to judge whether or not they may admit of application to the uses of common life. Those who are solicitous to become adepts in the art of mineral analysis, may read attentively the numerous papers of Vauquelin, Hatchett, and other skilful analysts, dispersed through various chemical collections; and also an admirable work of M. Klaproth, lately trans-

lated into English, entitled, "Analytical Essays towards improving the Chemical Knowledge of Minerals," 2 vols. 8vo., published by Cadell and Davies, 1801.

The great variety of mineral bodies, which nature presents in the composition of this globe, have been classed by late writers under a few general divisions. They may be arranged under four heads. 1st, EARTHS; 2d, SALTS; 3d, INFLAMMABLE FOSSILS; and, 4th, METALS, and their Ores.

1. EARTHS.—The formation of such a definition of earths as would apply exactly to the bodies defined, and to no others, is attended with considerable difficulty, and indeed has never yet been effected. It would lead me into too long a discussion, to comment, in this place, on the definitions that have been generally offered, and to state the grounds of objection to each of them. Sensible, therefore, that I am unable to present an unexceptionable character of earthy bodies, I shall select such a one as may be sufficient for the less accurate purpose of general distinction.

"The term earth," says Mr. Kirwan, "denotes a tasteless, inodorous, dry, brittle, unflammable substance, whose specific gravity does not exceed 4.9 (*i. e.* which is never five times heavier than water), and which gives no tinge to borax in fusion." After stating some exceptions to this definition, afforded by the strong taste of certain earths, and the solubility of others, he adds, "Since, however, a line must be drawn between salts and earths, I think it should begin where solution is scarcely perceptible; salts terminating, and earths, in strictness, commencing, where the weight of the water, requisite for the solution, exceeds that of the solvent 1000 times. But, not to depart too widely from the commonly received import of words that are in constant use, substances that require 100 times their weight of water to dissolve them, and have the other sensible properties of earths, may be so styled in a loose and popular sense."

The simple, or primitive earths, are those which can only be resolved into oxygen and a metallic basis. Such are lime, magnesia, alumine, silice, &c.

The compound earths are composed of two or more primitive earths, united chemically together. Sometimes the union of an earth with an acid constitutes what is vulgarly called an earth; as in the examples of sulphate of lime, fluoate of lime, &c.

II. SALTS.—Under this head Mr. Kirwan arranges "all those substances that require less than 100 times their weight of water to dissolve them." This description, though by no means so amply characteristic of the class of salts as to serve for an exact definition, is sufficient for our present purpose.

III. "By INFLAMMABLE FOSSILS," the same author observes, "are to be understood all those of mineral origin, whose principal character is inflammability; a criterion which excludes the diamond and metallic substances, though also susceptible of combustion."

IV. METALLIC SUBSTANCES are so well characterized by ex-

ternal properties, as not to require any definition.—“Those on which nature has bestowed their proper metallic appearance, or which are alloyed only with other metals or semi-metals, are called *native* metals. But those that are distinguished, as they commonly are in mines, by combination with some other unmetallic substances, are said to be mineralized. The substance that sets them in that state is called a mineralizer, and the compound of both, an ore.” Thus, in the most common ore of copper, this metal is found oxydized, and the oxide combined with sulphur. The copper may be said to be mineralized by oxygen and sulphur, and the compound of the three bodies is called an ore of copper.

SECTION II.

Method of examining a Mineral, the Composition of which is unknown.

A MINERAL substance, presented to our examination without any previous knowledge of its composition, should first be referred to one of the above four classes, in order that we may attain a general knowledge of its nature, before proceeding to analyze it minutely.

I. To ascertain whether the unknown mineral contain saline matter, let 100 grains, or any other determinate quantity, in the state of fine powder, be put into a bottle, and shaken up repeatedly with 30 times its weight of water, of the temperature of 120° or 130° . After having stood an hour or two, pour the contents of the bottle on a filtering paper, previously weighed and placed on a funnel. When the water has drained off, dry the powder on a filtering paper, in a heat of about 212° : and, when dry, let the whole be accurately weighed. If the weight be considerably less than the joint weight of the powder before digestion and the filtering paper, we may infer that some salt has been dissolved, and the decrease of weight will indicate its quantity.

In certain cases it may be advisable to use repeated portions of boiling water, when the salt suspected to be present is difficult of solution.

Should the mineral under examination be proved, by the foregoing experiment, to contain much saline matter, the kind and proportion must next be determined, by rules which will hereafter be laid down.

II. The second class, *viz.* earthy bodies, are distinguished by their insolubility in water, by their freedom from taste, by their unflammability, and by their specific gravity never reaching 5. If, therefore, a mineral be insoluble in water, when tried in the foregoing manner; and if it be not consumed, either wholly or in considerable part, by keeping it, for some time, on a red-hot iron; we may conclude that it is neither a salt nor an inflammable body.

III. The only remaining class with which it can be confounded

are ores of metals, from many of which it may be distinguished merely by poising it in the hand, the ores of metals being always heavier than earths; or, if a doubt should still remain, it may be weighed hydrostatically. The mode of doing this it may be proper to describe; but the principle on which the practice is founded, cannot with propriety be explained here. Let the mineral be suspended by a piece of fine hair, silk, or thread from the scale of a balance, and weighed in the air. Suppose it to weigh 250 grains. Let it next (still suspended to the balance) be immersed in a glass of distilled water, of the temperature of 60° Faht. The scale containing the weight will now preponderate. Add, therefore, to the scale from which the mineral hangs, as many grain-weights as are necessary to restore the equilibrium. Suppose that 50 grains are necessary, then the specific gravity may be learned by dividing the weight in air by the weight lost in water. Thus, in the foregoing case, $250 \div 50 = 5$; or, a substance which should lose weight in water, according to the above proportion, would be five times heavier than water. It must, therefore, contain some metal, though probably in no great quantity. Any mineral, which, when weighed in the above manner, proves to be 5, 6, 7, or more, times heavier than water, may, therefore, be inferred to contain a metal, and may be referred to the class of ores.

IV. Inflammable substances are distinguished by their burning away, either entirely or in considerable part, on a red-hot iron; and by their detonating, when mixed with powdered nitre, and thrown into a red-hot crucible. Certain ores of metals, however, which contain a considerable proportion of inflammable matter, answer to this test, but may be distinguished from purely inflammable substances by their greater specific gravity.

I shall now proceed to offer a few general rules for the more accurate examination of substances of each of the above classes.

SECTION III.

Examination of Salts.

1. A SOLUTION of saline matter, obtained in the foregoing manner (see page 607), may be slowly evaporated, and left to cool gradually. When cold, crystals will probably appear, which a chemist, acquainted with the forms of salts, will easily recognize. But, as several different salts may be present in the same solution, and may not crystallize in a sufficiently distinct shape, it may be necessary to have recourse to the evidence of tests.

2. Let the salt, in the first place, be referred to one of the following orders.

(a) *Acids, or salts with excess of acid.* These are known by their effect on blue vegetable colours. The particular species of acid may be discovered by the tests described, page 600.

(b) *Alkalis.* These are characterized by their effect on vegetable colours, and by the other properties enumerated, p. 148, 149.

(c) *Salts with metallic bases.* Metallic salts afford a very copious precipitate when mixed with a solution of prussiate of potash. To ascertain the species of metal, precipitate the whole by prussiate of potash, calcine the precipitate, and proceed according to the rules which will hereafter be given for separating metals from each other.

(d) *Salts with earthy bases.* If a solution of salt, in which ferro-prussiate of potash occasions no precipitation, afford a precipitate, on adding pure or carbonated potash, we may infer, that a compound of an acid, with some one of the earths, is present in the solution. Or if, after ferro-prussiate of potash has ceased to throw down a sediment, the above-mentioned alkali precipitates a farther portion, we may infer that both earthy and metallic salts are contained in the solution. In the first case, add the alkaline solution, and, when it has ceased to produce any effect, let the sediment subside, decant the supernatant liquor, and wash and dry the precipitate. The earths may be examined, according to the rules that will be given in the following article. In the second case, ferro-prussiate of potash must be added, as long as it precipitates any thing, and the liquor must be decanted from the sediment, which is to be washed with distilled water, adding the washings to what has been poured off. The decanted solution must next be mixed with the alkaline one, and the precipitated earths reserved for experiment. By this last process, earths and metals may be separated from each other.

(e) *Neutral salts with alkaline bases.* These salts are not precipitated either by prussiate or carbonate of potash. It may happen, however, that salts of this class may be contained in a solution, along with metallic or earthy ones. In this case the analysis becomes difficult; because the alkali, which is added to precipitate the two last, renders it difficult to ascertain whether the neutral salts are owing to this addition, or were originally present. I am not aware of any method of obviating this difficulty, except the following: Let the metals be precipitated by prussiate of ammonia, and the earths by carbonate of ammonia, in a temperature of 180° or upwards, in order to ensure the decomposition of magnesian salts, which this carbonate does not effect in the cold. Separate the liquor by filtration, and boil it to dryness. Then expose the dry mass to such a heat as is sufficient to expel the ammoniacal salts.* Those with bases of fixed alkali will remain unvolatilized. By this process, indeed, it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be learned by adding to the salt under examination, before its solution in water, some pure potash, which, if ammonia be contained in the salt,

* This application of heat will drive off, also, any excess of the ammoniacal carbonate, which might have retained in solution either yttria, glucine, or zircon. The alkaline salts may be separated from these earths, by boiling the mixture in water, filtering, and evaporating.

will produce the peculiar smell of that alkali. The vegetable and mineral alkalis may be distinguished by adding to the solution a little tartarous acid, which precipitates the former but not the latter; or by muriate of platina, which acts only on the vegetable alkali.

Having ascertained the basis of the salt, the acid will easily be discriminated. Muriated barytes will indicate sulphuric acid; nitrate of silver the muriatic; and salts, containing nitric acid, may be known by a detonation ensuing on projecting them, mixed with powdered charcoal, into a red-hot crucible.

SECTION IV.

Examination of Earths and Stones.

WHEN a mineral, the composition of which we are desirous to discover, resists the action of water, and possesses characters that rank it among earthy bodies, the next object of inquiry is the nature of the earths that enter into its composition; in other words, how many of the simple earths, and which of them it may contain.—Of these earths, (*viz.* silex, alumine, magnesia, lime, strontites, barytes, zircon, glucine, and yttria), one or more may be expected in the composition of a mineral, beside a small proportion of metals, to which the colour of the stone is owing. In general, however, it is not usual to find more than four of the simple earths in one mineral. The newly discovered earths, zircon, glucine, and yttria, occur very rarely.

A stone, which is intended for chemical examination, should be finely powdered, and care should be taken that the mortar is of harder materials than the stone, otherwise it will be liable to abrasion, and uncertainty will be occasioned in the result of the process. A longer or shorter time is required, according to the texture of the stone. Of the harder gems, 100 grains require two or three hours trituration. For soft stones, a mortar of Wedgwood's ware is sufficient; but, for very hard minerals, one of agate, or hard steel, is required; and the stone should be weighed both before and after pulverization, that the addition, if any, may be ascertained and allowed for. Gems, and stones of equal hardness, gain generally from 10 to 13 *per cent.* When a stone is extremely difficult to be reduced to powder, it may sometimes be necessary to make it red-hot, and while in this state to plunge it into cold water. By this process it becomes brittle, and is afterwards easily pulverized. But this treatment is not always effectual; for Klaproth found the hardness of corundum not at all diminished by igniting it, and quenching in cold water.

The chemical agents, employed in the analysis of stones, should be of the greatest possible purity. To obtain them in this state, directions have been given in the former part of this work.

In treating of the analysis of stones, it may be proper to divide them, 1st, into such as are soluble, either wholly or in part, and with effervescence, in nitric or muriatic acids, diluted with five or six parts of water; and, 2dly, into such as do not dissolve in these acids.

1. *Earths or stones, soluble with effervescence, in diluted nitric or sulphuric acids.**

(A) If it be found, on trial, that the mineral under examination effervesces with either of these acids, let a given weight, finely powdered, be digested with one of them diluted in the above proportion, in a gentle heat, for two or three hours. Ascertain the loss of weight, in the manner pointed out, p. 208, and filter the solution, reserving the insoluble portion.

(B) The solution, when effected, may contain lime, magnesia, alumine, barytes, or strontites. To ascertain the presence of the two last, dilute an aliquot part of the solution with 20 times its bulk of water, and add a little sulphuric acid, or, in preference, solution of sulphate of soda. Should a white precipitate fall down, we may infer the presence of barytes, of strontites, or of both.

(C) To ascertain which of these earths (*viz.* barytes or strontites) is present, or, if both are contained in the solution, to separate them from each other, add sulphate of soda till the precipitate ceases; decant the supernatant liquid; wash the sediment on a filter, and dry it. Then digest it, with four times its weight of pure carbonate of potash, and a sufficient quantity of water, in a gentle heat, during two or three hours. A double exchange of principles will ensue, and we shall obtain a carbonate of barytes or strontites, or a mixture of both. Pour on these, after being well washed, nitric acid, of the specific gravity 1.4, diluted with an equal weight of distilled water. This will dissolve the strontites, but not the barytes. To determine whether any strontites has been taken up by the acid, evaporate the solution to dryness, and dissolve the dry mass in alcohol. This alcoholic solution, if it contain nitrate of strontites, will burn with a deep blood-red flame.

Barytes and strontites may also be separated from each other in the following manner: To a saturated solution of the two earths in an acid, add prussiate of potash, which, if pure, will occasion no immediate precipitation; but, after some time, small and insoluble crystals will form on the surface of the jar. These are the prussiated barytes, which may be changed into the carbonate by a red-heat, continued, with the access of air, till the black colour disappears. The strontites may be afterward separated from the solution by carbonate of potash.

A third method of separating strontites from barytes is founded on the stronger affinity of barytes, than of the former earth, for acids. Hence if the two earths be present in the same solution, add a solution of pure barytes, till the precipitation ceases. The

* The sulphuric acid is chiefly eligible for stones of the magnesian genus.

barytes will seize the acid, and will throw down the strontites. The strontitic solution, in this case, should have no excess of acid, which would prevent the action of the barytic earth.*

(D) The solution (B), after the addition of sulphate of soda, may contain lime, magnesia, alumine, and some metallic oxides. To separate the oxides, add prussiate of potash, till its effect ceases, and filter the solution, reserving the precipitate for future experiments.

(E) When lime, magnesia, and alumine, are contained in the same solution, proceed as follows :

(a) Precipitate the solution, previously made hot, by carbonate of potash; wash the precipitate well, and dry it. It will consist of carbonate of lime, magnesia, and alumine. (b) The alumine may be separated, by digestion with a solution of pure potash, which will dissolve the alumine but not the other earths. (c) To this solution of alumine, add diluted muriatic acid, till the precipitate ceases; decant the supernatant liquor; wash the precipitate well with distilled water, and dry it. Then expose it to a low red-heat, in a crucible, and weigh it, which will give the proportion of alumine.

(F) Magnesia and lime may be separated by the following process: Evaporate the solution, in nitric or muriatic acid, to dryness. Weigh the dry mass, and pour on it, in a glass evaporating dish,† more than its own weight of strong sulphuric acid. Apply a sand-heat till the acid ceases to rise, and then raise the heat, so as to expel the excess of sulphuric acid. Weigh the dry mass, and digest it in twice its weight of cold distilled water. This will dissolve the sulphate of magnesia, and will leave the sulphate of lime, which must be put on a filtre, washed with a little more water, and dried in a low red-heat. To estimate the quantity of lime deduct, from the weight of the sulphate, fifty-nine per cent. According to Klaproth,‡ crystallized sulphate of lime contains one third of earth.

If the lime be only in very small proportion to the magnesia, the two sulphates may be separated by evaporation, that of lime crystallizing first.

From Klaproth's experiments, 100 parts of sulphuric acid, specific gravity 1850, when saturated with lime, give 160 of sulphate. To saturate 100 parts of this acid, 55 parts of pure lime are required, or 100 of carbonate of lime.

The magnesia is next to be precipitated from the sulphate by the carbonate of potash, in a heat approaching 212° ; and the precipitate, after being well washed, must be dried, and calcined for an hour. Its weight, after calcination, will give the quantity of magnesia contained in the stone.

* Klaproth separates barytes from strontites by evaporating the mixed solutions of both. The barytic salt, being less soluble, separates first; and the strontitic is contained in the last portions.

† The bottom of a broken Florence flask answers this purpose extremely well, and bears, without breaking, the heat necessary to expel the sulphuric acid.

‡ Vol. i. page 76, n.

(G) If magnesia and alumine only be contained in a solution (the absence of lime being indicated by the non-appearance of a precipitate, on adding oxalate of ammonia), the two earths may be separated by adding, to the cold solution, the carbonate of ammonia. This will separate the alumine, which may be collected, washed, and dried. To ascertain that a complete separation of the two earths has been accomplished, the process may be followed, recommended by Klaproth, vol. i. page 418.* The magnesia, remaining in solution, may be precipitated by carbonate of potash; heat being applied, to expel the excess of carbonic acid.

Magnesia and alumine may, also, be separated by succinate of soda, which precipitates the latter earth only.†

When the solution of magnesia, of alumine, or of both, contains a small proportion of iron, this may be separated from either or both of the earths by evaporating to dryness, calcining the residue, during one hour, in a low red-heat, and dissolving again in dilute nitric acid, which does not take up iron when thus oxydized.

(H) The insoluble residue (A) may contain alumine, silex, and oxides of metals, so highly charged with oxygen as to resist the action of nitric and muriatic acids.

(a) Add concentrated sulphuric acid, with a small quantity of potash, and evaporate the mixture to dryness, in the vessel described in the note, page 612. On the dry mass pour a fresh portion of the acid; boil again to dryness, and let this be done repeatedly, three or four times. By this operation, the alumine will be converted into a sulphate of alumine and potash, which will be easily soluble in warm water; and from the solution, crystals of alum will shoot on evaporation.‡ Let the sulphate of alumine be washed off, and the insoluble part be collected and dried. The alumine may be precipitated by carbonate of potash; washed, dried, and ignited; and its weight ascertained.

During the evaporation of a solution of alumine, which has been separated from silex, portions of the latter earth continue to fall, even to the last.§ These must be collected, and washed with warm water; the collected earth added to the portion (b), and the washings to the solution (a).

Alumine may be separated from oxide of iron by a solution of pure potash.

From whatever acid alumine is precipitated by fixed alkali, it is apt to retain a small portion of the precipitant. To ascertain the true quantity of this earth, it must, therefore, be re-dissolved in acetic acid, again precipitated by solution of pure ammonia, dried, and ignited.

(b) The oxides (generally of iron only) may be separated from the silex in the following manner:—Let the insoluble part (a) be

* Analytical Essays. C.

† See section I, xvii. of the chapter on Mineral Waters.

‡ Klaproth procured crystals of alum from one fourth of a grain of alumine. The quantity of alumine he estimates at one tenth the weight of the crystallized alum which is obtained.

§ See Klaproth, vol. i. pages 66 and 75.

heated in a crucible with a little wax. This will render the oxides soluble in diluted sulphuric acid, and the silex will be left pure and white. Let it be washed, ignited, and its weight ascertained.

2. *Stones insoluble in diluted nitric and muriatic acids.*

These stones must be reduced to powder, observing the cautions given in page 610.

(I) Let 100 grains, or any other determinate quantity, be mixed with three times their weight of pure and dry potash. Put the whole into a crucible of pure silver, set in one of earthenware of a larger size, the interstice being filled with sand; and add a little water.* The crucible, covered with a lid, must then be gradually heated; and, as the materials swell and would boil over, they are to be stirred constantly with a rod or spatula of silver. When the moisture is dissipated, and the mass has become quite dry, raise the heat as far as can be done without melting the crucible, if of silver, and continue the heat during half an hour, or an hour.

The phenomena that occur during this operation, indicate, in some degree, the nature of the mineral under examination. If the mixture undergo a perfectly liquid fusion, we may presume that the stone contains much siliceous earth; if it remain pasty and opaque, the other earths are to be suspected; and lastly, if it have the form of a dry powder, the bulk of which has considerably increased, it is a sign of the predominance of alumine.

If the fused mass have a dark green or brownish colour, the presence of oxide of iron is announced; a bright green indicates manganese, especially if the colour be imparted to water; and a yellowish green the oxide of chrome.

(a) The disintegration of stones, consisting chiefly of alumine, is not easily effected, however, by means of potash. Mr. Chenevix found (*Philosophical Transactions*, 1802) that minerals of this class are much more completely decomposed by fusion with calcined borax. One part of the mineral to be examined, reduced to very fine powder, and mingled with $2\frac{1}{2}$ or three times its weight of glass of borax (see chap. xvi), is to be exposed to a strong heat for two hours in a crucible of platina, set in a larger earthen one, and surrounded by sand. The crucible and its contents, which adhere very strongly to it, are then to be digested, for some hours, with muriatic acid, by which a perfect solution will be accomplished. The whole of the earthy part is then to be precipitated by sub-carbonate of ammonia; and the precipitate, after being well washed, is to be re-dissolved in muriatic acid. By this means, the borax is separated. The analysis is afterwards to be conducted nearly in the manner which will presently be described.

(K) The crucible, being removed from the fire, is to be well cleaned on the outside, and set, with its contents, in a porcelain or

* Klaproth effected the disintegration of corundum (which resisted eleven successive fusions with alkali) by adding to the powdered stone, in a crucible, a solution of pure potash, boiling to dryness, and pushing the mixture to fusion. The alkali must be perfectly caustic, and must have been purified by alcohol, as recommended, page 149. A platina crucible is unfit for this purpose, as it is corroded by pure alkalis.

glass vessel, filled with hot water, which is to be stirred and renewed, occasionally, till the whole mass is detached. The water dissolves a considerable part of the compound of alumine and silex with potash, and even the whole, if added in sufficient quantity. During cooling, a sediment occasionally forms, in the filtered liquor, of a brownish colour, which is oxide of manganese. (See Klaproth, i. 345, *b*.)

(L) To the solution (K), and the mass that has resisted solution, in the same vessel, add muriatic acid. The first portions of acid will throw down a flocculent sediment, which consists of the earths that were held dissolved by the alkali. Then an effervescence ensues; and a precipitate occurs, which is no sooner formed than it is dissolved. Lastly, the portion that resisted the action of water is taken up, silently if it contain alumine, and with effervescence if it be calcareous earth.

(M) From the phenomena attending the action of muriatic acid, some indications may be derived. If the solution assume a purplish red colour, it is a sign of oxide of manganese; an orange red shows iron; and a gold yellow colour betokens chrome. Freedom from colour proves, that the stone contains no metallic ingredients.

(N) When the solution is complete, it is to be evaporated to dryness in a glass vessel; but, if any thing resist solution, it must be heated, as before (I), with potash. When the liquor approaches to dryness, it assumes the form of a jelly, and must then be diligently stirred till quite dry.

(O) (*a*) Let the dry mass be digested, in a gentle heat, with three or four pints, or even more, of distilled water, and filtered. (*b*) Wash what remains on the filter, repeatedly, till the washing ceases to precipitate the nitrate of silver, and add the washings to the filtered liquor. (*c*) Let the residue on the filter be dried and ignited in a crucible. Its weight shows the quantity of silex. If pure, it should be perfectly white, but if it has any colour, an admixture of some metallic oxide is indicated. From this it may be purified by digestion in muriatic acid, and may again be washed, ignited, and weighed.

(P) The solution (O), which, owing to the addition of the washings, will have considerable bulk, is next to be evaporated, till less than a pint remains; carbonate of potash must then be added, and the liquor must be heated during a few minutes. Let the precipitate, occasioned by the alkali, subside; decant the liquor from above it, and wash the sediment, repeatedly, with warm water. Let it then be put on a filter and dried.

(Q) The dried powder may contain alumine, lime, magnesia, barytes, or strontites; besides metallic oxides, which may be separated from each other by the rules already given.

(R) It may be proper to examine the solution (P) after the addition of carbonate of potash, in order to discover whether any and what acid was contained in the stone.

(*a*) For this purpose, let the excess of alkali be neutralized by muriatic acid, and the liquor filtered.

(b) Add, to a little of this liquor, a solution of muriated barytes. Should a copious precipitate ensue, which is insoluble in dilute muriatic acid, the presence of sulphuric acid is detected. And if much barytes, strontites, or lime, has been found in the precipitate (Q), we may infer the presence of a sulphate of one of these three earths.

(c) If, on mixing the liquid (a) with the solution of muriated barytes, a precipitate ensues which is soluble, without effervescence, in muriatic acid, the phosphoric acid may be known to be present; and, if lime be also found, the phosphate of lime is indicated.

(d) To a portion of the liquor (a) add a solution of muriate of lime, till the precipitate if any ceases. Collect this precipitate, wash it, dry it, and pour on it a little sulphuric acid. Should acid fumes arise, the fluoric acid may be suspected. To ascertain its presence decisively, distil a portion of the precipitate with half its weight of sulphuric acid. The fluoric acid will be known by its effects on the retort, and by the properties described, chap. xvii.

(S) The method of separating, from each other, the metallic oxides, usually found as the colouring ingredients of stones, remains to be accomplished.

(a) Let the precipitate, by the prussiate of potash (D), be exposed to a red-heat, by which the prussic acid will be decomposed. The oxides thus obtained, if insoluble in dilute nitric or muriatic acid, will be rendered soluble, by again calcining them with the addition of a little wax or oil.

(b) Or the process may be varied by omitting the precipitation by prussiate of potash, and proceeding as directed (E), page 612.

The oxides will remain mixed with the magnesia and lime, and after the addition of sulphuric acid, will be held in solution by that acid, along with magnesia only.

In both cases the same method of proceeding may be adopted; such variation only being necessary as is occasioned by the presence of magnesia in the latter.

(c) To the solution (a or b), containing several metallic oxides dissolved by an acid, add a solution of crystallized carbonate of potash, as long as any precipitation ensues. This will separate the oxides of iron, chrome, and nickel; but the oxide of manganese and the magnesia, if any be present, will remain dissolved.

If a small quantity of oxide of manganese be suspected in an oxide of iron, it may be detected by mixing the oxide with nitre, and throwing the mixture into a red-hot crucible. Manganese will be indicated by an amethystine red tinge in the solution of this nitre.

To separate the oxides of iron and manganese from each other, Gehlen recommends succinic acid, which is preferred, also, by Klaproth and Bucholz. Berzelius employs for this purpose the compounds of benzoic acid. Dr. John advises the addition of oxalate of potash to the solution of the two oxides, first rendered as neutral as possible; but Bucholz finds that this process is imperfect, and that the oxalates precipitate manganese as well as iron.

Mr. Hatchett has lately published a new method of separating iron from manganese. The solution of the ore, made by muriatic acid, and filtrated, must be diluted with three or four pints of cold distilled water. To this liquid, pure ammonia must be gradually added, till it slightly restores the blue colour of reddened litmus paper. The oxide of iron will thus be separated, and will remain on the filtre upon which the liquor is thrown; and the oxide of manganese will pass through it, in a state of solution. The oxide of manganese may be obtained by evaporation to dryness, and by calcining in a heat sufficient to expel the muriate of ammonia.*

(d) Magnesia and oxide of manganese may be separated by adding to their solution (c) the hydro-sulphuret of potash,† which will throw down the manganese, but not the magnesia. The precipitated manganese must be calcined with the access of air and weighed. The magnesia may afterward be separated by solution of pure potash; and, when precipitated, must be washed, dried, and calcined.

(e) The oxide of chrome may be separated from those of iron and nickel, by repeatedly boiling the three to dryness, with nitric acid. This will acidify the chrome, and will render it soluble in pure potash, which does not take up the other oxides. From this combination with potash the chromic oxide may be detached, by adding muriatic acid, and evaporating the liquor till it assumes a green colour. Then, on adding a solution of pure potash, the oxide of chrome will fall down, because the quantity of oxygen, required for its acidification, has been separated by the muriatic acid.

(f) The oxides of iron and nickel are next to be dissolved in muriatic acid; and to the solution pure liquid ammonia is to be added, till there is an evident excess of it. The oxide of iron will be precipitated, and must be dried and weighed. If highly oxidized, it must, before weighing, be calcined with wax, in a crucible.‡ The oxide of nickel remains dissolved by the excess of ammonia, to which it imparts a blue colour. It may be separated by evaporating the solution to dryness and dissolving the salt.§

The analysis of the stone is now completed, and its accuracy may be judged by the correspondence of the weight of the component parts with that of the stone originally submitted to experiment.

It may be proper to observe, that certain stones, which are not soluble in diluted nitric and muriatic acids, may be decomposed by an easier process than that described (A). Among these are the compounds of barytes, strontites, and lime, with acids, chiefly with the sulphuric, fluoric, and phosphoric. The sulphates of barytes, strontites, and lime; the fluat of lime; and the phosphate of lime; are all found native in the earth, and, except the last, are all insoluble.

* Thomson's Annals, v. 343.

† See page 252.

‡ Dr Marcet alleges that after this operation, the iron still remains in the state of peroxide. Geolog. Transact. i.

§ For an example of the separation of nickel from iron, see Klaproth, vol. i. p. 422; where, also, and page 428, is an instance of the testing of nickel for copper.

ble in the above-mentioned acids. They may be known generally by their external characters. The compounds of barytes and strontites have a specific gravity greater than that of other earths, but inferior to that of metallic ores. They have, frequently, a regular or crystallized form, are more or less transparent, have some lustre, and their hardness is such as does not prevent their yielding to the knife. The combinations of lime, with the above-mentioned acids, are distinguished by similar characters, except that they are much less heavy. To the mineralogist, the outward form and characters of these stones are sufficient indications of their composition.

Instead of the fusion with alkali, an easier process may be recommended. Let the mineral under examination be reduced to powder, and be digested, in nearly a boiling heat, during one or two hours, with three or four times its weight of carbonate of potash, and a sufficient quantity of distilled water. The acid, united with the earth, will quit it and pass to the potash, while the carbonic acid will leave the alkali and combine with the earth. We shall obtain, therefore, a compound of the acid of the stone with potash, which will remain in solution, while the carbonated earths will form an insoluble precipitate. The solution may be assayed to discover the nature of the acid, according to the formula (I); and the earths may be separated from each other by the processes (B), &c.

(T) In the foregoing rules for analysis I have omitted the mode of detecting and separating *glucine*, because this earth is of very rare occurrence. When alumine and glucine are present in a mineral, they may be separated from the precipitate (E. a) by pure potash, which dissolves both these earths. A sufficient quantity of acid is then to be added to saturate the alkali; and carbonate of ammonia is to be poured in till a considerable excess of this carbonate is manifested by the smell. The alumine is thus separated, but the glucine, being soluble in the carbonate of ammonia, remains dissolved, and may be precipitated by boiling the solution.

(U) Zircon may be separated from alumine, by boiling the mixed earths with pure soda, which acts only on the latter.* From an acid solution containing both earths, the alumine is thrown down by saturated carbonate of potash, which, when added in excess, re-dissolves the zircon. Glucine and zircon, or glucine and yttria, may be separated, when mixed together in solution, by prussiate of potash, which has no action on glucine, but precipitates the two other earths.

(V) To separate yttria from alumine, precipitate them from a solution containing both earths, by pure ammonia; boil the precipitate in a solution of pure soda, which chiefly takes up alumine; neutralize the solution with sulphuric acid, and add carbonate of soda to the solution, brought to the boiling temperature. A precipitate will ensue, consisting of alumine, with some yttria. To separate the latter earth, dissolve in muriatic acid, and add an excess of carbonate of ammonia, which takes up only the yttria. To ensure, still farther, the purity of the alumine, dissolve the resi-

* Klaproth, vol. ii. page 213.

due in an excess of sulphuric acid : add a small portion of sulphate of potash, and crystallize the solution. The crystals of alum, that are produced, contain one tenth of alumine.

(W) The presence of potash (which has lately been discovered in some stones) may be detected by boiling the powdered mineral, repeatedly to dryness, with strong sulphuric acid. Wash the dry mass with water, add a little excess of acid, and evaporate the solution to a smaller bulk. If crystals of alum should appear, it is a decisive proof of potash, because this salt can never be obtained, in a crystallized form, without the addition of the vegetable alkali.

But since a mineral may contain potash, and little or no alumine, in which case no crystals of alum will appear, it may be necessary, in the latter case, to add a little alumine along with the sulphuric acid. Or the stone may be so hard as to resist the action of sulphuric acid ; and it will then be necessary to fuse it (in the manner directed (I) with soda, which has also a solvent power over alumine and silex. The fused mass is to be dissolved in water, and supersaturated with sulphuric acid. Evaporate to dryness, redissolve in water ; and filter, to separate the silex. Evaporate the solution, which will first afford crystals of sulphate of soda, and afterwards of sulphate of potash, should the latter alkali be contained in the mineral.

Klaproth first discovered potash in leucite, on summing up the results of its analysis, which gave a considerable loss of weight. By boiling the stone with diluted muriatic acid, and evaporation, he obtained crystals of muriate of potash. Another proof of the presence of potash was, that, when sulphuric acid was boiled with it, the solution gave crystals of alum, to which potash is essential. He also boiled the stone with muriatic acid, and, after dissolving the muriate of alumine by alcohol, muriate of potash remained. The volcanic leucite contained less potash than other kinds. The same alkali he also detected, afterwards, in lepidolite.

The potash, contained in sulphate of alumine, may be separated from the earth by adding a solution of pure barytes as long as any precipitation is produced. The alumine and sulphate of barytes will fall down together, and the potash will remain in solution. Its presence may be known by the tests, enumerated in the first chapter of part ii (sect. 2.)

X. Soda may be detected in a mineral by the following experiments :—Let the powdered stone be treated with sulphuric acid, as in (U) ; wash off the solution, and add pure ammonia, till the precipitation ceases ; then filter, evaporate the solution to dryness, and raise the heat so as to expel the sulphate of ammonia. The sulphate of soda will remain, and may be known by the characters, page 236.

Soda was first found, by Klaproth, in chryolite, in the large proportion of 36 per cent. This analysis was confirmed by Vauquelin, whose mode of separating it happens to be the one I now recommend. Both the fixed alkalis have since been frequently discovered in native minerals ; viz. soda in basalt (Klaproth, ii. 195) ; in pitch-stone (207) ; and in kling-stone, amounting to 8 per cent.

(182.) The same skilful analyst has found potash in Hungarian pearl-stone (263); and, accompanied by soda, in pumice (20).

A new method has been proposed by Sir H. Davy,* for analyzing stones, containing either of the fixed alkalis; *viz.* by means of the boracic acid. The process is sufficiently simple. One hundred grains of the stone to be examined must be fused, during half an hour, at a strong red-heat, with 200 grains of boracic acid. An ounce and a half of nitric acid, diluted with seven or eight parts of water, must be digested on the mass, till the whole has been decomposed. The fluid must be evaporated, till its quantity is reduced to an ounce and half, or two ounces.

If the stone contain silex, this earth will be separated in the process of solution and evaporation. It must be collected on a filter, and washed well with water, till the boracic acid, and all the saline matter are separated. The fluid, and all that has passed through the filter, must be evaporated to about half a pint; then saturated with carbonate of ammonia; and boiled with an excess of that salt, till all the materials that it contains, capable of being precipitated, have fallen to the bottom of the vessel. The solution must then be passed through a filter, which retains the earths and metallic oxides. It must then be mixed with nitric acid, till it tastes strongly sour, and evaporated till the boracic acid appears free. The fluid must next be evaporated to dryness; when by exposure to a heat of 450° Fahrenheit, the nitrate of ammonia will be decomposed, and the nitrate of potash or soda will remain in the vessel.

The remaining earths and metallic oxides are separated from each other by common processes; *viz.* alumine by solution of potash; lime by sulphuric acid; oxide of iron by succinate of ammonia; oxide of manganese by hydrosulphuret of potash; and magnesia by pure soda.

2. *Table of Substances which may be expected in Earths and Stones, and references to the means of separating them from each other.*

Acid, fluoric, R. d.

phosphoric, R. c.

sulphuric, R. b.

Alumine from lime and magnesia, E.

its quantity, E. c.

from magnesia, G.

silex, H. a.

metallic oxides, H. a.

glucine, T.

Barytes and Strontites from other earths, B.

from strontites, C.

* Philosophical Transactions, 1805; or Nicholson's Journal, xiii. 86.

- Chrome* from manganese, &c. S. c.
 iron and nickel, S. e.
Earths from oxides, D.
Glucine from alumine, T.
Iron from manganese, S. c.
 nickel, S. f.
Lime from magnesia, F.
 alumine, E. b.
 its quantity, F.
Magnesia from lime, F.
 alumine, G.
 manganese, S. d.
 its quantity, F.
Manganese, indications of, M.
 from iron, chrome, and nickel, S. c.
 magnesia, S. d.
Nickel from manganese, S. c.
 iron, S. f.
Oxides, metallic, from earths, D.
Potash from earths and oxides, W.
Silex from alumine, H. a.
 earths in general, O. c.
 oxides, H. b.
Soda from earths and oxides, X.
Strontites, see *Barytes*.
Ytria from alumine, &c. V.
Zircon from alumine, &c. U.

SECTION V.

Analysis of Inflammable Fossils.

THE exact analysis of inflammable fossils is seldom necessary in directing the most beneficial application of them. It may be proper, however, to offer a few general rules for judging of their purity.

I.—*Sulphur.*

Sulphur should be entirely volatilized by distillation in a glass retort. If any thing remain fixed, it must be considered as an impurity, and may be examined by the preceding rules.

Sulphur, also, should be totally dissolved by boiling with solution of pure potash, and may be separated from its impurities by this alkali.

Impure sulphur, consumed by burning in a small crucible, leaves a residue of oxide of iron and silex.

II.—*Coals.*

1. The proportion of bituminous matter in coal may be learnt by distillation, in an earthen retort, and collecting their product.

2. The proportion of earthy or metallic ingredients may be found, by burning the coal with access of air, on a red-hot iron. What remains unconsumed must be considered as an impurity, and may be analyzed by the foregoing rules.

3. The proportion of carbon may be ascertained by observing the quantity of nitrate of potash which a given weight of the coal is capable of decomposing. For this purpose, let 500 grains, or more, of perfectly pure nitre be melted in a crucible, and, when red-hot, let the coal to be examined, reduced to a coarse powder, be projected on the nitre, by small portions at once, not exceeding one or two grains. Immediately, when the flame, occasioned by one projection, has ceased, let another be made, and so on till the effect ceases. The proportion of carbon in the coal is directly proportionate to the quantity required to alkalize the nitre. Thus, since 12.709 of carbon are required to alkalize 100 of nitre, it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitre which it is capable of decomposing. This method, however, is liable to several objections, which its inventor, Mr. Kirwan, seems fully aware of.*

Plumbago, or *black-lead*, is another inflammable substance, which it may sometimes be highly useful to be able to identify, and to judge of its purity.—When projected on red-hot nitre, it should detonate; and, on dissolving the decomposed nitre, an oxide of iron should remain, amounting to one tenth its weight of plumbago. Any mineral, therefore, that answers to these characters, and leaves a shining trace on paper, like that of the black-lead pencils, is plumbago.

SECTION VI.*Analysis of Metallic Ores.*

THE class of metals comprehends so great a number of individuals, that it is almost impossible to offer a comprehensive formula for the analysis of ores. Ores of the same metal, also, as the mineralizing ingredients vary, require very different treatment. Yet some general directions are absolutely necessary, to enable the naturalist to judge of the composition of bodies of this class.

The ores of metals may be analyzed in two modes, in the humid and the dry way. The first is effected with the aid of acids and of other liquid agents, and may often be accomplished by persons who are prevented by the want of furnaces, and other necessary appa-

* See his *Elements of Mineralogy*, vol. ii. page 514.

tus, from attempting the second. If sulphur, however, be present in an ore, which may be generally known by its external characters, as described by mineralogical writers, it impedes the action of acids; and should be separated, either by roasting the ore on a muffle, or by projecting it, mixed with twice or thrice its weight of nitre, into a red-hot crucible, washing off the alkali afterwards by hot water.

It is hardly possible to employ a solvent, capable of taking up all the metals. Thus, the nitric acid does not act on gold or platina; and the nitro-muriatic, which dissolves these metals, has no solvent action on silver. It will be necessary, therefore, to vary the solvent according to the nature of the ore under examination.

1. *For ores of gold and platina*, the nitro-muriatic acid is the most proper solvent. A given weight of the ore may be digested with this acid, as long as it extracts any thing. The solution may be evaporated to dryness, in order to expel the excess of acid, and dissolved in water. The addition of a solution of muriate of tin will show the presence of gold by a purple precipitate; and platina will be indicated by a precipitate, on adding a solution of muriate of ammonia. When gold and platina are both contained in the same solution, they may be separated from each other by the last-mentioned solution, which throws down the platina but not the gold. In this way platina may be detached, also, from other metals.

When gold is contained in a solution, along with several other metals, it may be separated from most of them by adding a dilute solution of sulphate of iron. The only metals, which this salt precipitates, are gold, palladium, silver, and mercury.

2. *For extracting silver from its ores*, the nitric acid is the most proper solvent. Nitric acid, however, does not act on horn-silver ore, which must be decomposed by carbonate of soda. The silver may be precipitated from nitric acid by muriate of soda (common salt). Every 100 parts of the precipitate contain 75 of silver. But, as lead may be present in the solution, and this metal is also precipitated by muriate of soda, it may be proper to immerse in the solution (which should not have any excess of acid) a polished plate of copper. This will precipitate the silver, if present, in a metallic form. The muriate of silver is also soluble in liquid ammonia, which that of lead is not. For examples of the analysis of silver ores, the reader may consult Klaproth, vol. i. page 554, &c.

3. *Copper ores* may be analyzed by boiling them with five times their weight of concentrated sulphuric acid, till a dry mass is obtained, from which water will extract the sulphate of copper. This salt is to be decomposed by a polished plate of iron, immersed in a dilute solution of it. The copper will be precipitated in a metallic state, and may be scraped off and weighed.

If silver be suspected along with copper, nitrous acid must be employed as the solvent; and a plate of polished copper will detect the silver.

The reader who engages in the analysis of copper ores, will derive much advantage from the examples to be found in Klaproth's Essays, vol. i. pages 54, 541, &c.; and also from Mr. Chenevix's

paper on the analysis of arseniates of copper and iron, Philosophical Transactions, 1801, or Nicholson's Journal, 8vo. vol. 1.; and from Vauquelin's remarks in Thomson's Annals, iv. 157.

4. *Iron ores* may be dissolved in dilute muriatic acid, or, if the metal be too highly oxydized to be dissolved by this acid, they must be previously mixed with one eighth of their weight of powdered charcoal, and calcined in a crucible for one hour. The iron is thus rendered soluble.

The solution must then be diluted with 10 or 12 times its quantity of water, previously well boiled, to expel the air, and must be preserved in a well-stopped glass bottle for six or eight days. The phosphate of iron will, within that time, be precipitated, if any be present, and the liquor must be decanted off.

The solution may contain the oxides of iron, manganese, and zinc. It may be precipitated by carbonate of soda, which will separate them all. The oxide of zinc will be taken up by a solution of pure ammonia; distilled vinegar will take up the manganese, and will leave the oxide of iron. From the weight of this, after ignition, during a quarter of an hour, 28 per cent. may be deducted. The remainder shows the quantity of iron.

5. *Tin ores.* To that most accomplished analyst, Klaproth, we owe the discovery of a simple and effectual mode of analysing tin ores in the humid way.

Boil 100 grains, in a silver vessel, with a solution of 600 grains of pure potash. Evaporate to dryness, and then ignite, moderately, for half an hour. Add boiling water, and, if any portion remain undissolved, let it undergo a similar treatment.

Saturate the alkaline solution with muriatic acid, which will throw down an oxide of tin. Let this be re-dissolved by an excess of muriatic acid; again precipitated by carbonate of soda; and, being dried and weighed, let it, after lixiviation, be once more dissolved in muriatic acid. The insoluble part consists of silex. Into the colourless solution, diluted with two or three parts of water, put a stick of zinc, round which the reduced tin will collect. Scrape off the deposit, wash, dry, and fuse it under a cover of talow in a capsule placed on charcoal. A button of pure metallic tin will remain at the bottom, the weight of which, deducted from that of the ore, indicates the proportion of oxygen.

The presence of tin in an ore is indicated by a purple precipitate, on mixing its solution in muriatic acid with one of gold in nitro-muriatic acid.

6. *Lead ores* may be analyzed by solution in nitric acid, diluted with an equal weight of water. The sulphur, if any, will remain undissolved. Let the solution be precipitated by carbonate of soda. If any silver be present, it will be taken up by pure liquid ammonia. Wash off the excess of ammonia by distilled water; and add concentrated sulphuric acid, applying heat, so that the muriatic acid may be wholly expelled. Weigh the sulphate of lead, and, after deducting 70 *per cent.*, the remainder shows the quantity of lead.

Muriate of lead may also be separated from muriate of silver by

its greater solubility in warm water. From the solution, iron may be separated by prussiate of potash, and the solution decomposed by sulphuric acid.

7. *Mercury* may be detected in ores that are supposed to contain it, by distillation in an earthen retort with half their weight of iron filings or lime. The mercury, if any be present, will rise and be condensed in the receiver.

8. *Ores of zinc* may be digested with the nitric acid, and the part that is dissolved boiled to dryness, again dissolved in the acid, and again evaporated. By this means the iron, if any be present, will be rendered insoluble in dilute nitric acid, which will take up the oxide of zinc. To this solution add pure liquid ammonia, in excess, which will separate the lead and iron, if any should have been dissolved; and the excess of alkali will retain the oxide of zinc. This may be separated by the addition of an acid, or by the evaporation of the solvent.

9. *Antimonial ores.* Dissolve a given weight, in three or four parts of muriatic and one of nitric acid. This will take up the antimony, and leave the sulphur, if any. On dilution with water, the oxide of antimony is precipitated, and the iron and mercury remain dissolved. Lead may be detected by sulphuric acid.*

10. *Ores of arsenic* may be digested with nitro-muriatic acid, composed of one part nitric, and one and a half or two of muriatic acid. Evaporate the solution to one fourth, and add water, which will precipitate the arsenic. The iron may afterwards be separated by ammonia.†

11. *Ores of bismuth* are also assayed by digestion in nitric acid moderately diluted. The addition of water precipitates the oxide, and, if not wholly separated at first, evaporate the solution; after which, a farther addition of water will precipitate the remainder.‡

12. *Ores of cobalt* may be dissolved in nitro-muriatic acid. Then add carbonate of potash, which at first separates iron and arsenic. Filter, and add a farther quantity of the carbonate, when a greyish red precipitate will fall down, which is oxide of cobalt. The iron and arsenic may be separated by heat, which volatilizes the arsenic. Cobalt is also ascertained, if the solution of an ore in muriatic acid give a sympathetic ink.§

13. *Ores of nickel.* Dissolve them in nitric acid, and add to the solution pure ammonia, in such proportion that the alkali may be considerably in excess. This will precipitate other metals, and will retain the oxide of nickel in solution, which may be obtained by evaporation to dryness, and heating the dry mass till the nitrate of ammonia has sublimed.

14. *Ores of manganese.* The earths, and several of the metals,

* See Klaproth on the Analysis of Antimoniated Silver Ore, vol. i. page 560.

† See Chenevix, Philosophical Transactions, 1801, page 215.

‡ See Analysis of an Ore of Bismuth and Silver, in Klaproth, vol. i. page 554; Mode of detecting a small Quantity of Silver in Bismuth, page 220. c.

§ See chap. xix. sect. 17.—An example of the analysis of an ore of cobalt may be seen in Klaproth, vol. i. page 564; and of sulphate of cobalt, page 579.

contained in these ores, may first be separated by diluted nitric acid, which does not act on highly oxydized manganese. The ore may afterwards be digested with strong muriatic acid, which will take up the oxide of manganese. Oxygenized muriatic acid will arise, if a gentle heat be applied, and may be known by its peculiar smell, and by its discharging the colour of wet litmus paper exposed to the fumes. From muriatic acid the manganese is precipitated by carbonate of soda, in the form of a white oxide, which becomes black when heated in a crucible. Ores, suspected to contain manganese, may also be distilled *per se*, or with sulphuric acid, when oxygen gas will be obtained. Oxide of manganese may be separated from oxide of iron by solution of pure potash, which takes up the former but not the latter.*

Ores of manganese may also be distinguished by the colour they impart to borax, when exposed together to the blow-pipe.†

15. *Ores of uranium.* These may be dissolved in dilute nitric acid, which takes up the uranic oxide, and leaves that of iron; or in dilute sulphuric acid, which makes the same election; or, if any iron has got into the solution, it may be precipitated by zinc. Then add caustic potash, which throws down the oxide of zinc and uranium. The former may be separated by digestion in pure ammonia, which leaves, undissolved, the oxide of uranium. This, when dissolved by dilute sulphuric acid, affords, on evaporation, crystals of a lemon yellow colour.

If copper be present, it will be dissolved, along with the zinc, by the ammonia. If lead, it will form, with sulphuric acid, a salt much less soluble than the sulphate of uranium, and which, on evaporation, will therefore separate first.

16. *Ores of tungsten.* For these the most proper treatment seems to be digestion in nitro-muriatic acid, which takes up the earths and other metals. The tungsten remains in the form of a yellow oxide, distinguishable, by its becoming white on the addition of liquid ammonia, from the oxide of uranium. To reduce this oxide to tungsten, mix it with an equal weight of dried blood, heat the mixture to redness, press it into another crucible, which should be nearly full, and apply a violent heat for an hour at least.

17. *Ores of molybdena.* Repeated distillation to dryness, with nitric acid, converts the oxide into an acid, which is insoluble in nitric acid, and may thus be separated from other metals, except iron, from which it may be dissolved by sulphuric or muriatic acids. The solution in sulphuric acid is blue, when cold, but colourless, when heated. That in muriatic acid is only blue, when the acid is heated and concentrated.‡

Respecting the ores of the remaining metals, sufficient information has been already given for the purposes of the general stu-

* See the analysis of an ore of manganese, *vid. humidâ*, in Klaproth, vol. i. page 510; and of a cobaltic ore of manganese, page 569.

† See chap. xix. sect. 18, and also Thomson's Annals, iii. 312.

‡ See Hatchett's Analysis of the Carinthian Molybdate of Lead, Philosophical Transactions, 1796; and Klaproth, vol. i. pages 534, 538.

dent, in part i. chap. xix. of this work; and they are of such rare occurrence, that it is unnecessary to describe them more in detail. It may be proper, however, to state where the best examples of the analysis of each may be found.

18. *Ores of titanium.* Consult Gregor, in *Journ. de Physique*, xxxix. 72. 152; Klaproth, i. 496; and Chenevix, Nicholson's Journal, v. 132.

19. *Ores of tellurium.* See Klaproth, ii. 1.

20. *Ores of tantalum.* *Ann. de Chim.* xliii. 276.

21. *Ores of chromium.* Vauquelin, *Ann. de Chim.* xxv.

22. *Ores of columbium.* Hatchett, *Phil. Trans.* 1802.

23. *Ores of palladium and rhodium.* Wollaston, *Phil. Trans.* 1805.

24. *Ores of iridium and osmium.* Tennant, *Phil. Trans.* 1804.

25. *Ores of cerium.* Hisenger and Berzelius, and Vauquelin, Nicholson's Journal, xii.

SECTION VII.

Analysis of Ores in the dry Way.

To analyze ores in the dry way, a method which affords the most satisfactory evidence of their composition, and should always precede the working of large and extensive strata, a more complicated apparatus is required.—An assaying furnace, with muffles, crucibles, &c. are absolutely necessary. These have already been enumerated in the chapter on Apparatus, and will be found described in the Explanation of the Plates. Much useful information respecting the composition of minerals may, also, be gained from experiments with the blow-pipe. The most ample directions for assays of this kind are given in a Memoir by Haussman, in the 43d volume of the Philosophical Magazine.

The reduction of an ore requires, frequently, previously roasting, to expel the sulphur and other volatile ingredients: or this may be effected, by mixing the powdered ore with nitre, and projecting the mixture into a crucible. The sulphate of potash, thus formed, may be washed off, and the oxide must be reserved for subsequent experiments.

As many of the metals retain their oxygen so forcibly, that the application of heat is incapable of expelling it, the addition of inflammable matter becomes expedient. And, to enable the reduced particles of metal to agglutinate and form a collected mass, instead of scattered grains, which would otherwise happen, some fusible ingredient must be added, through which, when in fusion, the reduced metal may descend, and be collected at the bottom of the crucible. Substances that answer both these purposes are called *fluxes*. The alkaline and earthy part of fluxes serve also another end, *viz.* that of combining with any acid which may be attached to a metal, and which would prevent its reduction if not separated.

The ores of different metals, and different ores of the same metal, require different fluxes. To offer rules, however, for each individual case, would occupy too much room in this work: I shall, therefore, only state a few of those fluxes that are most generally applicable.

The *black flux* is formed, by setting fire to a mixture of one part of nitrate of potash, and two of acidulous tartrate of potash; which affords an intimate mixture of sub-carbonate of potash, with a fine light coal. *White flux* is obtained by projecting into a red hot crucible equal parts of the same salts. Two parts of muriate of soda, previously dried in a crucible, one part of dry and powdered lime, one part of fluuate of lime, and half a part of charcoal; or 400 parts of calcined borax, 40 of lime, and 50 of charcoal; or, two parts of pounded and finely sifted glass, one of borax, and half a part of charcoal, are all well adapted to the purpose of fluxes. The ore, after being roasted, if necessary, is to be well mixed with three or four times its weight of the flux, and put into a crucible, with a little powdered charcoal over the surface. A cover must be luted on, and the crucible exposed to the necessary heat in a wind furnace. Ores of iron, as being difficultly reduced, require a very intense fire. Those of silver and lead are metallized by a lower heat. The metal is found at the bottom of the crucible, in the form of a round button.

The volatile metals, as mercury, zinc, arsenic, tellurium, and osmium, it is obvious, ought not to be treated in the above manner, and require to be distilled with inflammable matters in an earthen retort.

For minute instructions respecting the analysis of every species of ore, both in the humid and dry ways, I refer to the second volume of Mr. Kirwan's Mineralogy; and, for various excellent examples, to the essays of Vauquelin, in the *Annales de Chimie*; to those of Mr. Hatchett and Mr. Chenevix, in the *Philosophical Transactions*; of Dr. Kennedy, in *Nicholson's Journal*; and of Mr. Klaproth, in the work already frequently referred to. It is only, indeed, by an attention to these, and a few other models of chemical skill and accuracy, conjoined with the practical imitation of them, that facility, or certainty, in the art of analyzing minerals can be acquired: and though general rules are, in this instance, of considerable utility, it is impossible to frame any that can be adapted to the infinite variety which nature presents in the productions of the mineral kingdom.

ELEMENTS OF EXPERIMENTAL CHEMISTRY.

PART III.

APPLICATION OF CHEMICAL TESTS AND RE-AGENTS TO VARIOUS USEFUL PURPOSES.

CHAPTER I.

METHOD OF DETECTING POISONS.

WHEN sudden death is suspected to have been occasioned by the administration of poison, either wilfully or by accident, the testimony of the physician is occasionally required to confirm or invalidate this suspicion. He may also be sometimes called upon to ascertain the cause of the noxious effects arising from the presence of poisonous substances in articles of diet; and it may therefore serve an important purpose, to point out concisely the simplest and most practicable modes of obtaining, by experiment, the necessary information.

The only poisons, however, that can be clearly and decisively detected by chemical means, are those of the mineral kingdom. Arsenic, and corrosive sublimate,* are most likely to be exhibited with the view of producing death; and lead and copper may be introduced undesignedly, in several ways, into our food and drink. The continued and unsuspected operation of the two last may often produce effects less sudden and violent, but not less baneful to health and life, than the more active poisons; and their operation generally involves, in the pernicious consequences, a greater number of sufferers.

* I use the term arsenic, instead of the more proper one, arsenous acid; and corrosive sublimate, for muriate of mercury; because the former terms are more generally understood.

SECTION I.

Method of discovering Arsenic.

WHEN the cause of sudden death is believed, from the symptoms preceding it, to be the administration of arsenic, the contents of the stomach must be attentively examined. To effect this, let a ligature be made at each orifice, the stomach removed entirely from the body, and its whole contents washed out into an earthen or glass vessel. The arsenic, on account of its greater specific gravity, will settle to the bottom, and may be obtained separate, after washing off the other substances by repeated affusions of cold water. These washings should not be thrown away till the presence of arsenic has been clearly ascertained. It may be expected at the bottom of the vessel in the form of a white powder, which must be carefully collected, dried on a filter, and submitted to experiment.

(A) Boil a small portion of the powder with a few ounces of distilled water, in a clean Florence flask, and filter the solution.

(B) To this solution add a portion of water, saturated with sulphuretted hydrogen gas. If arsenic be present, a golden yellow sediment will fall down, which will appear sooner, if a few drops of acetic acid be added.

(C) A similar effect is produced by the addition of sulphuret of ammonia, or hydro-sulphuret of potash.*

It is necessary, however, to observe that these tests are decomposed not only by all metallic solutions but by the mere addition of any acid. But among these precipitates, Dr. Bostock assures us,† the greatest part are so obviously different as not to afford a probability of being mistaken; the only two, which bear a close resemblance to it, are the precipitate from tartarized antimony, and that separated by an acid. In the latter, however, the sulphur preserves its peculiar yellow colour, while the arsenic presents a deep shade of orange; but no obvious circumstance of discrimination can be pointed out between the hydro-sulphurets of arsenic and of antimony. Hence Dr. Bostock concludes that sulphuretted hydrogen and its compounds merit our confidence only as collateral tests. They discover arsenic with great delicacy: sixty grains of water, to which one grain only of liquid sulphuret (hydroguretted sulphuret?) had been added, was almost instantly rendered completely opaque by $\frac{1}{80}$ th of a grain of the white oxide of arsenic in solution.

(D) To a little of the solution (A) add a single drop of a weak solution of carbonate of potash, and afterward a few drops of a solution of sulphate of copper. The presence of arsenic will be manifested by a yellowish green precipitate. Or boil a portion of

* See vol. i. page 349, 350.

† Edinburgh Medical and Surgical Journal, v. 166.

the suspected power with a dilute solution of pure potash, and with this precipitate the sulphate of copper, when a similar appearance will ensue still more remarkably, if arsenic be present. The colour of this precipitate is perfectly characteristic. It is that of the pigment called Scheele's green.* To identify the arsenic with still greater certainty, it may be proper, at the time of making the experiments on a suspected substance, to perform similar ones, as a standard of comparison, on what is actually known to be arsenic. Let the colour, therefore, produced by adding an alkaline solution of the substance under examination to a solution of sulphate of copper, be compared with that obtained by a similar admixture of a solution of copper with one of real arsenic in alkali.

The proportions, in which the different ingredients are employed, Dr. Bostock has found to have considerable influence on the distinct exhibition of the effect. Those, which he has observed to answer best, were one of arsenic, three of potash (probably the sub-carbonate or common salt of tartar), and five of sulphate of copper. For instance, a solution of one grain of arsenic, and three grains of potash, in two drachms of water, being mingled with another solution of five grains of sulphate of copper in the same quantity of water, the whole was converted into a beautiful grass green, from which a copious precipitate of the same hue slowly subsided, leaving the supernatant liquor transparent and nearly colourless. The same materials, except with the omission of the arsenic, being employed in the same manner, a delicate sky-blue resulted, so different from the former, as not to admit of the possibility of mistake. In this way, $\frac{1}{40}$ th of a grain of arsenic, diffused through sixty grains of water, afforded, by the addition of sulphate of copper and potash in proper proportions, a distinct precipitate of Scheele's green. In employing this test, it is necessary to view the fluid by reflected and not by transmitted light, and to make the examination by day-light. To render the effect more apparent, a sheet of white paper may be placed behind the glass in which the mixed fluids are contained.†

(E) The sediments, produced by any of the foregoing experiments, may be collected, dried, and laid on red-hot charcoal. A smell of sulphur will first arise, and will be followed by that of garlic.

(F) A new process for detecting arsenic has been proposed by Mr. Hume of London in the *Philosophical Magazine* for May 1809, vol. xxxiii. The test, which he has suggested, is the fused nitrate of silver or lunar caustic, which he employs in the following manner:‡

Into a clean Florence oil flask, introduce two or three grains of any powder suspected to be arsenic; add not less than eight ounce-measures of either rain or distilled water; and heat this gradually

* See chap. xix. sect. 16.

† Lib. citat. page 170.

‡ London Medical and Physical Journal, xxiii. 448.

over a lamp or a clear coal fire, till the solution begins to boil. Then, while it boils, frequently shake the flask, which may be readily done by wrapping a piece of leather round its neck, or putting a glove upon the hand. To the hot solution, add a grain or two of sub-carbonate of potash or soda, agitating the whole to make the mixture uniform.

In the next place, pour into an ounce phial or a small wine glass about two table spoonfuls of this solution, and present, to the mere surface of the fluid, a stick of dry nitrate of silver or lunar caustic. If there be any arsenic present, a beautiful yellow precipitate will instantly appear, which will proceed from the point of contact of the nitrate with the fluid, and settle towards the bottom of the vessel as a flocculent and copious precipitate. This precipitate, Mr. Hume is confident, cannot be confounded with any other substance, so as to lead to a doubtful opinion.

The nitrate of silver, Mr. Hume finds, also, acts very sensibly upon *arsenate* of potash, and decidedly distinguishes this salt from the above solution or *arsenite* of potash; the colour of the precipitate, occasioned by the *arsenate*, being much darker and more inclined to brick or red. In both cases, he is of opinion, that the test of nitrate of silver is greatly superior to that of sulphate of copper; inasmuch as it produces a much more copious precipitate, when equal quantities are submitted to experiment. The tests he recommends to be employed in their dry state, in preference to that of solution; and that the piece of salt be held on the surface only.

A modified application of this test has since been proposed by Dr. Marcet, whose directions are as follow. Let the fluid, suspected to contain arsenic, be filtered; let the end of a glass rod, wetted with a solution of pure ammonia, be brought into contact with this fluid, and let the end of a clean rod similarly wetted with solution of nitrate of silver, be immersed in the mixture. If the minutest quantity of arsenic be present, a precipitate of a bright yellow colour inclining to orange will appear at the point of contact, and will readily subside to the bottom of the vessel. As this precipitate is soluble in ammonia, the greatest care is necessary not to add an excess of that alkali. The acid of arsenic, with the same test, affords a brick red precipitate.*

Mr. Sylvester has objected to this test, that it will not produce the expected appearance, when common salt is present. He has, therefore, proposed the red acetate of iron as a better test of arsenic, with which it forms a bright yellow deposit; or the acetate of copper, which affords a green precipitate. Of the two, he recommends the latter in preference, but advises that both should be resorted to in doubtful cases.† Dr. Marcet, however, has replied, that the objection arising from the presence of common salt is easily obviated; for if a little dilute muriatic acid be added to the suspected liquid, and then nitrate of silver very cautiously till the precipitate ceases, the muriatic acid will be removed, but the arse-

* Med. Chir. Trans. ii. 156.

† 33 Nich. Jour 306.

nic will remain in solution, and the addition of ammonia will produce the yellow precipitate in its characteristic form. It is scarcely necessary to add that the quantity of ammonia must be sufficient to saturate any excess of nitric acid which the fluid may contain.*

(G) But the most decisive mode of determining the presence of arsenic, is by reducing it to a metallic state, in which its characters are clear and unequivocal. For this purpose, let a portion of the white sediment, collected from the contents of the stomach, be mixed with three times its weight of black flux (see page 426); or if this cannot be procured, with two parts of very dry carbonate of potash (the salt of tartar of the shops), and one of powdered charcoal. Dr. Bostock finds that for this mixture, we may advantageously substitute one composed of half a grain of charcoal, and two drops of oil, to a grain of the sediment. Procure a tube eight or nine inches long, and one fourth or one sixth of an inch in diameter, of thin glass, sealed hermetically at one end. Coat the closed end with clay, for about an inch, and let the coating dry. Then put into the tube the mixture of the powder and its flux, and if any should adhere to the inner surface, let it be wiped off by a feather, so that the inner surface of the upper part of the tube may be quite clean and dry. Stop the end of the tube loosely, with a little paper, and heat the coated end only, on a chaffing-dish of red-hot coals, taking care to avoid breathing the fumes. The arsenic, if present, will rise to the upper part of the tube, on the inner surface of which it will form a thin brilliant coating. Break the tube, and scrape off the reduced metal. Lay a little on a heated iron, when, if it be arsenic, a dense smoke will arise, and a strong smell of garlic will be perceived. The arsenic may be farther identified, by putting a small quantity between two polished plates of copper, surrounding it by powdered charcoal, to prevent its escape, binding these tightly together by iron wire, and exposing them to a low red-heat. If the included substance be arsenic, a white stain will be left on the copper.

(H) It may be proper to observe, that neither the stain on copper, nor the odour of garlic, is produced by the white oxide of arsenic, when heated without the addition of some inflammable ingredient. The absence of arsenic must not therefore be inferred, if no smell should be occasioned by laying the white powder on a heated iron.

Dr. Black ascertained, that all the necessary experiments, for the detection of arsenic, may be made on a single grain of the white oxide; this small quantity having produced, when heated in a tube with its proper flux, as much of the metal as clearly established its presence.

If the quantity of arsenic in the stomach should be so small, which is not very probable, as to occasion death, and yet to remain suspended in the washings, the whole contents, and the water employed to wash them, must be filtered, and the clear liquor assayed for arsenic by the test (B), (C), (D), and (E).

* Phil. Mag. xli. 124.

SECTION II.

Discovery of Corrosive Sublimate.

CORROSIVE sublimate (the muriate of mercury), next to arsenic, is the most virulent of the metallic poisons. It may be collected by treating the contents of the stomach in the manner already described; but as it is more soluble than arsenic, viz. in about 19 times its weight of water, no more water must be employed than is barely sufficient, and the washings must be carefully preserved for examination.

If a powder should be collected, by this operation, which proves, on examination, not to be arsenic, it may be known to be corrosive sublimate by the following characters:

(A) Expose a small quantity of it, without any admixture, to heat in a coated glass tube, as directed in the treatment of arsenic. Corrosive sublimate will be ascertained by its rising to the top of the tube, lining the inner surface in the form of a shining white crust.

(B) Dissolve another portion in distilled water; and it may be proper to observe how much of the salt the water is capable of taking up.

(C) To the watery solution add a little lime-water. A precipitate of an orange yellow colour will instantly appear.

(D) To another portion of the solution add a single drop of a dilute solution of sub-carbonate of potash (salt of tartar.) A white precipitate will appear; but, on a still farther addition of alkali, an orange coloured sediment will be formed.

(E) The carbonate of soda has similar effects.

(F) Sulphuretted water throws down a dark coloured sediment, which, when dried and strongly heated, is wholly volatilized, without any odour of garlic.

For the detection of corrosive sublimate, Mr. Sylvester has recommended the application of galvanism, which exhibits the mercury in a metallic state. A piece of zinc wire, or if that cannot be had, of iron wire about three inches long, is to be twice bent at right angles, so as to resemble the Greek letter Π . The two legs of this figure should be distant about the diameter of a common gold wedding ring from each other, and the two ends of the bent wire must afterwards be tied to a ring of this description. Let a plate of glass, not less than three inches square, be laid as nearly horizontal as possible, and on one side, drop some sulphuric acid, diluted with about six times its weight of water, till it spreads to the size of a halfpenny. At a little distance from this, towards the other side, next drop some of the solution supposed to contain corrosive sublimate, till the edges of the two liquids join together; and let the wire and ring prepared as above be laid in such a way that the wire may touch the acid, while the gold ring is in contact with the sus-

pected liquid. If the minutest quantity of corrosive sublimate be present, the ring in a few minutes will be covered with mercury on the part which touched the fluid.

The only mineral poison of great virulence that has not been mentioned, and which, from its being little known to act as such, it is very improbable we should meet with, is the carbonate of barytes. This, in the country where it is found, is employed as a poison for rats, and there can be no doubt would be equally destructive to human life. It may be discovered by dissolving it in muriatic acid, and by the insolubility of the precipitate which this solution yields on adding sulphuric acid, or sulphate of soda. Barytic salts, if these have been the means of poison, will be contained in the water employed to wash the contents of the stomach, and will be detected, on adding sulphuric acid, by a copious precipitate.

SECTION III.

Method of detecting Copper or Lead.

COPPER and lead sometimes gain admission into articles of food, in consequence of the employment of kitchen utensils of these materials.

I. If COPPER be suspected in any liquor, its presence will be ascertained by adding a solution of pure ammonia, which will strike a beautiful blue colour. If the solution be very dilute, it may be concentrated by evaporation; and if the liquor contain a considerable excess of acid, like that used to preserve pickles, as much of the alkali must be added as is more than sufficient to saturate the acid. In this, and all other experiments of the same kind, the fluid should be viewed by reflected, and not by transmitted light.

II. LEAD is occasionally found, in sufficient quantity to be injurious to health, in water that has been kept in leaden vessels, and sometimes even in pump-water, in consequence of this metal being used in the construction of the pump. Acetate of lead has also been known to be fraudulently added to bad wines, with the view of concealing their defects.

Lead may be discovered by adding, to a portion of the suspected water, about half its bulk of water impregnated with sulphuretted hydrogen gas. If lead be present, it will be manifested by a dark brown, or blackish, tinge. This test is so delicate, that water condensed by the leaden worm of a still-tub, is sensibly affected by it. It is also detected by a similar effect ensuing on the addition of sulphuret of ammonia, or potash.

The competency of this method, however, to the discovery of very minute quantities of lead, has been lately set aside by the experiments of Dr. Lambe,* the author of a skilful analysis of the

* See his "Researches into the Properties of Spring Water." 8vo. London. Johnson. 1803.

springs of Lemington Priors, near Warwick. By new methods of examination, he has detected the presence of lead in several spring waters, that manifest no change on the addition of the sulphuretted test; and has found that metal in the precipitate, separated from such waters by the carbonate of potash or of soda. In operating on these waters, Dr. Lambe noticed the following appearances:

(a) The test forms sometimes a dark cloud, with the precipitate effected by alkalis, which has been redissolved in nitric acid.

(b) Though it forms, in other cases, no cloud, the precipitate itself becomes darkened by the sulphuretted test.

(c) The test forms a white cloud, treated with the precipitate as in (a). These two appearances may be united.

(d) The test neither forms a cloud, nor darkens the precipitate.

(e) In the cases (b), (c), (d), heat the precipitate, in contact with an alkaline carbonate, to redness; dissolve out the carbonate by water; and treat the precipitate as in (a). The sulphuretted test then forms a dark cloud with the solution of the precipitate. In these experiments, it is essential that the acid, used to redissolve the precipitate, shall not be in excess; and if it should so happen, that excess must be saturated before the test is applied. It is better to use so little acid, that some of the precipitate may remain undissolved.

(f) Instead of the process (e) the precipitate may be exposed without addition, to a red-heat, and then treated as in (a). In this case, the test will detect the metallic matter; but with less certainty than the foregoing one.

The nitric acid used in these experiments, should be perfectly pure; and the test should be recently prepared by saturating water with sulphuretted hydrogen gas.

Another mode of analysis, employed by Dr. Lambe, consists in precipitating the lead by muriate of soda; but as muriate of lead is partly soluble in water, this test cannot be applied to small portions of suspected water. The precipitate must be, therefore, collected, from two or three gallons, and heated to redness with twice its weight of carbonate of soda. Dissolve out the soda; add nitric acid, saturating any superfluity; and then apply the sulphuretted test.

The third process, which is the most satisfactory of all, and is very easy, except for the trouble of collecting a large quantity of precipitate, is the actual reduction of the metal, and its exhibition in a separate form. The precipitate may be mixed with its own weight of alkaline carbonate, and exposed either with or without the addition of a small proportion of charcoal, to a heat sufficient to melt the alkali. On breaking the crucible, a small globule of lead will be found reduced at the bottom. The precipitate from about fifty gallons of water yielded Dr. Lambe about two grains of lead.

For discovering the presence of lead in wines, a test invented by Dr. Hahnemann, and known by the title of Hahnemann's wine test, may be employed. This test is prepared by putting together, into a small phial, sixteen grains of sulphuret of lime, prepared in the dry way (by exposing to a red-heat, in a covered crucible, equal

weights of powdered lime and sulphur, accurately mixed), and 20 grains of acidulous tartrate of potash (cream of tartar). The phial is to be filled with water, well corked, and occasionally shaken for the space of ten minutes. When the powder has subsided, decant the clear liquor, and preserve it, in a well-stopped bottle, for use. The liquor, when fresh prepared, discovers lead by a dark coloured precipitate. A farther proof of the presence of lead in wines is the occurrence of a precipitate on adding a solution of the sulphate of soda.

The quantity of lead, which has been detected in sophisticated wine, may be estimated at forty grains of the metal in every fifty gallons.*

When a considerable quantity of acetate of lead has been taken into the stomach (as sometimes, owing to its sweet taste, happens to children), after the exhibition of an active emetic, the hydro-sulphuret of potash or of ammonia may be given; or a solution of the common sulphuret.

Mr. Sylvester has lately proposed the gallic acid as an excellent test of the presence of lead.†

In cases of the accidental swallowing of sulphuric acid, which also sometimes happens to children, M. Fourcroy recommends the speedy administration of a solution of soap, or a mixture of carbonate of magnesia or carbonate of lime (common chalk) with water.‡

CHAPTER II.

RULES FOR ASCERTAINING THE PURITY OF CHEMICAL PREPARATIONS, EMPLOYED FOR THE PURPOSES OF MEDICINE, AND FOR OTHER USES.

I.—*Sulphuric acid*,—*Acidum Sulphuricum of the London Pharmacopæia*,—*Oil of Vitriol*.

THE specific gravity of sulphuric acid should be 1850. It should remain perfectly transparent when diluted with distilled water. If a sediment occur, on dilution, it is a proof of the presence of sulphate of lead or sulphate of lime.

Iron may be detected in sulphuric acid, by saturating a diluted portion of the diluted acid with pure carbonate of soda, and adding prussiate of potash, which will manifest the presence of iron by a prussian blue precipitate; or it will be discovered by a purplish or blackish tinge, on the addition of tincture of galls to a similarly saturated portion. Copper may be discovered, by pouring, into a similarly saturated solution, pure solution of ammonia; and lead may be detected by the sulphuret of ammonia. The latter

* Lambe, page 175.

† Système, vol. i. page 240.

‡ 33 Nicholson's Journal, 310.

metal, however, is generally precipitated, on dilution, in combination with sulphuric acid.

Sulphate of potash or of soda may be found by saturating the diluted acid with ammonia, evaporating to dryness, and applying a pretty strong heat. The sulphate of ammonia will escape, and that of potash or of soda will remain, and may be distinguished by its solubility and other characters.*

II.—*Nitric and Nitrous Acids,—Acidum Nitricum, P. L.—Aqua Fortis.*

The nitric acid should be perfectly colourless, and as limpid as water. It should be preserved in a dark place, to prevent its conversion into the nitrous kind.

These acids are most likely to be adulterated with sulphuric and muriatic acids. The sulphuric acid may be discovered by adding to a portion of the acid, largely diluted, nitrated or muriated barytes, which will occasion, with sulphuric acid, a white and insoluble precipitate. The muriatic acid may be ascertained by nitrate of silver, which affords a sediment, at first white, but which becomes coloured by exposure to the direct light of the sun. Both these acids, however, may be present at once; and, in this case, it will be necessary to add a solution of nitrate of barytes, as long as any precipitate falls, which will separate the sulphuric acid. Let the sediment subside, decant the clear liquor, and add the nitrate of silver. If a precipitate appear, muriatic acid may be inferred to be present also. Muriatic acid may, also, be detected by adding a solution of sulphate of silver.

These acids should have the specific gravity of 1550.

III.—*Muriatic Acid,—Acidum Muriaticum, P. L.—Spirit of Salt.*

This acid generally contains iron, which may be known by its yellow colour; the pure acid being perfectly colourless. It may also be detected by the same mode as was recommended in examining sulphuric acid.

Sulphuric acid is discoverable by a precipitation, on adding, to a portion of the acid, diluted with five or six parts of pure water, a solution of the muriate of barytes.

The specific gravity of this acid should be at least 1170.

IV.—*Acetic acid,—Acidum Aceticum,—Radical or concentrated Vinegar.*

This acid is often contaminated by sulphurous and sulphuric acid. The first may be known by drawing a little of the vapour into the lungs, when, if the acid be pure, no unpleasant sensation will be felt; but, if sulphurous acid be contained in the acetic, it will not fail to be discovered in this mode. The sulphuric acid is

* See page 235.

detected by muriated barytes; copper, by supersaturation with pure ammonia; and lead, by sulphuret of ammonia.

The specific gravity of this acid should be 1060 at least.

V.—*Acetous Acid*,—*Acidum Aceticum*, P. L.—*Distilled Vinegar*.

If vinegar be distilled in copper vessels, it can hardly fail being contaminated by that metal; and, if a leaden worm be used for its condensation, some portion of lead will certainly be dissolved. The former metal will appear on adding an excess of solution of pure ammonia; and lead will be detected by the sulphuretted ammonia, or by water saturated with sulphuretted hydrogen. (See the preceding chapter.)

It is not unusual, in order to increase the acid taste of vinegar, to add sulphuric acid. This acid may be immediately discovered by solutions of barytes, which, when vinegar has been thus adulterated, throw down a white precipitate.

VI.—*Boracic Acid*,—*Sedative Salt of Homberg*.

Genuine boracic acid should totally dissolve in five times its weight of boiling alcohol; and the solution, when set on fire, should emit a green flame. The best boracic acid forms small hexangular scaly crystals of a shining silvery white colour. Its specific gravity is 1480.

VII.—*Tartaric Acid*.

This acid often contains sulphuric acid; to discover which, let a portion be dissolved in water, and a solution of acetate of lead be added. A precipitate will appear, which, if the acid be pure, is entirely re-dissolved by a few drops of pure nitric acid, or by a little pure acetic acid. If any portion remain undissolved, sulphuric acid is the cause. Muriate of barytes, also, when the acid is adulterated with sulphuric acid, but not otherwise, gives a precipitate insoluble by an excess of muriatic acid.

VIII.—*Acid of Amber*.

Acid of amber is adulterated, sometimes with sulphuric acid and its combinations; sometimes with tartaric acid; and at others with muriate of ammonia.

Sulphuric acid is detected by solutions of barytes; tartaric acid by carbonate of potash, which forms a difficultly soluble tartrate; and muriate of ammonia by nitrate of silver, which discovers the acid, and by a solution of pure potash, which excites a strong smell of ammonia.

Pure acid of amber is a crystalline white salt of an acid taste, soluble in twenty-four parts of cold or eight of hot water, and is volatilized, when laid on red-hot iron, without leaving any ashes or other residue.

IX.—*Acid of Benzoin,—Acidum Benzoicum, P. L.*

This acid is not very liable to adulteration. The best has a brilliant white colour and a peculiarly grateful smell. It is soluble in a large quantity of boiling water or alcohol, and leaves no residue when placed on a heated iron.

X.—*Sub-carbonate of Potash,—Potassæ Subcarbonas, P. L.*

The salt of tartar of the shops generally contains sulphate and muriate of potash, and siliceous and calcareous earths. It should dissolve entirely, if pure, in twice its weight of cold water; and any thing that remains undissolved may be regarded as an impurity. Sometimes one fourth of foreign mixtures may thus be detected, the greater part of which is sulphate of potash. To ascertain the nature of the adulteration, dissolve a portion in pure and diluted nitric acid: the siliceous earth only will remain undissolved. Add, to one portion of the solution, nitrate of barytes; this will detect sulphate of potash by a copious precipitate. To another portion add nitrate of silver, which will discover muriatic salts; and, to a third, oxalate or fluat of ammonia, which will detect calcareous earth.

The solution of sub-carbonate of potash (*liquor potassæ subcarbonatis, P. L.*) may be examined in a similar manner.

XI.—*Solution of pure Potash,—Liquor Potassæ, P. L.*

This may be assayed, for sulphuric and muriatic salts, by saturation with nitric acid, and by the tests recommended in speaking of carbonate of potash. A perfectly pure solution of potash should remain transparent on the addition of barytic water. If a precipitate should ensue, which dissolves with effervescence in dilute muriatic acid, it is owing to the presence of carbonic acid: if the precipitate is not soluble, it indicates sulphuric acid. A redundancy of carbonic acid is also shown by an effervescence, on adding diluted sulphuric acid, and an excess of lime by a white precipitate, on blowing air from the lungs, through the solution, by means of a tobacco-pipe, or a glass tube.

This solution should be of such a strength, as that an exact wine-pint may weigh 18 ounces troy.

XII.—*Sub-carbonate of Soda,—Sodæ Subcarbonas, P. L.*

Carbonate of soda is scarcely ever found free from muriate and sulphate of soda. These may be discovered by adding, to a little of the carbonate saturated with pure nitric acid, first nitrate of barytes, to detect sulphuric acid, and afterward nitrate of silver, to ascertain the presence of muriatic acid. Carbonate of potash will be shown by a precipitate ensuing on the addition of tartarous acid to a strong solution of the alkali; for, this acid forms a difficultly soluble salt with potash, but not with soda.

XIII.—*Solution of Carbonate of Ammonia, —Liquor Ammoniae Carbonatis, P. L.*

This should have the specific gravity of 1150; should effervesce on the addition of acids; and should afford a strong coagulum on adding alcohol.

XIV.—*Carbonate of Ammonia, —Ammoniae Carbonas, P. L.*

This salt should be entirely volatilized by heat. If any thing remain, when it is laid on a heated iron, carbonate of potash or of lime may be suspected; and these impurities are most likely to be present if the carbonate of ammonia be purchased in the form of a powder. It should therefore always be bought in solid lumps. Sulphuric and muriatic salts, lime, and iron, may be discovered by adding to the alkali, saturated with nitric acid, the appropriate tests already often mentioned.

XV.—*Solution of pure Ammonia in Water, —Liquor Ammoniae, P. L. —Strong Spirit of Sal Ammoniac.*

The volatile alkali, in its purest state, exists as a gas condensible by water, and its solution in water is the only form under which it is applicable to useful purposes. This solution should contain nothing besides the volatile alkali; the alkali should be perfectly free from carbonic acid, and should be combined with water in the greatest possible proportion. The presence of other salts may be discovered by saturating a portion of the solution with pure nitric acid, and adding the tests for sulphuric and muriatic acids. Carbonic acid is shown by a precipitation on mixing the solution with one of muriate of lime; for this earthy salt is not precipitated by pure ammonia. The only mode of determining the strength of the solution is by taking its specific gravity, which, at 60° Fahrenheit, should be as 905, or thereabouts, to 1000.

XVI.—*Spirit of Hartshorn.*

This may be counterfeited by mixing the *aqua ammoniae puræ* with the distilled spirit of hartshorn, in order to increase the pungency of its smell, and to enable it to bear an addition of water. The fraud is detected by adding alcohol to the sophisticated spirit; for, if no considerable coagulation ensues, the adulteration is proved. It may also be discovered by the usual effervescence not ensuing with acids. The solution should have the specific gravity of 1500.

XVII.—*Sulphate of Soda, —Sodæ Sulphas, P. L. —Glauber's Salt.*

This salt ought not to contain an excess of either acid or alkali, both of which may be detected by the vegetable infusions, p. 588, 589.

Nor should it be mixed with earthy or metallic salts; the former of which are detected by carbonate, and the latter by prussiate of potash. Muriate of soda is discovered by adding nitrate of barytes till the precipitate ceases, and afterwards nitrate of silver, or more simply by a solution of sulphate of silver. Sulphate of potash is discovered by its more sparing solubility. The sulphate of soda, however, being itself one of the cheapest salts, there is little risk of its being intentionally sophisticated.

XVIII.—*Sulphate of Potash*,—*Potassæ Sulphas, P. L.*—*Vitriolated Tartar.*

The purity of this salt may be ascertained by the same means as that of the former one. The little value of this salt renders it pretty secure from wilful adulteration.

XIX.—*Nitrate of Potash*,—*Potassæ Nitræs, P. L.*—*Nitre or Salt Petre.*

Nitrate of potash is, with great difficulty, freed entirely from muriate of soda; and a small portion of the latter, except for nice chemical purposes, is an admixture of little importance. To discover muriate of soda, a solution of nitrate of silver must be added as long as any sediment is produced. The precipitate, washed and dried, must be weighed. Every hundred grains will denote about $42\frac{1}{2}$ of muriate of soda.

Sulphate of potash or soda may be discovered by nitrate or muriate of barytes.

XX.—*Muriate of Soda*,—*Common Salt.*

Common salt is scarcely ever found free from salts with earthy bases, chiefly muriates of magnesia and lime, which are contained in the brine, and adhere to the crystals. The earths may be precipitated by carbonate of soda, and the precipitated lime and magnesia may be separated from each other by the rules given page 612.

XXI.—*Muriate of Ammonia*,—*Ammoniæ Murias, P. L.*—*Sal Ammoniac.*

This salt ought to be entirely volatilized, by a low heat, when laid on a heated iron. It sometimes contains sulphate of ammonia, however, which, being also volatile, cannot be thus detected. To ascertain the presence of the latter salt, add the muriate or nitrate of barytes, which will indicate the sulphate by a copious and insoluble precipitate.

XXII.—*Acetate of Potash*,—*Potassæ Acetas, P. L.*

Genuine acetate of potash is perfectly soluble in four times its weight of alcohol, and may thus be separated from other salts that

are insoluble in alcohol. The tartrate of potash (soluble tartar) is the adulteration most likely to be employed. This may be discovered by adding a solution of tartaric acid, which, if the suspected salt be present, will occasion a copious precipitate. The tartrate is also detected by its forming a precipitate with acetate of lead or muriate of barytes, soluble in acetic or muriatic acid; and sulphates by a precipitate with the same agents, insoluble in acids.

XXIII.—*Neutral Tartrate of Potash*,—*Potassæ Tartaris*, P. L.—*Soluble Tartar*.

This salt should afford a very copious precipitate on adding tartarous acid. The only salt likely to be mixed with it is sulphate of soda, which may be detected by a precipitate with muriated barytes, insoluble in diluted muriatic acid.

XXIV.—*Acidulous Tartrate of Potash*,—*Potassæ Supertartras*, P. L.—*Cream of Tartar*.

The only substance with which this salt is likely to be adulterated is sulphate of potash. To determine whether this be present, pour, on about half an ounce of the powdered crystals, two or three ounce measures of distilled water; shake the mixture frequently, and let it stand one or two hours. The sulphate of potash, being more soluble than the tartrate, will be taken up; and may be known by the bitter taste of the solution, and by a precipitate, on adding muriate of barytes, which will be insoluble in muriatic acid.

XXV.—*Compound Tartrate of Soda and Potash*,—*Soda Tartrazata*, P. L.—*Rochelle or Seignette's Salt*.

Sulphate of soda, the only salt with which this may be expected to be adulterated, is discovered by adding to a solution of Rochelle salt the acetate of lead or muriate of barytes.—The former, if the sulphate be present, affords a precipitate insoluble in acetous acid, and the latter one insoluble in muriatic acid.

XXVI.—*Sulphate of Magnesia*,—*Magnesiæ Sulphas*, P. L.—*Epsom Salt*.

This salt is very likely to be adulterated with sulphate of soda, or Glauber's salt, which may be made to resemble the magnesian salt in appearance, by stirring it briskly at the moment when it is about to crystallize. The fraud may be discovered very readily if the salt consist entirely of the sulphate of soda, because no precipitation will ensue on adding carbonate of potash. If only a part of the salt be sulphate of soda, detection is not so easy, but may still be accomplished. For, since 100 parts of pure sulphate of magnesia give between thirty and forty of the dry carbonate, when complete-

ly decomposed by carbonate of potash, if the salt under examination afford a considerably less proportion, its sophistication may be fairly inferred: or, to discover the sulphate of soda, precipitate all the magnesia by pure ammonia, with the aid of heat. Decant the clear liquor from the precipitate, filter it, and, after evaporation to dryness, apply such a heat as will volatilize the sulphate of ammonia, when that of soda will remain fixed.

Muriate of magnesia or of lime may be detected by the salt becoming moist when exposed to the air, and by a precipitation with nitrated silver, after nitrate of barytes has separated all the sulphuric acid and magnesia. Lime is discoverable by oxalic acid.

XXVII.—*Sulphate of Alumine,—Alum.*

Perfectly pure alum should contain neither iron nor copper. The former is manifested by adding, to a solution of alum, prussiate of potash, and the latter by an excess of pure ammonia.

XXVIII.—*Borate of Soda,—Sodæ Boras, P. L.—Borax.*

Borate of soda, if adulterated at all, will probably be so with alum or fused muriate of soda. To discover these, borax must be dissolved in water, and its excess of alkali be saturated with nitric acid. Nitrate of barytes, added to this saturated solution, will detect the sulphuric salt, and nitrate of silver the muriate of soda.

XXIX.—*Sulphate of Iron,—Ferri Sulphas, P. L.—Green Vitriol.*

If this salt should contain copper, which is the only admixture likely to be found in it, pure ammonia, added till a precipitation ceases, will afford a blue liquor. Any copper that may chance to be present, may be separated, and the salt purified, by immersing, in a solution of it, a clear polished plate of iron.

XXX.—*Glass of Antimony.*

A large quantity of glass of lead was lately introduced into the London market, as glass of antimony. To discover this criminal imposition, whenever it may be practised, the following distinctive characters of the two substances have lately been described by Mr. Luke Howard.*

Glass of antimony has a rich brown or reddish colour, with the usual transparency of coloured glasses. The glass of lead is of a deeper and duller colour against the light; is much less transparent; and even, in some samples, quite opaque.

The specific gravity of the true never exceeds 4.95; that of the spurious or lead glass is 6.95; or, in round numbers, their comparative weights are as 5 to 7.

* Philosophical Magazine, xxxv. 236.

Let twenty grains be rubbed fine in a glass mortar, adding half an ounce of good muriatic acid. The true dissolves with an hepatic smell; the solution is turbid, but has no sediment. The spurious turns the acid yellow, giving out an oxymuriatic odour, and leaves much sediment.

Let a little of each solution be separately dropped into water. The true deposits oxide of antimony in a copious white coagulum; or, if the water has been previously tinged with sulphuret of ammonia, in a fine orange precipitate. The spurious gives no precipitate in water, and, in the other liquid, one of a dark brown or olive colour.

A solution of the spurious in distilled vinegar has a sweet taste, together with the other properties of acetate of lead.

A very small mixture of the spurious may be detected by its debasing, more or less, the bright orange colour of the precipitate thrown down by the sulphuret of ammonia from the solution in any acid.

The samples of the spurious, hitherto detected, are of a much thicker and clumsier cast than the genuine; but the appearance is not to be trusted, and no specimen should be allowed to pass without a trial either of the specific gravity or chemical properties.

XXXI.—*Tartarized Antimony*,—*Antimonium Tartarizatum*, P. L.—*Emetic Tartar*.

A solution of this salt should afford, with acetate of lead, a precipitate perfectly soluble in dilute nitric acid. A few drops of the sulphuret of ammonia, also, should immediately precipitate a gold coloured sulphuret of antimony.

XXXII.—*Muriate of Mercury*,—*Hydrargyri Oxymurias*, P. L.—*Corrosive Sublimate*.

If there be any reason to suspect arsenic in this salt, the fraud may be discovered as follows: Dissolve a small quantity of the sublimate in distilled water; add a solution of carbonate of ammonia till the precipitate ceases, and filter the solution. If on the addition of a few drops of ammoniated copper* to this solution, a precipitate of a yellowish green colour is produced, the sublimate contains arsenic.

XXXIII.—*Sub-muriate of Mercury*,—*Hydrargyri Sub-murias*, P. L.—*Calomel*.

Calomel should be completely saturated with mercury. This may be ascertained, by boiling, for a few minutes, one part of calomel with $\frac{1}{32}$ part of muriate of ammonia (sal ammoniac) in 10 parts of distilled water. When carbonate of potash is added to the filtered solution, no precipitation will ensue if the calomel be pure. This

* Prepared by digesting a little verdgris in the solution of pure ammonia.

preparation, when rubbed in an earthen mortar with pure ammonia, should become intensely black, and should exhibit nothing of an orange hue.

XXXIV.—*Mercury, or Quicksilver,—Hydrargyrus, P. L.*

Scarcely any substance is so liable to adulteration as mercury, owing to the property which it possesses of dissolving completely some of the baser metals. This union is so strong, that they even rise along with the quicksilver when distilled. The impurity of mercury is generally indicated by its dull aspect; by its tarnishing and becoming covered with a coat of oxide, on long exposure to the air; by its adhesion to the surface of glass; and, when shaken with water in a bottle, by the speedy formation of a black powder. Lead and tin are frequent impurities, and the mercury becomes capable of taking up more of these if zinc or bismuth be previously added. In order to discover lead, the mercury may be agitated with a little water, in order to oxydize that metal. Pour off the water, and digest the mercury with a little acetous acid. This will dissolve the oxide of lead, which will be indicated by a blackish precipitate with sulphuretted water. Or, to this acetous solution, add a little sulphate of soda, which will precipitate a sulphate of lead, containing, when dry, 72 *per cent.* of metal. If only a very minute quantity of lead be present, in a large quantity of mercury, it may be detected by solution in nitric acid and the addition of sulphuretted water. A dark brown precipitate will ensue, and will subside if allowed to stand a few days. One part of lead may thus be separated from 15263 parts of mercury.* Bismuth is detected by pouring a nitric solution, prepared without heat, into distilled water; a white precipitate will appear if this metal be present. Tin is manifested, in like manner, by a weak solution of nitro-muriate of gold, which throws down a purple sediment; and zinc, by exposing the metal to heat.

XXXV.—*Red Oxide of mercury,—Hydrargyri Oxydum Rubrum, P. L.*

This substance is rarely found adulterated, as it would be difficult to find a substance well suited to this purpose. If well prepared, it may be totally volatilized by heat.

XXXVI.—*Red Oxide of Mercury by Nitric Acid,—Hydrargyri Nitrico-Oxydum, P. L.—Red Precipitate.*

This is very liable to adulteration with minium, or red lead. The fraud may be discovered by digesting it in acetic acid, and adding to the solution sulphuretted water, or sulphuret of ammo-

* See Mr. Accum's valuable papers on the detection of adulterations, in Nicholson's Journal, 4to.

nia, either of which produces, with the compounds of lead, a dirty dark coloured precipitate. It should also be totally volatilized by heat.

XXXVII.—*White Oxide of Mercury,—Hydrargyrus Præcipitatus Albus, P. L.—White precipitate.*

White lead is the most probable adulteration of this substance, and chalk may also be occasionally mixed with it. The oxide of lead may be discovered as in the last article; and chalk, by adding to the dilute solution a little oxalic acid.

XXXVIII.—*Red Sulphuretted Oxide of Mercury,—Hydrargyri Sulphuretum Rubrum, P. L.—Factitious Cinnabar.*

This substance is frequently adulterated with red lead, which may be detected by the foregoing rules. Chalk and dragon's blood are also sometimes mixed with it. The chalk is discovered by an effervescence on adding acetic acid, and by pouring oxalic acid into the acetous solution. Dragon's blood will be left unvolatilized when the sulphuret is exposed to heat, and may be detected by its giving a colour to alcohol, when the cinnabar is digested with it.

XXXIX.—*Black sulphuretted Oxide of Mercury,—Ethiops Mineral.*

The mercury and sulphur, in this preparation, should be so intimately combined, that no globules of the metal can be discovered by a magnifier; and that, when rubbed on gold, no white stain may be communicated. The admixture of ivory-black may be detected by its not being wholly volatilized by heat; or, by boiling with alkali to extract the sulphur, and afterwards exposing the residuum to heat which ought entirely to evaporate.

XI.—*Yellow Oxide or Sub-sulphate of Mercury—Hydrargyrus Virirolatus, P. L.—Turbit Mineral.*

This preparation should be wholly evaporable; and, when digested with distilled water, the water ought not to take up any sulphuric acid, which will be discovered by muriate of barytes.

XLI.—*Fused Nitrate of Silver,—Argenti Nitras, P. L.—Lunar Caustic.*

The most probable admixture with this substance is nitrate of copper, derived from the employment of an impure silver. In moderate proportion this is of little importance. It may be ascertained by solution in water, and adding an excess of pure ammonia, which will detect copper by a deep blue colour.

The watery solution of lunar caustic, when mingled with one of common salt, should give a copious curdy precipitate.

XLII.—*White Oxide of Zinc,—Zinci Oxydum, P. L.—
Flowers of Zinc.*

Oxide of zinc may be adulterated with chalk, which is discoverable by an effervescence with acetous acid, and by the precipitation of this solution with oxalic acid. Lead is detected by adding, to the acetous solution, sulphuretted water, or sulphuret of ammonia. Arsenic, to which the activity of this medicine has been sometimes ascribed, is detected also, by sulphuretted water, added to the acetous solution: but in this case the precipitate has a yellow colour, and, when laid on red-hot charcoal, gives first a smell of sulphur, and afterwards of arsenic.

XLIII.—*White Oxide of Lead,—Plumbi Carbonas, P. L.—
White Lead.*

This is frequently sophisticated with chalk; the presence of which may be detected by cold acetous acid, and by adding, to this solution, oxalic acid. Carbonate of barytes is detected by sulphate of soda added to the same solution, very largely diluted with distilled water; and sulphate of barytes, or sulphate of lead, by the insolubility of the cerusse in boiling distilled vinegar.

XLIV.—*Superacetate of Lead,—Plumbi Superacetas, P. L.—
Sugar of Lead.*

If the acetate of lead should be adulterated with acetate of lime or of barytes, the former may be detected by adding, to a dilute solution, the oxalic acid; and the latter by sulphuric acid, or solution of sulphate of soda, added to a solution very largely diluted with water. Acetate of lead ought to dissolve entirely in water, and any thing that resists solution may be regarded as an impurity.

XLV.—*Green Oxide, or Sub-acetate of Copper,—Ærugo, P. L.—
Verdegris.*

This substance is scarcely ever found pure, being mixed with pieces of copper, grape-stalks, and other impurities. The amount of this admixture of insoluble substances may be ascertained by boiling a portion of verdegris with 12 or 14 times its weight of distilled vinegar, allowing the undissolved part to settle, and ascertaining its amount. Sulphate of copper may be detected by boiling the verdegris with water, and evaporating the solution. Crystals of acetate of copper will first separate, and, when the solution has been farther concentrated, the sulphate of copper will crystallize. Or, it may be discovered by adding to the watery solution muriate of barytes, which will throw down a very abundant precipitate. Tartrate of copper, another adulteration sometimes met with, is discovered by dissolving a little of the verdegris in acetous acid, and adding acetate or muriate of barytes, which will afford, with the tartarous acid, a precipitate soluble in muriatic acid.

XLVI.—*Crystallized Acetate of Copper,—Distilled or Crystallized Verdegris.*

This is prepared by dissolving the common verdegris in distilled vinegar, and crystallizing the solution. These crystals should dissolve entirely in six times their weight of boiling water, and the solution should give no precipitation with solutions of barytes; for, if these solutions throw down a precipitate, sulphate of copper is indicated. This impurity, which I have frequently met with, may be discovered by evaporating the solution very low, and separating the crystals of acetate of copper. Farther evaporation and cooling will crystallize the sulphate, if any be present.

XLVII.—*Sub-carbonate of Magnesia,—Magnesiæ Carbonas, P. L.*

Carbonate of magnesia is most liable to adulteration with chalk; and, as lime forms with sulphuric acid a very insoluble salt, and magnesia one very readily dissolved, this acid may be employed in detecting the fraud. To a suspected portion of magnesia add a little sulphuric acid, diluted with eight or ten times its weight of water. If the magnesia should entirely be taken up, and the solution should remain transparent, it may be pronounced pure, but not otherwise. Another mode of discovering the deception is as follows:—Saturate a portion of the suspected magnesia with muriatic acid, and add a solution of carbonate of ammonia. If any lime be present, it will form an insoluble precipitate, but the magnesia will remain in solution.

XLVIII.—*Pure Magnesia,—Magnesia, P. L.—Calcined Magnesia.*

Calcined magnesia may be assayed by the same tests as the carbonate. It ought not to effervesce at all with dilute sulphuric acid; and, if the earth and acid be put together into one scale of a balance, no diminution of weight should ensue on mixing them together. It should be perfectly free from taste, and, when digested with distilled water, the filtered liquor should manifest no property of lime-water. Calcined magnesia, however, is very seldom so pure as to be totally dissolved by diluted sulphuric acid; for a small insoluble residue generally remains, consisting chiefly of siliceous earth, derived from the alkali. The solution in sulphuric acid, when largely diluted, ought not to afford any precipitation with oxalate of ammonia.

XLIX.—*Spirit of Wine, Alcohol, and Æthers.*

The only decisive mode of ascertaining the purity of spirit of wine and of æthers, is by determining their specific gravity. Highly rectified alcohol should have the specific gravity of 800 to 1000. Common spirit of wine 837. Sulphuric æther 739. The *spiritus ætheris sulphurici, P. L.*, or sweet spirit of vitriol, about 753,—and

nitric æther, the *spiritus ætheris nitrosus*, or sweet spirit of nitre, 908. The æthers ought not to redden the colour of litmus, nor ought those formed from sulphuric acid to give any precipitation with solution of barytes.

L.—*Essential or Volatile Oils.*

As essential oils constitute only a very small proportion of the vegetables from which they are obtained, and bear generally a very high price, there is a considerable temptation to adulterate them. They are found sophisticated, either with cheaper volatile oils, with fixed oils, or with the spirit of wine. The fixed oils are discovered by distillation with a very gentle heat, which elevates the essential oils, and leaves the fixed ones. These last may, also, be detected by moistening a little writing-paper with the suspected oil, and holding it before the fire. If the oil be entirely essential, no stain will remain on the paper. Alcohol, also, detects the fixed oils, because it only dissolves the essential ones, and the mixture becomes milky. The presence of cheaper essential oils is discovered by the smell. Alcohol, a cheaper liquid than some of the most costly oils, is discovered by adding water, which if alcohol be present, occasions a milkiness.

CHAPTER III.

USE OF CHEMICAL RE-AGENTS TO CERTAIN ARTISTS AND MANUFACTURERS.

TO point out all the beneficial applications of chemical substances to the purposes of the arts, would require a distinct and very extensive treatise. In this place I have no farther view than to describe the mode of detecting adulterations in certain articles of commerce; the strength and purity of which are essentials to the success of chemical processes.

I.—*Mode of detecting the Adulteration of Potashes, Pearlashes, and Barilla.*

Few objects of commerce are sophisticated to a greater extent than the alkalis, to the great loss and injury of the bleacher, and dyer, the glass-maker, the soap-boiler, and of all other artists who are in the habit of employing these substances. Several methods of determining the strength of alkalis have been recommended; and, in the former edition of this work, I gave, as the best, that of Mr. Kirwan, described in the Transactions of the Royal Irish Academy for 1789, which consists in ascertaining the quantity of alum,

decomposed by the alkali under examination. Experience, however, has since convinced me, that a more certain and practicable mode of making this assay is by means of diluted sulphuric acid, in the way described by M. Descroizilles* with a minuteness of detail, which, though not required by the practised chemists, renders the steps of the operation much more intelligible to artists.

The apparatus required for this purpose is sufficiently simple. It consists, 1st of a glass tube, from five to six tenths of an inch diameter, sealed at one end, and inserted at this end into a pedestal which keeps it in a perpendicular position. The upper and open extremity may be a little funnel-shaped, and provided with a lip, for the convenience of pouring out fluids. On this tube is engraved a scale of 72 equal parts, the first degree being at the uppermost part of the tube, and the 72d, of course, near its sealed extremity. Each degree is intended to contain half a French gramme (the gramme being $15\frac{1}{2}$ English grains very nearly) of the acid test liquor.

The test liquor is formed by diluting one part by weight of sulphuric acid, s. g. 1.848,† with nine parts by weight of distilled water. Hence the specific gravity of the diluted acid will not be far from 1.0664, or very nearly 13 degrees of the instrument called in this country Twaddell's hydrometer, (from the artist who prepares and sells it at Glasgow).

2dly, Good syrup of violets is necessary, or if this cannot be had, litmus paper must be substituted, for discovering the excess of acid, and turmeric paper to ascertain a redundancy of alkali.

3dly, A small balance and weights.

4thly, A measure containing 3.05 cubic inches.

5thly, A glass bottle with an elongated neck, of such a capacity, that 6.1 cubic inches will fill it up to some part of the neck, where a mark is to be made with a file.

6thly, Small glass stirring rods, or slips of wood about the size of common matches.

7thly, A metal mortar and pestle, a small bottle of water, a tumbler glass, and a plate.

As an example of the use of this apparatus, let us suppose that we wish to assay a sample of American pearlash. Reduce to powder a sufficient quantity of the alkali to serve as a fair average specimen; and of this, put 154.5 grains into the small bottle already described, and add water either warm or cold, so as to fill about three fourths of its capacity. Let its contents be agitated till the solution is complete, and filter through paper.

Of the clear solution, take 3.05 cubic inches and pour it into a common tumbler. Then distribute all round the edge of the plate, drops of the syrup of violets, by means of one of the small wooden rods. Next, pour diluted acid into the tube to the line marked 0; and taking the tube in the left hand, add the liquor, which

* 60 Ann. de Chim. 17.

† Or rather 1.842, for this density, according to Vauquelin, corresponds with 6° of the *aréomètre*, at 55° Fahrenheit; vid. 76 Ann. de Ch. 160.

it contains, very slowly to the alkaline solution in the tumbler, stirring all the while with one of the wooden rods, and first using this rod, to remove the drop, which adheres to the lip of the tube. When the acid is lowered in the tube to about the 40th degree, it is proper to try if the alkali be neutralized, by taking a drop on the end of a glass or wooden rod, and mixing it with one of the drops of syrup of violets. Or, if that test liquor cannot be had, the liquor in the tumbler may be assayed, by slips of litmus and turmeric papers. By doing this repeatedly, the precise point of saturation will be at length attained; and the number on the tube, corresponding with the level of the remaining acid, will show the strength of the alkali. The mean strength of several varieties of potash was found to be 55, showing that they require 55 hundredths of their weight of concentrated sulphuric acid for saturation.

When soda or barilla is submitted to experiment, it is necessary to make the solution by means of hot water; and in all cases, it is advisable to repeat the experiment on some of the liquor which has been reserved; using, in the second trial, one fourth or some other aliquot part of the whole.

The following table shews the strength of some alkalis of commerce, commonly met with in France.

	Degrees.
American pearlash, 1st sort	60 to 63
American potash in reddish masses, 1st ditto	60 to 63
American pearlash, 2d sort	50 to 55
American potash in greyish masses, 2d ditto	50 to 55
White Russian potash	52 to 58
White Dantzick ditto	45 to 52
Blue Dantzick potash	45 to 52
Alicant barilla	20 to 33
Crystals of soda of commerce	36
Natron (kelp?)	20 to 33
Barilla and natron (kelp?) inferior	10 to 15

II.—*Mode of detecting the Adulteration of Manganese.*

In the section on drugs, instructions may be found for discovering impurities in several chemical preparations, employed by the artist, as cerusse or white lead, red lead, verdegris, &c. No rules, however, have been given for examining manganese, which is a substance that varies much in quality, and is often sophisticated; as the bleachers experience, to their no small disappointment and loss.

The principal defect of manganese arises from the admixture of chalk, which is not always an intentional adulteration, but is sometimes found united with it, as it occurs in the earth. When to this impure manganese mixed with muriate of soda, the sulphuric acid is added, the materials effervesce and swell considerably, and a large proportion passes into the receiver; in consequence of which the bleaching liquor is totally spoiled. This accident has, to my

knowledge, frequently happened, and can only be prevented by so slow and cautious an addition of the acid, as is nearly inconsistent with the business of an extensive bleaching work. The presence of carbonate of lime may be discovered in manganese, by pouring, on a portion of this substance, nitric acid diluted with 8 or 10 parts of water. If the manganese be good, no effervescence will ensue, nor will the acid dissolve any thing; but, if carbonate of lime be present, it will be taken up by the acid. To the solution add a sufficient quantity of carbonate of potash to precipitate the lime, wash the sediment with water, and dry it. Its weight will show how much chalk the manganese under examination contained.

Another adulteration of manganese, that may, perhaps, be sometimes practised, is the addition of some ores of iron. This impurity is less easily discovered. But if the iron be in such a state of oxydation as to be soluble in muriatic acid, the following process may discover it. Dissolve a portion, with the assistance of heat, in concentrated muriatic acid, dilute the solution largely with distilled water, and add a solution of crystallized carbonate of potash. The manganese will remain suspended, by the excess of carbonic acid, on mixing the two solutions, but the iron will be precipitated in the state of a coloured oxide.

From an observation of Klaproth,* it appears that oxides of iron and manganese are separable by nitrous acid with the addition of sugar, which takes up the manganese only.

CHAPTER IV.

APPLICATION OF CHEMICAL TESTS TO THE USES OF THE FARMER AND COUNTRY GENTLEMAN.

THE benefits that might be derived from the union of chemical skill, with the extensive observation of agricultural facts, are, perhaps, incalculable. At present, however, the state of knowledge among farmers is not such as to enable them to reap much advantage from chemical experiments; and the chemist has, himself, scarcely ever opportunities of applying his knowledge to practical purposes in this way. It may, perhaps, however, be of use, to offer a few brief directions for the analysis of marls, lime-stone, &c.

SECTION I.

Lime.

IT is impossible to lay down any general rules respecting the fitness of lime for the purposes of agriculture; because much must

* Essays, vol. i. page 572.

depend on the peculiarities of soil, exposure, and other circumstances. Hence a species of lime may be extremely well adapted for one kind of land and not for another. All that can be accomplished by chemical means is to ascertain the degree of purity of the lime, and to infer, from this, to what kind of soil it is best adapted. Thus a lime, which contains much argillaceous earth, is better adapted than a purer one to dry and gravelly soils; and stiff clayey lands require a lime as free as possible from the argillaceous ingredient.

To determine the purity of lime, let a given weight be dissolved in diluted muriatic acid. Let a little excess of acid be added, that no portion may remain undissolved owing to the deficiency of the solvent. Dilute with distilled water; let the insoluble part, if any, subside, and the clear liquor be decanted. Wash the sediment with farther portions of water, and pour it upon a filter, previously weighed. Dry the filter and ascertain its increase of weight, which will indicate how much insoluble matter the quantity of lime submitted to experiment contained. It is easy to judge by the external qualities of the insoluble portion, whether argillaceous earth abounds in its composition.

There is one earth, however, lately found in several lime-stones, which is highly injurious to the vegetation of plants, and is not discoverable by the foregoing process, being, equally with lime, soluble in muriatic acid. This earth is magnesia, which, by direct experiments, has been ascertained to be extremely noxious to plants. Mr. Tennant, the gentleman to whom we owe this fact, was informed, that in the neighbourhood of Doncaster two kinds of lime were employed, one of which it was necessary to use very sparingly, and to spread very evenly; for it was said, that a large proportion, instead of increasing, diminished the fertility of the soil; and that, whenever a heap of it was left in one spot, all fertility was prevented for many years. Fifty or sixty bushels on an acre were considered to be as much as could be used with advantage. The other sort of lime, which was obtained from a village near Ferrybridge, though considerably dearer, from the distant carriage, was more frequently employed, on account of its superior utility. A large quantity was never found to be injurious; and the spots which were covered with it, instead of being rendered barren, became remarkably fertile. On examining the composition of these two species of lime, the fertilizing one proved to consist entirely of calcareous earth, and the noxious one of three parts lime and two magnesia.

The presence of magnesia in lime proved, on farther investigation, to be a very common occurrence. The magnesian lime-stone appears to extend for thirty or forty miles from a little south-west of Worksop, in Nottinghamshire, to near Ferrybridge, in Yorkshire, and it has also been found at Breedon and Matlock, in Derbyshire.

The magnesian lime-stone, according to Mr. Tennant, may easily be distinguished from that which is purely calcareous, by the slowness of its solution in acids, which is so considerable, that even the softest kind of the former is much longer in dissolving than

marble. It has also frequently a crystallized structure, and sometimes, though not always, small black dots may be seen dispersed through it. In the countries where this lime-stone is found, the lime is generally distinguished, from its effects in agriculture, by the farmers, as *hot* lime, in opposition to the purely calcareous, which they term *mild*.

To ascertain, by chemical means, the composition of a lime or lime-stone suspected to contain magnesia, the following is the easiest, though not the most accurate, process. Procure a Florence flask, clean it well from oil by a little soap-lees or salt of tartar and quicklime mixed, and break it off, about the middle of the body, by setting fire to a string tied round it and moistened with oil of turpentine. Into the bottom part of this flask put 100 grains of the lime or lime-stone, and pour on it, by degrees, half an ounce of strong sulphuric acid. On each affusion of acid a violent effervescence will ensue; when this ceases, stir the acid and lime together with a small glass tube, or rod, and place the flask in an iron pan, filled with sand. Set it over the fire, and continue the heat till the mass is quite dry. Scrape off the dry mass, weigh it, and put it into a wine glass, which may be filled up with water. Stir the mixture, and when it has stood half an hour, pour the whole on a filtering-paper, placed on a funnel, and previously weighed. Wash the insoluble part with water, as it lies on the filter, and add the washings to the filtered liquor. To this liquor add a solution of half an ounce of salt of tartar in water, when, if magnesia be present, a very copious white sediment will ensue, if lime only, merely a slight milkiness. In the former case, heat the liquor by setting it in a tea-cup near the fire; let the sediment subside; pour off the clear liquor, which may be thrown away, and wash the white powder repeatedly with warm water. Then pour it on a filter of paper, the weight of which is known, dry it, and weigh. The result, if the lime-stone has been submitted to experiment, shows how much carbonate of magnesia was contained in the original stone, or, deducting 60 per cent., how much pure magnesia 100 parts of the lime-stone contained. If the burnt lime has been used, deduct from the weight of the precipitate 60 per cent., and the remainder will give the weight of the magnesia in each 100 grains of the burnt lime.

SECTION II.

Analysis of Marls.

THE ingredient of marls, on which their fitness for agricultural purposes depends, is the carbonate of lime. It is owing to the presence of this earth that marls effervesce on the addition of acids, which is one of their distinguishing characters. In ascertaining whether an effervescence takes place, let the marl be put into a glass, partly filled with water, which will expel a portion of air

contained mechanically in the marl, and thus obviate one source of fallacy. When the marl is thoroughly penetrated by the water, add a little muriatic acid, or spirit of salt. If a discharge of air should ensue, the marly nature of the earth is sufficiently established.

To find the composition of a marl, pour a few ounces of diluted muriatic acid into a Florence flask, place them in a scale, and let them be balanced. Then reduce a few ounces of dry marl into powder, and let this powder be carefully and gradually thrown into the flask, until, after repeated additions, no farther effervescence is perceived. Let the remainder of the powdered marl be weighed, by which the quantity projected will be known. Let the balance be then restored. The difference of weight between the quantity projected and that requisite to restore the balance, will show the weight of air lost during effervescence. If the loss amount to 13 per cent. of the quantity of marl projected, or from 13 to 32 per cent., the marl assayed is calcareous marl, or marl rich in calcareous earth.

Clayey marls, or those in which the argillaceous ingredient prevails, lose only 8 or 10 per cent. of their weight by this treatment, and sandy marls about the same proportion. The presence of much argillaceous earth may be judged by drying the marl, after being washed with spirit of salt, when it will harden and form a brick.

To determine, with still greater precision, the quantity of calcareous earth in a marl, let the solution in muriatic acid be filtered, and mixed with a solution of carbonate of potash, till no farther precipitation appears. Let the sediment subside, wash it well with water, lay it on a filter, previously weighed, and dry it. The weight of the dry mass will show how much carbonate of lime the quantity of marl submitted to experiment contained.

APPENDIX,

CONSISTING OF

VARIOUS USEFUL TABLES.

No. I.

CORRESPONDENCE BETWEEN ENGLISH AND FOREIGN WEIGHTS
AND MEASURES.

I.—*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.

II.—*German.*

71 lbs. or grs. English troy,	=	74 lbs. or grs. German apothecaries weight.
1 oz. Nuremberg, medic. weight,	=	7 dr. 2 sc. 9 gr. English.
1 mark Cologne,	=	7 oz. 2 dwt. 4 gr. English troy.

III.—*Dutch.*

1 lb. Dutch,	=	1 lb. 3 oz. 16 dwt. 7 gr. English troy.
787½ lbs. Dutch,	=	1038 lbs. English troy.

IV.—*Swedish Weights and Measures, used by Bergman and Scheele.*

The Swedish pound, which is divided like the English apothecary, or troy, pound, weighs 6556 grs. troy.

The kanne of pure water, according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubical inches. Hence the kanne of pure water weighs 48088.719444 English troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inches.

From these data, the following rules are deduced:

1. To reduce Swedish longitudinal inches to English, multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubical inches, multiply by 1.9, or divide by 0.5265.

3. To reduce the Swedish pound, ounce, dram, scruple, or grain, to the corresponding English troy denomination, multiply by 1.1382, or divide by .8786.

4. To reduce the Swedish kannes to English wine pints, multiply by .1520207, or divide by 6.57805.

5. To reduce Swedish kannes to English wine gallons, multiply by .82225, or divide by 1.216.

6. The lod, a weight sometimes used by Bergman, is the 32d part of the common Swedish pound of 16 oz. and the 24th part of the pound of 12 oz. Therefore to reduce it to the English troy pound, multiply by .03557, or divide by 28.1156.

V.—*Correspondence of English Weights and Measures with those used in France before the Revolution.*

§ 1.—WEIGHTS.

The Paris pound, *poids de marc* of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English troy grains.

The English troy pound of 12 ounces contains 5760 English troy grains, and is equal to 7021 Paris grains.

The English avoirdupois pound of 16 ounces contains 7000 English troy grains, and is equal to 8532.5 Paris grains.

To reduce Paris grains to English troy grains,	divide by	1.2189
To reduce English troy grains to Paris grains,	multiply by	
To reduce Paris ounces to English troy,	divide by	1.015734
To reduce English troy ounces to Paris,	multiply by	

Or the conversion may be made by means of the following tables :

1.—*To reduce French to English Troy Weight.*

The Paris pound	=	7561	} English troy grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

2.—*To reduce English Troy to Paris Weight.*

The English troy pound of 12 ounces	} =	7021.	} Paris grains.
The Troy ounce	=	585.0833	
The dram of 60 grains	=	73.1354	
The penny-weight or denier of 24 grains	} =	29.2541	
The scruple of 20 grains	=	24.3784	
The grain	=	1.2189	

3.—*To reduce English Avoirdupois to Paris Weight.*

The avoirdupois pound of 16 ounces, or 7000 troy grains	} =	8538.	} Paris grains.
The ounce	=	533.6250	

§ II.—LONG AND CUBICAL MEASURES.

To reduce Paris running feet, or inches, into English, multiply by	} 1.065977
English running feet, or inches, into Paris, divide by	
To reduce Paris cubic feet, or inches, to English, multiply by	} 1.211278
English cubic feet, or inches, to Paris, divide by	

Or by means of the following tables :

4.—*To reduce Paris Long Measure to English.*

The French toise	=	6.3945 English feet.	} English inches.
The Paris royal foot of 12 inches	=	12.7977	
The inch	=	1.0664	
The line, or 1-12th of an inch	=	.0888	
The 1-12th of a line	=	.0074	

5.—*To reduce English Long Measure to French.*

The English foot	=	11.2596	} Paris inches.
The inch	=	.9383	
The 1-8th of an inch	=	.1173	
The 1-10th	=	.0938	
The 1-12th	=	.0782	

6.—*To reduce French Cube Measure to English.*

The Paris cube	}	= 1.211278	{ English	{ 2093.088384	} in.
foot					
The cubical inch	=	.000700	{ feet, or	{ 1.211278	

7.—*To reduce English Cube Measure to French.**

The English cube foot, or	}	= 1427.4864	} French cubical
1728 cubical inches			
The cubical inch	=	.8260	
The cube tenth	=	.0008	inches.

§ III.—MEASURE OF CAPACITY.

The Paris pint contains 58.145 † English cubical inches, and the English wine pint contains 28.875 cubical inches; or, the Paris pint contains 2.0171082 English pints, and the English pint contains .49617 Paris pints; hence,

To reduce the Paris pint to the English,	}	2.0171082
multiply by		
To reduce the English pint to the Paris,		
divide by		

The septier of Paris is 7736 French, or 9370.45 English, cubical inches; and the muid is 92832 French, or 112445.4 English cubical inches.

* To convert the weight of a French cubic foot, of any particular substance given in French grains, into the corresponding weight of an English cubic foot in English troy grains, multiply the French grains by 0.6773181, and the product is the number of English troy grains contained in an English cubic foot of the same substance.

† It is said by Belidor, *Archit. Hydraul.* to contain 31 oz. 64 grs. of water, which makes it 58.075 English inches; but, as there is considerable uncertainty in the determinations of the weight of the French cubical measure of water, owing to the uncertainty of the standards made use of, it is better to abide by Mr. Everard's measure, which was made by the Exchequer standards, and by the proportions of the English and French foot, as established by the French Academy and Royal Society.

According to Beaumé, the Paris pint contains 32 French ounces of water, at the temperature of 54.5° of Fahrenheit; which would make it equal to 59.729 English cubical inches.

VI.—Table showing the Comparison between French and English Grains. (Poid de Marc.)

French grs. = English grs.		English grs. = French grs.	
* 1	0.8203	1	1.2189
2	1.6407	2	2.4378
3	2.4611	3	3.6568
4	3.2815	4	4.8757
5	4.1019	5	6.0947
6	4.9223	6	7.3136
7	5.7427	7	8.5325
8	6.5631	8	9.7515
9	7.3835	9	10.9704
10	8.203	10	12.189
20	16.407	20	24.378
30	24.611	30	36.568
40	32.815	40	48.757
50	41.019	50	60.947
60	49.223	60	73.136
70	57.427	70	85.325
80	65.631	80	97.515
90	73.835	90	109.704
100	82.03	100	121.89
200	164.07	200	243.78
300	246.11	300	365.68
400	328.15	400	487.57
500	410.19	500	609.47
600	492.23	600	731.36
700	574.27	700	853.25
800	656.31	800	975.15
900	738.35	900	1097.04
1000	820.3	1000	1218.9
2000	1640.7	2000	2437.8
3000	2461.1	3000	3656.8
4000	3281.5	4000	4875.7
5000	4101.9	5000	6094.7
6000	4922.3	6000	7313.6
7000	5742.7	7000	8532.5
8000	6563.1	8000	9751.5
9000	7383.5	9000	10970.4
* 10,000	8203.0	10,000	12189.0

* Per Farey, (Nicholson's Journal, xxii. 338,) 1 grain French = 0.8204 English; 10,000 ditto = 8204 ditto.

VII.—Table showing the Comparison between French and English Cubical Inches.

Cubic Inches.		Cubic Inches.	
French. = English.		English. = French.	
1	1.2136	1	0.8239
2	2.4272	2	1.6479
3	3.6408	3	2.4719
4	4.8544	4	3.2958
5	6.0681	5	4.1198
6	7.2817	6	4.9438
7	8.4953	7	5.7677
8	9.7089	8	6.5917
9	10.9225	9	7.4157
10	12.136	10	8.239
20	24.272	20	16.479
30	36.408	30	24.719
40	48.544	40	32.958
50	60.681	50	41.198
60	72.817	60	49.438
70	84.953	70	57.677
80	97.089	80	65.917
90	109.225	90	74.157
100	121.36	100	82.39
200	242.72	200	164.79
300	364.08	300	247.19
400	485.44	400	329.58
500	606.81	500	411.98
600	728.17	600	494.38
700	849.53	700	576.77
800	970.89	800	659.17
900	1092.25	900	741.57
1000	1213.6	1000	823.9
2000	2427.2	2000	1647.9
3000	3640.8	3000	2471.9
4000	4854.4	4000	3295.8
5000	6068.1	5000	4119.8
6000	7281.7	6000	4943.8
7000	8495.3	7000	5767.7
8000	9708.9	8000	6591.7
9000	10922.5	9000	7415.7
10,000	12136.0	10,000	8239.0

VIII.—*New French Weights and Measures (calculated by Dr. Duncan, jun.)*

1.—*Measures of Length: the Metre being at 32°, and the Foot at 62°.*

		English inches.						
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.*

		Cubic inches.						
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.*

		English grains.						
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

IX.—*Reduction of the Ounce Measures used by Dr. Priestley to Cubical Inches.*

Ounce Measures.	French cubical Inches.	English cubical Inches.
1	1.567	1.898
2	3.134	3.796
3	4.701	5.694
4	6.268	7.592
5	7.835	9.490
6	9.402	11.388
7	10.969	13.286
8	12.536	15.184
9	14.103	17.082
10	15.670	18.980
20	31.340	37.960
30	47.010	56.940
40	62.680	75.920
50	78.350	94.900
60	94.020	113.880
70	109.690	132.860
80	125.360	151.840
90	141.030	170.820
100	156.700	189.800
1000	1567.000	1898.000

X.—*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.*

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 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,

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

One hundred inches, therefore, would weigh 50.7 grains.

XI. *Specific Gravities of Solid and Liquid Substances.**

GEMS.	Specific Grav.	STONES, &c.	Specific Grav.
Diamond, white, oriental	3.5212	Jasper, brown	2.6911
Topaz, oriental	4.0106	Granite, Egyptian	2.6541
Sapphire, oriental	3.9941	Rock-crystal	2.6530
Garnet, Bohemian	4.1888	Chalcedony, bright . . .	2.6640
Beryl, oriental	3.5489	Carrara marble	2.7168
Hyacinth, common	3.6873	Alabaster, oriental . . .	2.7302
Emerald, from Peru	2.7755	Carnelian	2.6137
Crysolithe, from Brasil . .	2.6923	Slate, common, for roofs	2.8535
Amethyst, oriental	2.651	Flint	2.5941
Ruby, oriental	4.2833	Agate, oriental	2.5901
		Portland-stone	2.533
STONES, &c.		Serpentine, green, Italian	2.4295
Ponderous spar	4.4300	Opal, noble	2.144
Porphyry	2.7651	Pumice-stone	0.9145

SALTS.

	Hassenfratz.	Kirwan.	Muschenbrock.	Newton.
Potash	1.7085	4.6215		
Lime	1.5233	2.3908	2.3700	
Magnesia	0.3460	2.3298		
Alumine	0.8200	2.0000		
Barytes	2.3740	4.0000		
Sulphate of potash	2.4073	2.636	2.398	
———— alumine	1.7109		1.7260	1.714
———— zinc	1.9120		1.9	1.712
———— iron	1.8399		1.88	
———— copper	2.1943	2.23		
Nitrate of potash	1.9369	1.933	1.901	1.900
Muriate of soda	2.2001		2.0835	2.143
Acetate of lead	2.3450		2.3953	
Supertartrate of potash .	1.9153		1.8745	
Sub-borate of soda	1.7230		1.7170	1.714
Carbonate of potash	2.0120		2.749	
———— soda	1.3591	1.421		
———— ammonia	0.9660	1.8245	1.5026	

* For the specific gravities of the metals, see Table of the Qualities of Metals, near the close of this Appendix.

*Table of Specific Gravities of Solid and Liquid Substances,—
Continued.*

GLASSES AND VITRIFICATIONS.	Specific Grav.	SPIRITUOUS LIQUIDS.	Specific Grav.
Green bottle-glass	2.7325	Sulphuric ether †	0.7396
French crystal-glass	2.8922	Muriatic ether	0.7296
French mirror-glass, from St. Gobin	2.4882		
English flint-glass	3.3203	ETHEREAL OILS.	
China porcelain	2.3847	Oil of cinnamon	1.0439
		Oil of cloves	1.0363
		Oil of lavender	0.8938
		Spirit of turpentine	0.8697
INFLAMMABLES.			
Roll-sulphur	1.9907		
Phosphorus	1.714	FAT OILS.	
Pit-coal	1.3292	Linseed oil	0.9403
Amber	1.0780	Poppy oil	0.9288
Heaviest charcoal	0.441	Oil of sweet almonds	0.9170
Mineral naphtha	0.708	Olive oil	0.9153
Camphor	0.9887		
Liquid ammonia	0.8970	ANIMAL FLUIDS.	
		Asses' milk	1.0355
		Cows' milk	1.0324
WATERS.		Human milk	1.0203
Distilled water	1.0000	Human urine	1.0106
Sea water	1.0263		
Water from the Asphaltic Sea	1.2403	ANIMAL FATS.	
		Spermaceti	0.9433
ACIDS.		Butter	0.9423
Sulphuric acid of commerce	1.8500	Tallow	0.9419
Sulphuric acid, real	2.1250	Mutton suet	0.9235
Nitric acid	1.5800	Train oil	0.9235
Muriatic acid	1.1940	Hogs' Lard	0.9568
Concentrated acetic acid	1.0626	Ivory	1.825
		Bees' wax	0.9648
SPIRITUOUS LIQUIDS.		GUMS.	
Madeira wine	1.0382	Common gum	1.4817
Cyder	1.0181	Gum Arabic	1.4523
Brown beer	1.0338	Gum tragacanth	1.3161
Burgundy wine	0.9915		
Champaigne wine	0.962	GUM-RESINS.	
Brandy	0.8371	Asafoetida	1.3275
Alcohol *	0.8293	Scammonium, from Smyrna	1.2743
Nitric ether	0.9088	Galbanum	1.2120
Acetic ether	0.8664		

* Per Chaussier 0.7980.

† Per Lovitz 0.6320.

*Table of Specific Gravities of Solid and Liquid Substances,—
Continued.*

		Specific Grav.			Specific Grav.
RESINS.			WOODS.		
Guaiacum		1.2289	Ebony		1.2090
Jalap		1.2185	Heart of old oak . . .		1.1700
Ammoniacum		1.2071	Mahogany		1.063
Benzoe		1.0924	Olive tree		0.9270
Sandarac		1.0920	Mulberry tree, Spanish		0.8970
White resin		1.0819	Beech tree		0.8520
Colophony		1.0441	Yew tree, Spanish . . .		0.8070
Mastich		1.0742	Apple tree		0.7930
Copal, transparent . . .		1.0452	Plum tree		0.7850
Elastic resin		0.9335	Maple tree		0.7550
INSPISSATED JUICES.			Cherry tree		0.7150
Aloe <i>succotrina</i>		1.3795	Quince tree		0.7050
Opium		1.3366	Orange tree		0.7050
WOODS.			Walnut tree		0.6710
Lignum guaiacum		1.3330	Pear tree		0.6610
Box wood, Dutch		1.3280	Cypress, Spanish		0.6440
French box wood		0.912	Pine tree		0.5500
			White Spanish poplar tree		0.5294
			Cork		0.2400

☞ For a copious list of Specific Gravities, see the Table at the conclusion of the Appendix, extracted from Muschenbrock. C.

XII.—Rules for Calculating the Absolute from the Specific Gravities of Bodies.

In 1696, Mr. Everard, balance maker to the Exchequer, weighed before the commissioners of the House of Commons 2145.6 cubical inches, by the Exchequer standard foot, of distilled water, at the temperature of 55° of Fahrenheit, and found it to weigh 1131 oz. 14 dts. troy, of the Exchequer standard. The beam turned with 6 grs. when loaded with 30 pounds in each scale. Hence, supposing the pound avoirdupois to weigh 7000 grs. troy, a cubic foot of water weighs 62½ pounds avoirdupois or 1000 ounces avoirdupois, wanting 106 grains troy. And hence, if the specific gravity of water be called 1000, the proportional specific gravities of all other bodies will nearly express the number of avoirdupois ounces in a cubic foot. Or, more accurately, supposing the specific gravity of water expressed by 1, and of all other bodies in proportional numbers, as the cubic foot of water weighs, at the above temperature, exactly 437489.4 grains troy, and the cubic inch of water 253.175 grains, the absolute weight of a cubical foot or inch of any body in troy grains may be found by multiplying their specific gravity by either of the above numbers respectively.

By Everard's experiment, and the proportions of the English and French foot, as established by the Royal Society and French Academy of Sciences, the following numbers are ascertained :

Paris grains in a Paris cube foot of water	=	645511
English grains in a Paris cube foot of water	=	529922
Paris grains in an English cube foot of water	=	533247
English grains in an English cube foot of water	=	437489.4
English grains in an English cube inch of water	=	253.175
By an experiment of Picard with the measure and weight of the Chatelet, the Paris cube foot of water contains of Paris grains	=	641326
By one of Du Hamel, made with great care	=	641376
By Homberg	=	641666

These show some uncertainty in measure or in weights; but the above computation from Everard's experiment may be relied on, because the comparison of the foot of England with that of France was made by the joint labour of the Royal Society of London and the French Academy of Sciences: it agrees likewise very nearly with the weight assigned by M. Lavoisier, 70 Paris pounds to the cubical foot of water.

XIII.—*Table for reducing the Degrees of Baume's Hydrometer to the Common Standard.*

Baume's Hydrometer for Liquids lighter than Water.

Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
10 . . .	1.000	18 . . .	.942	26 . . .	.892	34 . . .	.847
11 . . .	.990	19 . . .	.935	27 . . .	.886	35 . . .	.842
12 . . .	.985	20 . . .	.928	28 . . .	.880	36 . . .	.837
13 . . .	.977	21 . . .	.922	29 . . .	.874	37 . . .	.832
14 . . .	.970	22 . . .	.915	30 . . .	.867	38 . . .	.827
15 . . .	.963	23 . . .	.909	31 . . .	.861	39 . . .	.822
16 . . .	.955	24 . . .	.903	32 . . .	.856	40 . . .	.817
17 . . .	.949	25 . . .	.897	33 . . .	.852		

Baume's Hydrometer for Liquids heavier than Water.

Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
0 . . .	1.000	21 . . .	1.170	42 . . .	1.414	63 . . .	1.779
3 . . .	1.020	24 . . .	1.200	45 . . .	1.455	66 . . .	1.848
6 . . .	1.040	27 . . .	1.230	48 . . .	1.500	69 . . .	1.920
9 . . .	1.064	30 . . .	1.261	51 . . .	1.547	72 . . .	2.000
12 . . .	1.089	33 . . .	1.295	54 . . .	1.594		
15 . . .	1.114	36 . . .	1.333	57 . . .	1.659		
18 . . .	1.140	39 . . .	1.373	60 . . .	1.717		

No. II.

ADMEASUREMENT AND EFFECTS OF HEAT.

I.—Correspondence between different Thermometers.

FAHRENHEIT's thermometer is universally used in Great Britain, chiefly also in the United States. In this instrument the range between the freezing and boiling points of water is divided into 180°; and as the greatest possible degree of cold was supposed to be that produced by mixing snow or muriate of soda, it was made the zero. Hence the freezing point became 32°, and the boiling point 212°.

The Centigrade thermometer places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the title of Celsius's thermometer.

Reaumur's thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero at the freezing point.

Wedgwood's pyrometer is only intended to measure very high temperatures. Its zero corresponds with 1077° of Fahrenheit's, and each degree of Wedgwood is equal to 130° of Fahrenheit.

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

$$\text{Therefore } 180^{\circ} \text{ F.} = 100^{\circ} \text{ C.} = 80^{\circ} \text{ R.} = 150^{\circ} \text{ D.} = \frac{18}{13} \text{ W.}$$

1. To reduce centigrade degrees to those of Fahrenheit, multiply by 9 and divide by 5, and to the quotient add 32, that is, $\frac{C \times 9}{5} + 32 = \text{F.}$

2. To reduce Fahrenheit's degrees to centigrade, $\frac{\text{F.} - 32 \times 5}{9} = \text{C.}$

3. To reduce Reaumur's to Fahrenheit's, we have the following formula, $\frac{R \times 9}{4} + 32 = \text{F.}$

4. To convert Fahrenheit to Reaumur, $\frac{\text{F.} - 32 \times 4}{9} = \text{R.}$

5. To reduce De Lisle's degrees under the boiling point, we have $\text{F} = 212 - \frac{\text{D.} \times 6}{5}$. To reduce those above the boiling point, $\text{F.} = 212 + \frac{\text{D.} \times 6}{5}$.

6. And, inversely, to reduce Fahrenheit's degrees to De Lisle's, under the boiling point $\frac{1060 - 5 \text{ F.}}{6} = \text{D.}$; above the boiling point $\frac{\text{F.} \times 5 - 1060}{6} = \text{D.}$

7. To reduce Wedgwood's to those of Fahrenheit, we have $W \times 130 + 1077 = F$.

8. Inversely, to reduce Fahrenheit to Wedgwood, $\frac{F - 1077}{130} = W$.

Table, showing the Correspondence between the Degrees of Fahrenheit's Thermometer and the new Scale of Mr. Dalton (see page 59.)

Fahrenheit's Scale.	Fahrenheit's Scale, corrected for the Expansion of Glass.	True equal Intervals of Temperature.
— 40.		— 175
— 21.12		— 68
— 17.06		— 58
— 12.96		— 48
— 8.52		— 38
— 3.76		— 28
+ 1.34		— 18
6.78		— 8
12.63		+ 2
18.74		12
25.21		22
<hr/>		
32.	32.	32
39.1	39.3	42
46.6	47.	52
54.44	55.	62
62.55	63.3	72
71.04	72.	82
79.84	81.	92
89.02	90.4	102
98.49	101.1	112
108.3	110.	122
118.5	120.1	132
129.	130.4	142
139.9	141.1	152
151.	152.	162
162.4	163.3	172
177.4	178.	182
186.5	186.9	192
199.	199.2	202
212.	212.	212
<hr/>		
359.1		312
539.8		412
754.7		512
1000.		612
1285.		712

II.—*Table of the Effects of Heat.*1.—*Freezing Points of Liquid.*

Fahrenheit.

— 55	Strongest nitric acid freezes (Cavendish)
46	Ether and liquid ammonia
39	Mercury
36	Sulphuric acid (Thomson)
22	Acetous acid
11	2 Alcohol, 1 water
7	Brandy
+ 1	Strongest sulphuric acid (Cavendish)
16	Oil of turpentine (Macquer)
20	Strong wines
23	Fluoric acid
	Oils bergamot and cinnamon
25	Human blood
28	Vinegar
30	Milk
32	Oxymuriatic acid
	Water
36	Olive oil
46	Sulphuric acid, specific gravity 1.78 (Keir)
64	Oil of aniseeds, 50 (Thomson)

2.—*Melting Points of Solids.*

40	Equal parts of sulphur and phosphorus
82	Adipocire of muscle
97	Lard (Nicholson)
99	Phosphorus (Pelletier)
104	Resin of bile
109	Myrtle Wax (Cadet)
112	Spermaceti (Bostock)
127	Tallow (Nicholson) 92 (Thomson)
149	Bees' wax
145	Ambergris (La Grange)
155	Bleached wax (Nicholson)
212	Bismuth 5 parts, tin 3, lead 2
234	Sulphur (Hope) 212 (Fourc.) 185 (Kirw.)
235	Adipocire of biliary calculi (Fourcroy)
283	Tin and bismuth, equal parts
303	Camphor
334	Tin 3, lead 2, or tin 2, bismuth 1
442	Tin (Chrichton) 413 (Irvine)
460	Tin 1, lead 4
476	Bismuth (Irvine)
612	Lead (Chrichton) 594 (Irv.) 540 (Newton)

Fahren.	Wedg.	
700		Zinc
809		Antimony
3809	21	Brass
4587	27	Copper
4717	28	Silver
5237	32	Gold
17977	130	Cobalt
20577	150	Nickel
21097	154	Soft nails
21637	158	Iron
21877	160	Manganese
23177	+170	Platine, tungsten, molybdena, uranium, titanium, &c.

3. *Solids and Liquids volatilized.*

98	Ether boils
140	Liquid ammonia boils
145	Camphor sublimes (Venturi)
170	Sulphur evaporates (Kirwan)
176	Alcohol boils, 174 (Black)
212	Water and essential oils boil
219	Phosphorus distils (Pelletier)
230	Muriate of lime boils (Dalton)
242	Nitrous acid boils
248	Nitric acid boils
283	White arsenic sublimes
540	Metallic arsenic sublimes
554	Phosphorus boils
560	Oil of turpentine boils, about 212° (Dal.)
570	Sulphur boils
590	Sulphuric acid boils (Dalton) 546 (Black)
600	Linseed oil boils, sulphur sublimes (Davy)
660	Mercury boils (Dalton) 644 (Secondat) 600 (Black) 672 (Irvine)

4. *Miscellaneous Effects of Heat.*

-90	Greatest cold produced by Mr. Walker
50	Natural cold produced at Hudson's Bay
23	Observed on the surface of the snow at Glasgow, 1780
14	At Glasgow, 1780
0	Equal parts, snow and salt
+43	Phosphorus burns slowly
59	Vinous fermentation begins
66	to 135, Animal putrefaction
75	to 80, Summer heat in this climate (Gr. Britain)
77	Vinous fermentation rapid, acetous begins
80	Phosphorus burns in oxygen, 104 (Gottling)

Fahren.	Wedg.	
88		Acetification ceases
96		to 100, Animal temperature
107		Feverish heat
122		Phosphorus burns vividly (Fourcroy) 148 (Thomson)
165		Albumen coagulates, 156 (Black)
303		Sulphur burns slowly
635		Lowest heat of ignition of iron in the dark
800		Hydrogen burns, 1000 (Thomson)
802		Charcoal burns (Thomson)
1050		Iron red in twilight
1207	1	Iron red in day light
1337	+2	Azotic gas burns
1857	6	Enamel colours burned
2897	14	Diamond burns (M'Kenzie) 30 W = 5000 F. (Morveau)
6277	40	Delft ware fired
8487	57	Working heat of plate glass
10177	70	Flint glass furnace
12257	86	Cream-coloured ware fired
13297	94	Worcester china vitrified
14337	102	Stone ware fired
14727	105	Chelsea china fired
15637	112	Derby china fired
15897	114	Flint glass furnace greatest heat
16007	121	Bow china vitrified
16807	124	Plate glass greatest heat
17327	125	Smith's forge
20577	150	Hessian crucible fused
25127	185	Greatest heat observed

III.—*Table of the Force of Steam at different Temperatures of Fahrenheit's Scale from actual Experiment.*

(Betancourt in Prony's Architecture Hydraulique.)

Tempera- ture.	Force in English Inches of Mercury.	Tempera- ture.	Force in English Inches of Mercury.
32	0	162	9.07
42 . . . . .	.08	172	11.0
52 . . . . .	.21	182	14.9
62 . . . . .	.38	192	18.7
72 . . . . .	.58	202	23.7
82 . . . . .	.87	212	29.8
92	1.26	222	37.4
102	1.74	232	46.5
112	2.37	242	57.3
122	3.16	252	69.7
132	4.16	262	83.6
142	5.43	272	97.1
152	7.00	282	108.

IV.—*Table of the Expansion of Air by Heat.*

(By Mr. Dalton.)

Fahren.		Fahren.		Fahren.	
32 .	1000	59 .	1064	86 .	1123
33 .	1002	60 .	1066	87 .	1125
34 .	1004	61 .	1069	88 .	1128
35 .	1007	62 .	1071	89 .	1130
36 .	1009	63 .	1073	90 .	1132
37 .	1012	64 .	1075	91 .	1134
38 .	1015	65 .	1077	92 .	1136
39 .	1018	66 .	1080	93 .	1138
40 .	1021	67 .	1082	94 .	1140
41 .	1023	68 .	1084	95 .	1142
42 .	1025	69 .	1087	96 .	1144
43 .	1027	70 .	1089	97 .	1146
44 .	1030	71 .	1091	98 .	1148
45 .	1032	72 .	1093	99 .	1150
46 .	1034	73 .	1095	100 .	1152
47 .	1036	74 .	1097	110 .	1173
48 .	1038	75 .	1099	120 .	1194
49 .	1040	76 .	1101	130 .	1215
50 .	1043	77 .	1104	140 .	1235
51 .	1045	78 .	1106	150 .	1255
52 .	1047	79 .	1108	160 .	1275
53 .	1050	80 .	1110	170 .	1295
54 .	1052	81 .	1112	180 .	1315
55 .	1055	82 .	1114	190 .	1334
56 .	1057	83 .	1116	200 .	1354
57 .	1059	84 .	1118	210 .	1372
58 .	1062	85 .	1121	212 .	1376

V.—*Table of the Expansion of Liquids by Heat.*

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	.....	103573	.....
150	101220	.....	102614	.....	102017	.....	.....
160	101322	.....	102893	.....	.....	.....	.....
170	101424	.....	103116	.....	.....	.....	.....
180	101526	.....	103339	.....	.....	.....	.....
190	101628	.....	103587	.....	103617	.....	.....
200	101730	.....	103911	.....	.....	.....	.....
212	101835	107250	.....	.....	104577	.....	.....

VI.—*Table of the Expansion of Water by Heat.*

(From Mr. Dalton's New System of Chemical Philosophy.)

Temperature.	Expansion.	Temperature.	Expansion.
12° Fahrenheit.	100236	122° Fahrenheit.	101116
22	100090	132	101367
32	100022	142	101638
42	100000	152	101934
52	100021	162	102245
62	100083	172	102575
72	100180	182	102916
82	100312	192	103265
92	100477	202	103634
102	100672	212	104012
112	100880		

VII.—*Table of the Expansion of Solids by Heat.*

Temp.	Platina.†	Antimon.	Steel.	Iron.	Cast Iron.	Bismuth.
32°	120000	120000	120000	120000	120000	120000
12	120104	120130	120147	120151		120167
White heat * }	.....	.....	123428	121500	122571	
	Copper.	Cast Brass.	Brass Wire.	Tin.	Lead.	Zinc.
32°	120000	120000	120000	120000	120000	120000
212	120204	120225	120232	120298	120344	120355
	Hamm ^d Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin ‡ 1
32°	120000	120000	120000	120000	120000	120000
212	120373	120323	120301	120274	120274	120218

Expansion of Glass.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	100°	100023	167°	100056
50	100006	120	100033	190	100069
70	100014	150	100044	212	100083

* Rinman.

† Borda.

‡ The metal, whose expansion is here given, was an alloy composed of three parts of copper, and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus, in the last column but two, the metal consisted of two parts of brass, alloyed with one of zinc.

VIII.—*Tables, exhibiting a collective View of all the Frigorific Mixtures, contained in Mr. Walker's Publication, 1808.*

(Communicated by Mr Walker.)

1.—*Table, consisting of Frigorific Mixtures, having the Power of generating, or creating cold, without the Aid of Ice, sufficient for all useful and Philosophical purposes, in any Part of the World at any Season.*

Frigorific Mixtures without Ice.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Muriate of ammonia . . . 5 parts Nitrate of potash 5 Water 16	From $+ 50^{\circ}$ to $+ 10^{\circ}$	40
Muriate of ammonia . . . 5 parts Nitrate of potash 5 Sulphate of soda 8 Water 16	From $+ 50^{\circ}$ to $+ 4^{\circ}$	46
Nitrate of ammonia . . . 1 part Water 1	From $+ 50^{\circ}$ to $+ 4^{\circ}$	46
Nitrate of ammonia . . . 1 part Carbonate of soda 1 Water 1	From $+ 50^{\circ}$ to $- 7^{\circ}$	57
Sulphate of soda 3 parts Diluted nitric acid 2	From $+ 50^{\circ}$ to $- 3^{\circ}$	53
Sulphate of soda 6 parts Muriate of ammonia . . . 4 Nitrate of potash 2 Diluted nitric acid 4	From $+ 50^{\circ}$ to $- 10^{\circ}$	60
Sulphate of soda 6 parts Nitrate of ammonia . . . 5 Diluted nitric acid 4	From $+ 50^{\circ}$ to $- 14^{\circ}$	64
Phosphate of soda 9 parts Diluted nitric acid 4	From $+ 50^{\circ}$ to $- 12^{\circ}$	62
Phosphate of soda 9 parts Nitrate of ammonia . . . 6 Diluted nitric acid 4	From $+ 50^{\circ}$ to $- 21^{\circ}$	71
Sulphate of soda 8 parts Muriatic acid 5	From $+ 50^{\circ}$ to 0°	50
Sulphate of soda 5 parts Diluted sulphuric acid . . 4	From $+ 50^{\circ}$ to $+ 3^{\circ}$	47

N. B.—If the materials are mixed at a warmer temperature, than that expressed in the Table, the effect will be proportionably greater; thus, if the most powerful of these mixtures be made, when the air is $+ 85^{\circ}$, it will sink the thermometer to $+ 2^{\circ}$.

2.—Table, consisting of *Frigorific Mixtures, composed of Ice, with chemical Salts and Acids.*

Frigorific Mixtures with Ice.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Snow, or pounded ice . . . 2 parts Muriate of soda 1	From any Temperature to — 5° to — 12° to — 18° to — 25°	.
Snow, or pounded ice . . . 5 parts Muriate of soda 2 Muriate of ammonia . . . 1		.
Snow, or pounded ice . . . 24 parts Muriate of soda 10 Muriate of ammonia . . . 5 Nitrate of potash 5		.
Snow, or pounded ice . . . 12 parts Muriate of soda 5 Nitrate of ammonia . . . 5		.
Snow 3 parts Diluted sulphuric acid . . . 2	From + 32° to — 23°	55
Snow 8 parts Muriatic acid 5	From + 32° to — 27°	59
Snow 7 parts Diluted nitric acid 4	From + 32° to — 30°	62
Snow 4 parts Muriate of lime 5	From + 32° to — 40°	72
Snow 2 parts Chryst. muriate of lime . . . 3	From + 32° to — 50°	82
Snow 3 parts Potash 4	From + 32° to — 51°	83

N. B.—The reason for the omissions in the last column of this Table, is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

5.—Table consisting of *Frigorific Mixtures* selected from the foregoing Tables, and combined, so as to increase or extend Cold to the extremest Degrees.

Combinations of Frigorific Mixtures.

MIXTURES.	Thermometer sinks.	Deg. of cold produced.
Phosphate of soda . . . 5 parts Nitrate of ammonia . . 3 Diluted nitric acid . . . 4	From 0° to — 34°	34
Phosphate of soda . . . 3 parts Nitrate of ammonia . . 2 Diluted mixed acids . . 4	From — 34° to — 50°	16
Snow 3 parts Diluted nitric acid . . . 2	From 0° to — 46°	46
Snow 8 parts Diluted sulphuric acid . 3 } Diluted nitric acid . . . 3 }	From — 10° to — 56°	46
Snow 1 part Diluted sulphuric acid . 1	From — 20° to — 60°	40
Snow 3 parts Muriate of lime 4	From + 20° to — 48°	68
Snow 3 parts Muriate of lime 4	From + 10° to — 54°	64
Snow 2 parts Muriate of lime 3	From — 15° to — 68°	53
Snow 1 part Chryst. muriate of lime 2	From 0° to — 66°	66
Snow 1 part Chryst. muriate of lime 3	From — 40° to — 73°	33
Snow 8 parts Diluted sulphuric acid 10	From — 68° to — 91°	23

N. B.—The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding tables.

IX.—*Table of Specific Heats, from Mr. Dalton's New System of Chemical Philosophy, Part I.*

GASES.		Eq.	Eq.	SOLIDS.		Eq.	Eq.
		Wts.	Blks.			Wts.	Blks.
Hydrogen		21.40	.002	Ice . . . . .		.90	.83
Oxygen		4.75	.006	Dried woods, and			
Common air		1.79	.002	other vegetable			
Carbonic acid		1.05	.002	substances, from			
Azotic . . . . .		.79	.001	.45 to . . . . .		.65	
Aqueous vapour		1.55	.001	Quicklime . . . . .		.30	
LIQUIDS.				Pit-coal (1.27) . . . . .		.28	.36
Water		1.00	1.00	Charcoal . . . . .		.26	
Arterial blood		1.03		Chalk . . . . .		.27	.67
Milk (1.026) . . . . .		.98	1.00	Hydrat. lime . . . . .		.25	
Carbonate of ammon. (1.035)		.95	.98	Flint glass (2.87) . . . . .		.19	.55
Carbonate of potash (1.30) .		.75	.98	Muriate of soda . . . . .		.23	
Solution of ammonia (.948)		1.03	.98	Sulphur . . . . .		.19	
Common vinegar (1.02) . . .		.92	.94	Iron . . . . .		.13	1.00
Venous blood . . . . .		.89		Brass . . . . .		.11	.97
Solut. of common salt (1.197)		.78	.93	Copper . . . . .		.11	.98
Solut. of sugar (1.17) . . . .		.77	.90	Nickel . . . . .		.10	.78
Nitric acid (1.20) . . . . .		.76	.96	Zinc . . . . .		.10	.69
Nitric acid (1.30) . . . . .		.68	.88	Silver . . . . .		.08	.84
Nitric acid (1.36) . . . . .		.63	.85	Tin . . . . .		.07	.51
Nitrate of lime (1.40) . . . .		.62	.87	Antimony . . . . .		.06	.40
Sulp. acid and water, equal p.		.52	.80	Gold . . . . .		.05	.97
Muriatic acid (1.153) . . . .		.60	.70	Lead . . . . .		.04	.45
Acetic acid (1.056) . . . . .		.66	.70	Bismuth . . . . .		.04	.40
Sulphuric acid (1.844) . . . .		.35	.65	Oxides of the metals surpass the metals themselves, according to Crawford.			
Alcohol (.85) . . . . .		.76	.65				
Alcohol (.817) . . . . .		.70	.57				
Sulphuric ether (.76) . . . . .		.66	.50				
Spermaceti oil (.87) . . . . .		.52	.45				
Mercury . . . . .		.04	.55				

No. III.

I.—Table of the Solubility of Salts in Water.

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
ACIDS.		
Arsenic	150.	
Benzoic	0.208	4.17
Boracic . . . . .	. . . . .	2.
Camphoric	1.04	8.3
Citric	133.	200.
Gallic	8.3	66.
Mucic	0.84	1.25
Molybdenic . . . . .	. . . . .	0.1
Oxalic	50.	100.
Suberic	0.69	50.
Succinic	4.	50.
Tartaric	Very soluble	
SALIFIABLE BASES.		
Barytes	5.	50.
crystallized	57.	Unlimited
Lime	0.2	
Potash	Very soluble	
Soda	do.	
Strontites	0.6	
crystallized	1.9	50.
SALTS.		
Acetate of ammonia	Very soluble	
barytes	do.	
lime	do.	
magnesia	do.	
potash	100.	
soda	Very soluble	
strontites . . . . .	. . . . .	40.
Carbonate of ammonia	+30.	100.
barytes	Insoluble	
lime	do.	
magnesia	2.	
potash	25.	83.
soda	50.	+100.
strontites	Insoluble	
Camphorate of ammonia	1.	33.

Table of the Solubility of Salts in Water—Continued.

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
SALTS.		
Camphorate of barytes	0.16	
lime	0.5	
potash	33.	+33.
Citrate of soda	60.	
lime	Insoluble	
Hyper-oxy muriate of barytes	25.	+25.
mercury	25.	
potash	6.	40.
soda	35.	+35.
Muriate of ammonia	33.	100.
barytes	20.	+20.
lead	4.5	
lime	200.	
magnesia	100.	
mercury	5.	50.
potash	33.	
silver	0. $\frac{1}{36}$	
soda	35.42	36.16
strontites	150.	Unlimited
Nitrate of ammonia	50.	200.
barytes	8.	25.
lime	400.	
magnesia	100.	+100.
potash	14.25	100.
soda	33.	+100.
strontites	100.	200.
Oxalate of strontites	0. $\frac{1}{19}$	
Phosphate of ammonia	25.	+25.
barytes	0.	0.
lime	0.	0.
magnesia	6.6	
potash	Very soluble	
soda	25.	50.
strontites	0.	0.
Phosphite of ammonia	50.	+50.
barytes	0. $\frac{1}{4}$	
potash	33.	+33.
Sulphate of ammonia	50.	100.
barytes	0.002	
copper	25.	50.
iron	50.	+100.
lead	0. $\frac{1}{12}$	
lime	0.2	0.22
magnesia	100.	133.
potash	6.25	20.
soda	37.	125.
strontites	0.	0.02

Table of the Solubility of Salts in Water—Continued.

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
SALTS.		
Sulphite of ammonia	100.	
lime	0.125	
magnesia	5.	
potash	100.	
soda	25.	100.
Saccholactate of potash		12.
soda		20.
Sub-borate of soda (borax)	8.4	16.8
Super-sulphate of alumine and pot- ash (alum)	5.	133.
potash	50.	+100.
Super-oxalate of potash		10.
tartrate of potash	1. $\frac{2}{3}$	3. $\frac{1}{3}$
Tartrate of potash	25.	
and soda	20.	
antimony and potash	6.6	33.

II.—Table of Substances soluble in Alcohol.

NAMES OF SUBSTANCES.	Temperature.	100 Parts Alco- hol dissolve.
Acetate of copper	176°	7.5
soda	176°	46.
Arsenate of potash	do.	3.75
soda	do.	1.7
Boracic acid	do.	20.
Camphor	do.	75.
Muriate of ammonia	do.	7.
alumine	54 $\frac{1}{2}$ °	100.
copper	176°	100.
iron	176°	100.
lime	do.	100.
magnesia	do.	547.
mercury		88.3
zinc	54 $\frac{1}{2}$ °	100.
Nitrate of ammonia	176°	89.2
alumine	54 $\frac{1}{2}$ °	100.
cobalt	54 $\frac{1}{2}$ °	100.
lime		125.
potash	176°	2.9
silver	do.	41.7
Succinic acid	do.	74.
Sugar, refined	do.	24 $\frac{1}{2}$.
Super-oxalate of potash		3.
Tartrate of potash		0.04

OTHER SUBSTANCES SOLUBLE IN ALCOHOL.—All the acids, except the sulphuric, nitric, and oxy-muriatic, which decompose it, and the phosphoric and metallic acids.—Potash, soda, and ammonia, very soluble. Soaps; extract; tan; volatile oils; adipocire; resins; urea.

SUBSTANCES INSOLUBLE, OR VERY SPARINGLY SOLUBLE, IN ALCOHOL.—Earths; phosphoric and metallic acids; almost all sulphates and carbonates; the nitrates of lead and mercury; the muriates of lead, silver, and soda (the last, *per* Chenevix, sparingly soluble); the sub-borate of soda; the tartrate of soda and potash, and super-tartrate of potash; fixed oils; wax; starch; gum; caoutchouc; woody fibre; gelatine; albumen, and gluten.

III.—*Dr. Wollaston's Numerical Table of Chemical Equivalents.*

N. B.—Dr. Wollaston's numbers represent the weights of the atoms of bodies, oxygen being taken as unity. To reduce them to Mr. Dalton's, multiply by 7 and divide by 10; and to reduce them to the standard adopted in this work, multiply by 7.5, and divide by 10.

1. Hydrogen	1.32	Oxide (+ 10 oxygen) . .	51.00
2. Oxygen	10.00	29. Mercury	125.50
3. Water	11.32	Red oxide (+ 10 oxygen)	135.50
4. Carbon	7.54	Black oxide (+ 125.5	
5. Carbonic acid (+ 20 oxy-		mercury)	261.00
gen)	27.54	30. Lead	129.50
6. Sulphur	20.00	Litharge (+ 10 oxygen) .	139.50
7. Sulphuric acid (+ 30 oxy-		31. Silver	135.00
gen)	50.00	Oxide (+ 10 oxygen) . .	145.00
8. Phosphorus	17.40	32. Sub-carbonate of ammonia	49.00
9. Phosphoric acid (+ 20 ox-		Bi-carbonate (+ 27.5 car-	
ygen)	37.40	bonic acid)	76.50
10. Azote or Nitrogen	17.54	33. Sub-carbonate of soda . .	66.60
11. Nitric acid (+ 50 oxygen)	67.54	Bi-carbonate (+ 27.5 C. A.	
12. Muriatic acid dry	34.10	+ 11.3 water)	105.50
13. Oxymuriatic acid (+ 10		34. Sub-carbonate of potash .	86.00
oxygen)	44.10	Bi-carbonate (+ 27.5 C. A.	
14. Chlorine 44.10 + 1.32 hy.		+ 11.3 water)	125.50
= muriatic acid gas	45.42	35. Carbonate of lime	63.00
15. Oxalic acid	47.0	36. ————— barytes	124.50
16. Ammonia	21.5	37. ————— lead	167.00
17. Soda	39.1	38. Sulphuric acid dry	50.00
18. Sodium (— 10 oxygen) . .	29.1	39. Do. s. g. 1.850 (50 + 11.3	
19. Potash	59.1	water)	61.30
20. Potassium (— 10 oxygen)	49.1	40. Sulphate of soda (+ 10	
21. Magnesia	24.6	water = 113.2)	202.30
22. Lime	35.46	41. Sulphate of potash	109.10
23. Calcium (— 10 oxygen) . .	25.46	42. Sulphate of magnesia dry	74.60
24. Strontites	69.00	Do. Crystallized (+ 7 wa-	
25. Barytes	97.00	ters = 79.3)	153.90
26. Iron	34.50	43. Sulphate of lime dry . . .	85.50
Black oxide (+ 10 oxy-		Crystallized (+ 2 waters	
gen)	44.50	= 22.64)	108.10
Red oxide (+ 15 oxygen)	49.50	44. Sulphate of strontites . .	119.00
27. Copper	40.00	45. ————— barytes	147.00
Black oxide (+ 10 oxygen)	50.00	46. ————— copper (1 acid	
28. Zinc	41.00	+ 1 oxide + 5 water)	156.60

*Dr. Wollaston's Numerical Table of Chemical Equivalents—
Continued.*

47. Sulphate of iron (7 water) 173.80	58. Muriate of potash 93.20
48. ——— zinc (do.) . . 180.20	Oxymuriate of do. (+ 60
49. ——— lead 189.50	oxygen) 153.20
50. Nitric acid dry 67.54	59. Muriate of lime 69.60
Do. s. g. 1.50 (+ 2 water	60. ——— barytes 131.00
= 22.64) 90.20	61. ——— lead 173.60
51. Nitrate of soda 106.60	62. ——— silver 179.10
52. ——— potash 126.60	63. ——— mercury 170.10
53. ——— lime 103.00	64. Sub-muriate of do. (1 acid
54. ——— barytes 164.50	+ 1 oxygen + 2 merc.) 296.10
55. ——— lead 207.00	65. Phosphate of lead 176.90
56. Muriate of ammonia 66.90	66. Oxalate of lead 186.50
57. ——— soda 73.20	67. Bin-oxalate of potash . . 153.00

The following are the data on which the above Table is founded:—

1, 2, 3. The specific gravities of oxygen and hydrogen gases are taken on the authority of Biot and Arago; and their proportions in water at 88.286 to 11.714, which numbers are in the ratio of 10 to 1.327.

4, 5. The specific gravities of oxygen and carbonic acid gases are 1.1036 to 1.5196, or as 20 (= 2 oxygen) to 27.54; and deducting the oxygen, we obtain 7.54 for the equivalent of carbon.

6. The equivalent of sulphur is inferred from Berzelius's analysis of galena, which makes the lead bear to the sulphur the proportion of 86.64 to 13.36, or of 129.5 to 20.

7. From the analysis of sulphate of barytes by Klaproth, the sulphuric acid is to the barytes as 34 to 66, or as 50 to 97. Deducting 30 of oxygen, we again obtain 20 for the equivalent of sulphur.

8, 9. In phosphate of lead, according to Berzelius, the litharge is to the acid as 380.56 to 100,* or as 139.5 to 37.4; and deducting from this last number 20 oxygen, we have 17.4 for the equivalent of phosphorus. The same number is deducible, also, from Rose's experiments on phosphoric acid.

10. To obtain the equivalent of azote, ammonia is assumed to consist of 1 volume of azote, and 3 of hydrogen. And as the specific gravity of hydrogen was found by Biot and Arago to be to that of azote as .07321 to .96913, these numbers will be in the proportion of 1.327 to 17.54; and $1.327 \times 3 = 3.98$ added to 17.54, the equivalent of azote, gives 21.52 for the equivalent of ammonia.

11. The equivalent of nitric acid is deduced from Richter's analysis of nitrate of potash,* which makes the potash to the acid as 46.7 to 53.3, or as 59.1 to 67.45; from which if we subtract one portion of azote 17.54, there remain 49.91, so nearly 5 portions of oxygen, that we may assume $17.54 + 50$, or 67.54, to be perfectly correct.

12. By dissolving 63 parts of carbonate of lime in muriatic acid, and evaporating to perfect dryness, we obtain 69.56 of muriate of lime; and deducting the weight of the lime, 35.46, we learn, by means of the difference 34.1, the equivalent of dry muriatic acid.

* 2 Mém. d'Arcueil. 59.

Or, if we choose to consider the dry salt as a compound of calcium and chlorine, we must transfer the weight of 10 oxygen to the muriatic acid, making 44.1 of oxymuriatic acid combined with 25.46 calcium.

15. In oxalate of lead, according to Berzelius, 296.6 of litharge are united with 100 oxalic acid, which are in the proportion of 139.5 to 47 oxalic acid. A result almost exactly the same was obtained by Dr. Wollaston from the analysis of binoxalate of potash.

17, 18. The equivalent of soda is inferred from the analysis of common salt, in which the muriatic acid is to the soda as 100 to 114.78, or as 34.1 to 39.1. The equivalent of sodium is obtained by deducting 10 of oxygen, and is 29.1.

19, 20. In muriate of potash, the acid is to the alkali as 100 to 173.47, or as 34.1 to 59.1, from which last number, if we deduct 10 the equivalent of oxygen, we obtain 49.1 for the equivalent of potassium.

21. The equivalent of magnesia is inferred from the composition of the sulphate, viz. 67 acid to 33 base; for as 67 to 33, so is 50 to 24.6.

22. The equivalent of lime is deduced from the carbonate of lime, in which the acid is to the earth as 43.7 to 56.3, or as 27.54 to 35.46; from which last number, deducting 10 oxygen, we have 25.46 for the equivalent of calcium.

24. In sulphate of strontites, the acid is to the earth as 42 to 58, or as 50 to 69.

25. In sulphate of barytes, 34 acid are united with 66 earth, which is in the proportion of 50 to 97.

26. In black oxide of iron, the oxygen is to the metal as 22.5 to 77.5, or as 10 to 34.5, to which, adding 10 oxygen, we have 44.5 for the equivalent of the oxide of iron.

27. Black oxide of copper contains 20 oxygen to 100 metal, which gives 50 for the equivalent of oxide of copper, and 40 for that of the metal.

28. In oxide of zinc, the oxygen is to the metal as 24.41 to 100, or as 10 to 41, to which last number, adding 10 oxygen, we have 51 for the equivalent of oxide of zinc.

29. In red oxide of mercury, the oxygen is to the metal as 8 to 100, or as 10 to 125. But as other statements differ a little from this, 125.5 may be taken as a mean; and adding 10 oxygen, 135.5 will denote the red-oxide.

30. In carbonate of lead, the acid is to the oxide as 16.5 to 83.5, or as 27.54 to 139.5, the equivalent of litharge; from which, deducting 10 oxygen, we have 129.5 for the equivalent of lead.

31. In muriate of silver, the acid is to the oxide of silver as 19.05 to 80.95, or as 34.1 to 145, the equivalent of the oxide, from which, if we take 10 oxygen, we have 135 the equivalent of silver. If we consider horn silver as a compound of 24.5 chlorine and 75.5 silver, the equivalent of silver will be 136; for $24.5 : 75.5 :: 44.1 : 136$.

32. The subcarbonate of ammonia consists of acid and alkali, according to Gay Lussac, in the proportion of 56.02 to 43.98 or of 27.54 to 21.6, which, therefore, again proves to be the equivalent of

ammonia. The two last numbers added together, give 49 for the equivalent of the subcarbonate.

33. In subcarbonate of soda, the acid is to the alkali as 41.24 to 58.76, or as 27.54 to 39.1; and the two last numbers, added together, express the equivalents of the subcarbonate.

35. The proportion of the elements of carbonate of lime is 43.7 acid to 56.3 base, or 27.54 to 35.46; and consequently carbonate of lime must be represented by those two numbers added together, viz. 63.

36. In carbonate of barytes, the acid is to the earth as 100 to 352.57, or as 27.54 to 97, which two numbers, added together, 124.50, express the equivalent of carbonate of barytes.*

37. The equivalent of carbonate of lead is obtained by adding together those of oxide of lead and of carbonic acid (see 30.)

38, 39. For the determination of the equivalent of sulphuric acid, see No. 7.

The remaining numbers, expressing the equivalents of compound bodies, are obtained by adding together the equivalents of their components. Thus the equivalent of muriate of potash 93.2 is obtained by adding together the equivalents of muriatic acid 34.1 and of potash 59.1.

IV.—*Table of Incompatible Salts.*†

SALTS.	INCOMPATIBLE WITH
1. Fixed alkaline sulphates	{ Nitrates of lime and magnesia, Muriates of lime and magnesia.
2. Sulphate of lime	{ Alkalis, Carbonate of magnesia, Muriate of barytes.
3. Alum	{ Alkalis, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia	{ Alkalis, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron	{ Alkalis, Muriate of barytes, Earthy carbonates.
6. Muriate of barytes	{ Sulphates, Alkaline carbonates, Earthy carbonates.
7. Muriate of lime	{ Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Muriate of magnesia	{ Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime	{ Alkaline carbonates, Carbonates of magnesia and alumine, Sulphates, except of lime.

* These numbers do not exactly coincide with that in the Table. It is not likely, indeed, under the uncertainties of the hypothesis itself, that every part should be correct. C.

† That is, salts which cannot exist together in solution, without mutual decomposition.

No. IV.

Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents.

Metals.	Prussiated Alkalis.	Tincture of Galls.	Water im- pregnated with Sul- phuretted Hydrogen.	Hydro- Sulphurets.
Gold	Yellowish- white	Solution turn- ed green. Precipitate brown of re- duced gold	Yellow	Yellow
Platina	No precip. ; but an orange co- loured one by pruss. of mercury	Dark green becoming paler	Precipi- tated in a metallic state	
Silver	White	Yellowish brown	Black	Black
Mercury	White changing to yellow	Orange yel- low	Black	Brownish black
Palladium	Olive.* Deep orange.†		Dark brown	Dark brown
Rhodium	No precip.			No precip.
Iridium	No precipi- tate. Colour discharged	No precipi- tate. Co- lour of so- lutions dis- charged		
Osmium		Purple, changing to deep vivid blue		
Copper	Bright red- dish brown	Brownish	Black	Black

* Chenevix.

† Wollaston.

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalis.	Tincture of Galls.	Water im- pregnated with Sul- phuretted Hydrogen.	Hydro- Sulphu- rets.
Iron { 1. Greensalts 2. Red salts	White, changing to blue Deep blue	No preci- pitate Black	Not preci- pitated	Black
Nickel	Green	Greyish white	Not preci- pitated	Black
Tin	White	No precip.	Brown	Black
Lead	White	White	Black	Black
Zinc	White	No precip.	Yellow	White
Bismuth	White	Orange	Black	Black
Antimony	White	A white oxide merely from di- lution	Orange	Orange
Tellurium	No precip.	Yellow		Blackish
Arsenic	White	Little change	Yellow	Yellow
Cobalt	Brownish yellow	Yellowish white	Not preci- pitated	Black
Manganese	Yellowish white	No preci- pitate	Not preci- pitated	White
Chrome	Green	Brown		Green
Molybdena	Brown	Deep brown	Brown	
Uranium	Brownish red	Chocolate		Brownish yellow
Tungsten				

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalis.	Tincture of Galls.	Water im- pregnated with Sul- phuretted Hydrogen.	Hydro- Sulphurets.
Titanium	Grass green, with a tinge of brown	Reddish brown	Not pre- cipitated	Grass green
Columbium	Olive	Orange		Chocolate
Tantalum				
Cerium		Yellowish		Brown, becoming deep green

No. VI.

*Table of Simple Affinity.**

OXYGEN.	Caloric ?	Manganese	Silver
Carbon	Mercury	Zinc	Gold
Charcoal	Silver	Iron	
Manganese	Arsenous acid	Tin	
Zinc	Nitric oxide	Uranium	
Iron	Gold	Molybdena	CARBON.
Tin	Platina	Tungsten	Oxygen
Antimony	Carbonic oxide	Cobalt	Iron
Hydrogen	Muriatic acid	Antimony	Hydrogen
Phosphorus	White oxide of	Nickel	
Sulphur	manganese	Arsenic	
Arsenic	White oxide of	Chrome	
Nitrogen	lead	Bismuth	NITROGEN.
Nickel		Lead	Oxygen
Cobalt		Copper	Sulphur ?
Copper	OXYGEN.†	Tellurium	Phosphorus
Bismuth	Titanium	Platina	Hydrogen
		Mercury	

* This table, it may be necessary to observe, does not express accurately the comparative affinities of bodies, but denotes merely the actual order of decomposition, which, as Berthollet has shown, may often be contrary to that of affinity, owing to the influence of various extraneous forces.

† Vauquelin's table of the affinity of the metals for oxygen, according to the difficulty with which their oxides are decomposed by heat.

Table of Simple Affinity—Continued.

HYDROGEN.	<i>Acids.</i> Mucic Boracic Nitrous Carbonic Prussic	<i>Acids.</i> Phosphoric Oxalic Tartaric Fluoric Nitric Muriatic Succinic Acetic Arsenic Boracic Carbonic	MAGNESIA.
Oxygen	Oil	Water	<i>Acids.</i> Oxalic Phosphoric Sulphuric Fluoric Arsenic Mucic Succinic Nitric Muriatic Tartaric Citric Malic ? Lactic Benzoic Acetic Boracic Sulphurous Nitrous Carbonic Prussic Sulphur
Sulphur	Water		
Carbon	Sulphur		
Phosphorus			
Nitrogen			
SULPHUR. PHOSPHORUS?	BARYTES.	LIME.	
Potash	<i>Acids.</i> Sulphuric Oxalic Succinic Fluoric Phosphoric Mucic Nitric Muriatic Suberic Citric Tartaric Arsenic Lactic Benzoic Acetic Boracic Sulphurous Nitrous Carbonic Prussic	<i>Acids.</i> Oxalic Sulphuric Tartaric Succinic Phosphoric Mucic Nitric Muriatic Suberic Fluoric Arsenic Lactic Citric Malic Benzoic Acetic Boracic Sulphurous Nitrous Carbonic Prussic	
Soda			
Iron			
Copper			
Tin			
Lead			
Silver			
Bismuth			
Antimony			
Mercury			
Arsenic			
Molybdena			
POTASH, SODA, AND AMMONIA.	STRONTITES.		ALUMINE.
<i>Acids.</i> Sulphuric Nitric Muriatic Phosphoric Fluoric Oxalic Tartaric Arsenic Succinic Citric Lactic Benzoic Sulphurous Acetic	<i>Acids.</i> Sulphuric		<i>Acids.</i> Sulphuric Nitric Muriatic Oxalic Arsenic Fluoric Tartaric Succinic Mucic Citric Phosphoric Lactic Benzoic Acetic Boracic Sulphurous

Table of Simple Affinity—Continued.

Acids.	Sulphurous	Mucic	Fixed alkalis
Nitrous	Nitric	Oxalic	Ammonia
Carbonic	Arsenic	Arsenic	Fixed oils
Prussic	Fluoric	Tartaric	
	Tartaric	Phosphoric	
	Citric	Muriatic	
	Lactic	Sulphurous	OXIDE OF ARSE-
SILEX.	Succinic	Suberic	NIC.
	Acetic	Nitric	
Fluoric acid	Prussic	Fluoric	Gallic
Potash	Carbonic	Citric	Muriatic
	Ammonia	Malic	Oxalic
		Succinic	Sulphuric
		Lactic	Nitric
OX. OF PLATINA.		Acetic	Tartaric
GOLD.*	OXIDE OF MER-	Benzoic	Phosphoric
	CURY.	Boracic	Fluoric
Gallic acid	Gallic acid	Prussic	Succinic
Muriatic	Muriatic	Carbonic	Citric
Nitric	Oxalic	Fixed oils	Acetic
Sulphuric	Succinic	Ammonia	Prussic
Arsenic	Arsenic		Fixed alkalis
Fluoric	Phosphoric		Ammonia
Tartaric	Sulphuric	OXIDE OF COP-	Fixed oils
Phosphoric	Mucic	PER.	Water
Oxalic	Tartaric		
Citric	Citric	Gallic	
Acetic	Malic	Oxalic	OXIDE OF IRON.
Succinic	Sulphurous	Tartaric	
Prussic	Nitric	Muriatic	Gallic
Carbonic	Fluoric	Sulphuric	Oxalic
Ammonia	Acetic	Mucic	Tartaric
	Benzoic	Nitric	Camphoric
	Boracic	Arsenic	Sulphuric
OXIDE OF SIL-	Prussic	Phosphoric	Mucic
VER.	Carbonic	Succinic	Muriatic
		Fluoric	Nitric
Gallic acid		Citric	Phosphoric
Muriatic		Lactic	Arsenic
Oxalic	OXIDE OF LEAD.	Acetic	Fluoric
Sulphuric		Boracic	Succinic
Mucic	Gallic	Prussic	Citric
Phosphoric	Sulphuric	Carbonic	Lactic

* Omitting the oxalic, citric, succinic, and carbonic, and adding sulphuretted hydrogen after ammonia.

Table of Simple Affinity—Continued.

Acetic	Phosphoric	SULPHURIC	PHOSPHORIC
Boracic	Citric	ACID.	ACID.
Prussic	Succinic	PRUSSIC.†	CARBONIC.§
Carbonic	Fluoric		
	Arsenic	Barytes	Barytes
	Lactic	Strontites	Strontites
	Acetic	Potash	Lime
OXIDE OF TIN.*	Boracic	Soda	Potash
	Prussic	Lime	Soda
Gallic	Carbonic	Magnesia	Ammonia
Muriatic	Fixed alkalis	Ammonia	Magnesia
Sulphuric	Ammonia	Glucine	Glucine
Oxalic		Ytria	Alumine
Tartaric		Alumine	Zircon
Arsenic		Zircon	Metallic oxides
Phosphoric		Metallic ox-	Silex
Nitric	OXIDE OF ANTI-	ides	
Succinic	MONY.		
Fluoric			
Mucic	Gallic		PHOSPHOROUS
Citric	Muriatic		ACID.
Lactic	Benzoic		
Acetic	Oxalic	SULPHUROUS	Lime
Boracic	Sulphuric	ACID.	Barytes
Prussic	Nitric	SUCCINIC.‡	Strontites
Ammonia	Tartaric		Potash
	Mucic	Barytes	Soda
	Phosphoric	Lime	Ammonia
	Citric	Potash	Glucine
OXIDE OF ZINC.	Succinic	Soda	Alumine
	Fluoric	Strontites	Zircon
Gallic	Arsenic	Magnesia	Metallic oxides
Oxalic	Lactic	Ammonia	
Sulphuric	Acetic	Glucine	
Muriatic	Boracic	Alumine	
Mucic	Prussic	Zircon	NITRIC ACID.
Nitric	Fixed alkalis	Metallic ox-	MURIATIC.—||
Tartaric	Ammonia	ides	Barytes

* Bergman places the tartaric before the muriatic.

† With the omission of all after ammonia.

‡ Ammonia should come before magnesia; and strontites, glucine, and zircon, should be omitted.

§ Magnesia should stand above ammonia, and alumina and silica should be omitted.

|| Ammonia should stand above magnesia.

Table of Simple Affinity—Continued.

Potash	ACETIC ACID.	BENZOIC ACID.	Magnesia
Soda	LACTIC —		Oxide of mer-
Strontites	SUBERIC —†	White oxide of	cury
Lime		arsenic	Other metallic
Magnesia	Barytes	Potash	oxides
Ammonia	Potash	Soda	Alumine
Glucine	Soda	Ammonia	
Alumine	Strontites	Barytes	
Zircon	Lime	Lime	
Metallic oxides	Ammonia	Magnesia	
	Magnesia	Alumine	
	Metallic oxides		ALCOHOL.
	Glucine		
	Alumine		Water
	Zircon	CAMPHORIC ACID.	Ether
FLUORIC ACID.			Volatile oil
BORACIC —*			Alkaline sul-
ARSENIC —†		Lime	phurets
TUNGSTIC —	OXALIC ACID.	Potash	
	TARTARIC —	Soda	
	CITRIC —§.	Barytes	
Lime		Ammonia	
Barytes	Lime	Alumine	SULPHURET-
Strontites	Barytes	Magnesia	TED HYDRO-
Magnesia	Strontites		GEN.
Potash	Magnesia		
Soda	Potash		Barytes
Ammonia	Soda	FIXED OIL.	Potash
Glucine	Ammonia		Soda
Alumine	Alumine	Lime	Lime
Zircon	Metallic oxides	Barytes	Ammonia
Silex	Water	Potash	Magnesia
	Alcohol	Soda	Zircon

* Silex should be omitted, and instead of it, water and alcohol be inserted.

† Except silex.

‡ With the omission of strontites, metallic oxides, glucine, and zircon.

§ Zircon after alumine.

Tables of Specific Gravities.

(From Musschenbroek. Nat. Phil. v. 2d. Edit. 1762. Lugd. Batav. 4to.)

<i>Metalla & Preparata.</i>			
Æs Japon. cusum	9.0000	Antim. cinnabaris	6.044
— fusum	8.7267	— a Gaubio præp. . . .	7.805
— fulvum Hispan. fusum . .	7.9598	— minera	5.810
— idem — cusum	8.43396	Argentum purum fusum . .	11.091
— fulvum (America. Chili)		— ex Lun. Corn.	
fusum	8.64197	reductum	10.5426
— idem — cusum	8.7685	— aliud	10.851
— fulv. ex Barbaria cusum .	7.8520	— Holland. major. va-	
— idem — fusum	8.5945	loris	10.535
— fulv. Anglicum cusum . .	8.8300	— minor. valoris	10.340
— ex Sueciæ monetâ cusa	8.7840	— fusum	10.2538
eadem fusa	8.3333	— idem tusum	10.5000
— nativum de aq. cæ-		Argenti Minera ex Wallia .	7.464
menti Hungariæ }	5.771	Aurum purissimum	19.640
— idem fusum absque ulla }	7.2426	— aliud fusum	19.521
re addita		— fusum	19.238
— idem fusum dein diu cu-		— Nativum de Aur.	
sum	9.0204	Aren. Guinensi	16.500
— fulvum Barbaricum cal-		— in aq. reg. solut. }	
cinatum	5.453	dein præcip. & }	18.948
Ærea moneta Cæsaris Clau-		fusum	
dii	8.313	Aurea Guinea Guliel. 3 . .	18.888
Æris minera	3.755	— Geor. 2	17.150
— viride compactum (Rus-		— Moneta Lusitan. . . .	17.140
cinonia	2.991	— Eques Holland. an.	
— striatum fibris con-		1749	17.528
vergent. . . .	4.107	— Philippæus 1741	17.652
— factitium Hispani-		— Ducat. Holland. Sig-	
ense	1.714	nat. . . .	18.261
— in acet. distil. }		— idem, modo fusus	17.01754
solut. dein }	1.6786	— idem, diu & vehement.	
crystalliz. . . .		cusum	18.588
Aurichalcum Sinense fusum .	8.431	— Ludovicus	18.166
— aliud fusum	8.6388	Bismuthum, modo fusum . .	8.7168
— Stolbergense fusum . . .	8.000	— idem, tusum quant.	
— aliud St. fusum	8.2353	potuit	9.6388
— idem Stol. cusum	8.349	Bismuthum	9.700
— idem ductum in filum . .	8.3258	— aliud	9.850
Tutia	4.615	—	9.866
Antimonium crudum German.	4.000	—	9.9259
— Arvernæ	4.858	Bismuthi minera pig.	
— Hungaricum	4.700	(Smalt.) cœrul. præb. . .	6.221
Antimonii Regulus per se . .	4.500	— Smaltina	2.949
— bis purificatus	6.602	— cobaltum ex vario }	
— ter purif. . . .	6.852	lucens, collum Co-	6.036
— cusum	6.8716	lumbin. dictum	
— idem modo		Chalybs laudatiss. probe	
fusus	6.4021	emollitus	7.7679
Antimonii Regulus Martialis	7.500	— idem diu & valde	
— Veneris	7.500	cusum	7.8955
Antim. Vitr. per se	4.760	— mollis	7.738
— aliud	5.280	— durissimus	7.704
		— elasticissimus	7.809

Tables of Specific Gravities—Continued.

Chalybis sal	1.803	Plumbum mixt. Ang. Scot.	
Ferrum cusum Osemont	7.7633	& Ger. =	11.225
emollitum	7.6000	calx	8.940
id. cusum diu frigide	7.875	cerussa	3.156
laudatis. German.		ustum	1.666
insig. (L.)	7.8076	Lytharg. auri	6.000
German. insig. B. R.	7.7876	argenti	6.044
Leodiense	7.6896	Sac. saturni	2.745
aliud	7.6450	Stannum purum	7.320
ex Suecia	7.7653	aliud	7.3654
nudum tessulatum		Anglic. puriss.	7.295
octohedrum	4.333	purum nigrum	7.3218
cubicum	4.4579	aliud	7.065
vetustate temporis		aliud	7.3167
in magnet. versum	4.0451	aliud	7.471
stibio prægnans	3.825	aliud	7.550
Ens mart. semel sublimat.	1.453	puriss. ex Malacca	7.331
ter do.	1.269	aliud	6.1256
Crocus metallorum	4.500	Indic. Bancas	7.2165
Ferri flos.	5.7143	Rosæ dictum	7.300
Mercurius Tyrol. virgineus	14.000	Malaccæ fusum	7.500
Tyrol.	13.652	idem, diu cusum	7.1181
alius	13.620	Anglic. fusum	7.6388
Britannicus	13.593	idem, diu cusum	7.1951
distil. ex calce a Gau-		Bancas modo fusum	7.6250
bio	13.619	idem, diu cusum	6.7481
semel a Boer-		Zincum Indicum	7.2401
haave	13.570	Goslar	7.215
cum aur. puriss. uni-		aliud	7.350
tus & centenis	13.550	aliud	7.065
vicibus destillatus		modo fusum	9.3548
cum argent. pur. &		idem diu cusum	7.1764
ut supra	13.580	Platina part. 1 Stanni p. 2	8.972
cum plumb. unit. &		Do. 1	4 . 7.794
resuscit.	13.550	do.	8 . 7.705
511 vicibus destill.	14.110	do.	12 . 7.613
sublim. corros.	8.000	do.	24 . 7.471
dulcis, bis sublim.	12.353	do. Plumbi 1	14.029
ter sublim.	9.882	do.	2 . 12.925
4ter sublim.	8.235	do.	4 . 12.404
turp. minerale	8.325	do.	8 . 11.947
Æthiops mineralis	2.227	do.	12 . 11.774
Cinnabaris nativus	2.2337	do.	24 . 11.575
Tyrol	7.300	do. Argent 1	13.535
Japon	7.273	do.	2 . 12.452
alia	7.000	do.	3 . 11.790
ex Guinea	6.280	do.	7 . 10.867
Almadiensis	6.188	do. Æris fulvi 1	11.400
factitia	8.002	do.	2 . 10.410
alia	7.8711	do. Æris 4	9.908
alia	7.8385	do.	5 . 9.693
Plumbum Indicum	11.2259	do.	8 . 9.300
Anglic. puriss.	11.4459	do.	12 . 9.251
ex Hull	11.424	do.	25 . 8.970
aliud	11.4794	do. Ferri 4	9.917
aliud	11.345	do.	12 . 8.700
Scotic. puriss.	11.38759	do.	16 . 8.202
aliud	11.4166	do.	7 . 7.800
German. puris.	11.4451		

Tables of Specific Gravities—Continued.

Plat. cum omn. heterog.	
arena alb. grana-	6.533
tis, pulv. nigro.	
— cum partib. quibusd.	
heterog.	16.995
— sine part. nigr. quæ	
a Magnet. trah. . .	4.128
— part. nig. quæ trah.	
a Magnate	5.555
— part. quæd. gravis-	
simæ electæ . . .	27.500*
— Regulus	15.52666

Lapides.

Achates pale red, variegated	2.631
— alius	2.628
— alius	2.5714
— amber coloured . .	2.592
— whitish, with flesh	3.058
coloured spots	
Dutchy of Bipont	
— British	2.512
Adamas (Diamond) Indian,	
white	3.517
— alius alb.	3.375
— alius	3.4666
— al. alb.	3.4736
— al. alb.	3.525
— E. Indian, rough	
octohedron	3.6545
— Brazil	3.518
— alius	3.521
— alius	3.511
— alius	3.501
— pallid. cærul. ex Ind.	
orient.	3.512
— profunde cærul. . .	3.495
— flavus	3.524
— alius	3.666
— profunde viridis . .	3.521
Alabastrum (sulp. of lime)	1.872
Alumen, plumose . . .	2.275
— do. officinarum . . .	2.625
— schist. nigri. friab. nativ.	2.064
Amianthus, ex Wallia . .	2.913
— fibris angulos.	
rigid. (Fahlun)	2.855
— Italicus	2.360
— fibris rigid. pur-	
purascensib.	2.428
— viridescens flexi-	
bil. fibris.	2.444
— fibris niveis	3.025
Ardosius cæruleus . . .	3.500
Arsenicum rub. sive, Sandar.	
Græc.	3.223
— flav. Auripig. nativ.	3.313
— factitium	3.694

Arsenici Regulus	8.308
Atramentarius lapis violac.	3.104
Mt. Rammelio	
— fulvus do.	2.140
Auripigmentum	3.521
Basaltes minimus striatus	2.683
Beryllus (aq. marine) ex	
Eibenstock	3.056
Bolus armena	2.727
Bononiensis lapis	4.996
Bristollensis lapis 2 510 alius	2.640
Burfordensis lapis . . .	2.049
Cæruleus lapis ex quo pavi-	
menta	2.740
Cadmia ex Issy	3.108
Calaminaris, Stolbergensis	5.000
— Hungaria	4.409
— Silesia	2.560
— ex antro Schartz-	
feldensi	2.268
Calcedony, Siberia	2.559
— Suecicus	3.978
— Bruxelles	2.613
— Oriental, sub-	2.569
pellucid blue-	
ish white	
— Bohemian	4.360
Calx usta ex lapide . . .	2.370
Carneolus	3.290
Chrysolithus	3.360
Corallachates	2.605
Cornelius	2.568
Cos Bremensis	1.666
— Turcicus	2.380
— alius	2.388
— alius	2.960
— particulis impalpab. cine-	
reis compact	2.745
— friabilibus Penn-	
sylvania	2.561
— flavus Lotharingia . . .	3.288
Creta alb. Anglic.	2.252
Crystallus rupium vulgaris	2.650
— alia 2.659	2.669
— acuminetetrahedro	3.169
— cubica	3.100
— ex Devonian	2.724
— Hibernia	2.688
— Helvetia	2.663
— Pennsylvania	2.645
— Islandica	2.720
Galena sterilis ex Scotia, dict.	
Potlood	7.5682
— ex Germania do. . . .	7.4661
Gallypot	1.928
Glacies Maria ex Muscovia	2.286
Goa, Lapis de	1.710
Grammatias	2.515
Granatus Bohemicus . . .	4.360

* This is undoubtedly a mistake—for 17.500. C.

[10] Erratum—in last page, xl., last line, for 7 under 16, read p. 35.

Tables of Specific Gravities—Continued.

Granatus Suecicus . . .	3.978	Onyx . . .	2.510
Granati Minera . . .	3.100	— aliud, semidiaph. E. Ind.	2.615
Hæmatites . . .	4.360	Opalus, ex Eibenstock 1.958	2.075
— ex Minorca . . .	2.806	Ophites nigricans punct. alb.	
Hibernicus lapis . . .	2.490	Misnia . . .	2.888
Hyacinthus 2.631 aliud	3.637	— virens, venis citrinis	
Jaspis . . .	2.666	& alb. Sahlberg	2.547
— totus pallide viridis.		Osteocolla . . .	2.240
German. . .	2.776	Plumbago, vulgaris . . .	1.860
— purpur. gran. albid.		— ex Pennsylv. . .	2.553
Helvet. . .	2.766	Porcellanum, purius Sinense	2.363
— rudis Pennsylvan. . .	2.576	— aliud . . .	2.324
— flav. opac. Freyenberg	2.666	— rudius Sinense	2.346
— rub. ex agro Bruxellen	2.703	Portlandicus Lapis . . .	2.570
— viridis Sibericus . . .	2.586	Pseudo Hyacinthus . . .	2.631
— in Russia oriund. . .	2.623	— Jaspis . . .	2.666
Iris . . .	2.130	— Topazius . . .	2.672
Judaicus (2.690) aliud . .	2.500	— aliud . . .	4.270
Lazuli . . .	3.054	Pyrites arosus aureo	
Lebetum . . .	2.782	virescens, ochra	
Lithanthrax (1.238) aliud .	1.240	metal. consper-	4.027
Lydius, seu Marmor nigrum	2.688	sus, Hohensolms	
Magnes Pennsylvanæ . . .	4.585	— cupri saturatis.	
— Hungariæ . . .	5.106	ochra sua viridi	3.988
Magnesia . . .	3.530	maculatus	
— Ilfeldensis . . .	4.325	— ex Cornuallia . . .	4.158
— Pennsylv. . .	3.240	— fulvo fuscus	
Malachites . . .	2.507	Mt. Andrea	7.514
— Sibericus . . .	3.994	Goslar	
— do. virore vario		— Fahlun . . .	3.800
undul. . .	3.348	— micaceus flavus . . .	3.719
Manatus, ex Jamaica . . .	2.270	— ferri flavus cubicus	4.912
— aliud . . .	2.330	— cubicus nitidiss.	
Marmor Ital. album . . .	2.707	Cornwall . . .	4.789
— aliud 2.700 . . .	2.718	— incarnatus	
— aliud . . .	2.765	cubicus . . .	3.678
— nigrum . . .	2.683	Quartzum puriss. varior.	
— aliud . . .	2.704	Germaniæ	2.763
Marga Marlyensis . . .	2.428	et Pennsylv.	
Mica partic. squam. auri		— aquei color.	
colorib. . .	2.564	pelluc. ochra	2.630
— aliud . . .	2.631	ferri tinct.	
— Argentea partic. dis-		Pennsylv.	
tinct. . .	2.192	— opacum alb. . .	2.486
— partic. squammos. &		— niveum pellucid.	2.664
membran. mistis	4.383	— purpureum,	
— ex freto Davisi	2.644	psuedo ame-	2.520
— membran. nigris	3.000	thyst. Bohe-	
Namurcensis cæruleus . . .	5.000	mia	
Nephriticus . . .	2.894	Rag . . .	2.470
Nitrum. album ex Pennsylv.	2.680	Rottenstein . . .	1.980
— Curassi-		Sapphirus . . .	4.090
vicum	2.681	— aliud, pallide cæ-	
Oculus catti . . .	3.703	ruleus . . .	3.855
Ollaris, Lapis fibris acerosis		— pallidi coloris . . .	4.668
friabilibus in-	3.163	— orientalis . . .	3.562
carnatus		Sardachates . . .	3.598
— ex fodina ferri Lan-	2.618	Sardonyx red passing to the	
gron Cumbria		Onyx, England . . .	2.625

Tables of Specific Gravities—Continued.

Scissilis cæruleus	3.500	Turcois, 2.508 alia	2.908
Schistus cinereus fragilis, seu		Turmaline, cryst. nigr. sa-	
Ardesia alb.	2.331	turo flammæ colore }	2.952
ruber fragilis, Fahlun	2.526	ex Ind. orient.	
niger friabilis	2.238	aliud, ex obs. Epini	3.000
Selenites 2.322— aliis	2.252	aliud, ex Gazophy-	
Osnabrugensis	2.637	lacio Gaubii	3.2941
Silex vulgaris	2.542	aliud, minus saturi	
pellucidus	2.641	coloris	3.2222
Britannicus	2.696	aliud, saturo flam-	
Brazil	2.591	meum	3.0074
alius	2.676	Vitrum puriss. alb. Britan.	3.150
alius	2.755	aliud	3.380
subcinereus		ex quo specula	2.888
(Ceylon)	4.8304	Venetum alb. ex quo	
Ceylon fla-		pocula	1.791
vescens }	2.655	viride, ex quo recipien-	
pond. 12lbs. }		tia Chemica	2.620
ex Corn-		Lagenæ	2.666
wallia	2.658	cærul. pellucid.	3.102
Egyptius	2.578	aliud	3.885
Pyromachus	2.603	Ex sequent. vitris monilia }	
Siliquastrum alb. color. Angl.	2.838	feminarum }	
Slate, Hibernicus	2.490	facta, vulgo }	
Smaragdus octohed. part }		Kraalen	
green and di-		cærul. opacum	2.479
aphanous; the }	3.095	album opacum	2.578
other opaque, }		pellucid.	2.440
ash col. Peru }		viride pellucid.	2.000
vulgaris	2.777	flavum pellucid.	2.525
orientalis pellu-		sanguineum pel-	
cidissim.	2.700	lucid.	2.567
Smiris solida	4.000	Arena alba vulgaris	2.681
alia	2.766	nigra magnetica	4.600
ex Insul. Naxos	3.067	Argilla Hollandica humid.	1.821
Normannia	3.038	Lateres durissimi ex hac	
Steatites subdiaphanus cor- }		Argilla	2.006
nuus cærulescens }	2.758		
Stellatus Lapis	3.450	VEGETABILIA.	
Spatum, various, but uncer-		Ligna.	
tain of their exact			
nature, but probably		Abies, mas 0.550 femina	0.498
fluor spars chiefly;		Acer	0.755
the sp. grav. varying		Agadiadata	1.2617
from 6.640 to	2.519	Alnus	0.800
Talcum Britannicum	2.600	Aloes American. maj. trunc.	
Jamaica	3.000	siccus	0.358
Siberia	2.295	alia pars interior	0.15865
Venetum	2.780	Aloe, sive Calambac	1.177
friabile, molliusculum		Amboinense	0.691
alb. opacum	2.680	Arbutus Hispan.	0.866
Terra fertilis hortorum	1.630	Aurant. malus	0.705
Lemnia	2.000	Axi sive Capsicum	0.861
Savonensis	2.094	Berberissa	0.8562
Siringum Rothomagi	3.088	Bolletree	0.9666
Topazus	2.653	alia	0.8204
alius, pallide flave-		Brazilium rubrum	1.031
scens	3.618	Buxus ex Turcico imperio	0.919
Tophus, sive Tiras	1.410	Gallia	0.912

Tables of Specific Gravities—Continued.

Buxus ex Holland	1.328	Nux Americana	0.643
Campechiæ	0.913	Olea	0.927
Camphora Sumat.	0.8446	Oxycantha	0.7575
Caliatour	1.0256	Pariera brava	0.800
Caro equina	0.943	Paradiso Hispanis, an Oleas-	
— Sorrinamia	1.000	trum	0.7555
Cayaten	0.690	Picea	0.300
Cedrus Indica	1.315	Pomus	0.793
— Sylvestris	0.596	Populus	0.383
— ex Palestina	0.613	— alb. Hispaniensis	0.5294
Cerasus	0.715	Provenc purpureum	1.358
Citrus Hispaniensis	0.7263	Prunus	0.785
Cinnamomi ramus	0.5934	— alia	0.663
Cocos lignum	1.0403	Purpureum sive Canotepi	0.857
Coco putamen	1.340	— aliud	0.97308
Colopesium	1.116	Pyrus	0.661
Colubrinum ex Ind. Hispan.	0.7634	Quercus, medulla (60 years)	1.170
— Britan.	0.7169	— Alburnum	1.078
Corallinum	0.6277	— alter. Medulla	1.208
Corylus	0.600	— Alburnum	1.108
Cupressus Hispanica	0.644	— alius Quer. Medul.	1.116
Cydonia vulgaris Hispan.	0.705	— inter Medul. & Albur.	1.076
Ebenum Indicum	1.209	— Medulla, 100 years	1.169
— Mauriti	1.193	— Alburnum of	1.126
— American.	1.331	— inter Medul. & Albur.	1.166
— aliud, sive Cytisus		— Medul. 110 years	1.110
Alpinus	1.146	— Alburnum of	1.096
Fagus	0.852	— inter Med. & Albur.	1.135
Fernambucum	1.014	— Turcica, Azyn dicta	0.938
Fiset.	0.7777	Regium	1.042
Fraxinus in ramo	0.734	Rosmarinum	0.7284
— in stipite	0.845	Rhodium	1.132
— sicca	0.800	Sakkerdane	0.981
Gleditsia	0.8863	Salamandriæ	0.801
Granadilla	1.354	Salmony	0.851
Granatus Hispaniensis	0.822	Salix	0.585
Guajacum	1.333	Sambucus	0.695
Guajaci Cortex	1.250	Sanderen	1.222
Jasminus Hispaniensis	0.770	Santalum album	1.041
Juniperinum	0.556	— citrinum	0.809
Laurus latifol. Belgic.	0.524	— rubrum	1.128
— Hispan.	0.822	Sapan	0.928
Lentiscus	0.849	Sassafras	0.482
Limones Hispaniensis	0.7033	Siamense rubrum	1.12674
Locust dictum	1.0714	Suber	0.240
Litteræ, sive variegatum		Suikerkisten	0.644
Virginicæ	1.192	Syringa	1.0989
— aliud 1.300—aliud	1.313	Tamariscus alba	0.898
Mahogany	1.063	— rubra	1.175
Divi Martini	0.9857	— alia	1.017
Mastichinum	0.849	Taxus Hispanica	0.807
— aliud	0.9091	— Hollandica	0.788
Mespilus Belgica	0.944	Thuya	0.5608
Metrosideros	1.023	Tilia	0.604
Morus Belgica	0.749	Ulmus ex stipite	0.671
— Hispaniensis	0.897	— ramo	0.600
Nephriticum	1.200	Vitæ	1.327
Nux Hollandica	0.636	Radix Chinæ	1.071
— Gallica	0.671	— Gentianæ	0.800

Tables of Specific Gravities—Continued.

Radix, Rub. Tinctor.	0.765
— Hypecacoannæ	1.14432
Cortex peruvian.	0.784
— winteran.	0.9268
— cinnamomi	0.689
— cascarillæ	1.18181
Galla	1.034
Avena	0.472
Hordeum	0.658
Pisa alba sicca	0.807
— cærulea	0.795
Triticum	0.757
— farina cum fur-	
furibus	0.495
— sine furfure	0.454
Cinis Ligni	0.930
Caryophylli Aromatici	0.998
Nux Moschata	1.083
Piper nigrum	0.996
— album	1.250

Resinæ & Gummi.

Aloe Succot.	1.358	Resina, Scammonii	1.200
Ammoniacum	1.238	Sagapenum	1.212
Animæ	1.091	Sandaracha	1.052
Arabicum (aliud 1.430)	1.375	Sanguis Draconis	1.280
Asafœtida	1.251	Scammonium	1.432
Bdellium	1.476	Thus	1.071
Benzoin	1.241	Tragacantha	1.333
Camphora	0.996		
Caranna	1.146		
— alba	1.065		
Catechu	1.200		
Carriman (pice species)	0.767		
Cerabouly	1.0333		
Copal	1.073		
Cowenaly	1.04334		
Elemni	1.041		
Galbanum	1.060		
Guttur	1.175		
Hederæ	0.946		
Hypocistis	1.243		
Hayawa alba	0.8711		
— nigra	0.91139		
Lacca	1.154		
Ladanum	2.209		
Mastiche	1.081		
— aliud	1.04166		
Myrrha	1.250		
Opium	1.363		
— aliud	1.360		
Opobalsamum	1.231		
Opoponax	1.480		
Ostescolla	2.240		
Pix	1.5714		
— Burgund.	1.150		
Resina, Guajaci	1.224		
— Jalapii	1.400		

Bitumina & Salia.

Asphaltum	1.400
Bitumen solid. puris. Gagas	
dictum	1.203
— aliud	1.238
— solidum nigrum	1.744
Succinum pellucidum	1.065
— ex Helvetia	1.08014
— aliud pingue	1.087
— citrinum	1.110
Sulphur minerale	1.875
— pellucid. Persicum	1.950
— nativ. pellucid. rub.	
Transylv.	2.871
— Ægæi maris	2.018
— Guadaloupe	2.077
— Quito	2.908
— vivum	2.000
— flores	0.9438
Alumen	1.714
— aliud	1.738
Borax	1.720
— alius	1.714
Cineres Clavellati	3.112
Magisterium Corallii	2.230
Nitrum	1.900
— purum	1.9299
— fixum	2.745
— regeneratum	1.8744
— cubicum	1.8694
Sal ammon. purum	1.453
— purissimum	1.4202
— fixum	1.6126
— Chalybis	1.733
— vol. Corn. Cerv.	1.496
— Enixum	2.148
— febrifug. Sylvii	1.1365
— Gemmæ	2.143
— Marinum	2.125
— depuratum	1.9183
— Mirab. Glaub.	2.246
— aliud	1.4063
— Guajaci	2.148
— polychrest	2.141
— aliud	2.5602
— Prunella	2.148
— Sedativ. Hombergii	1.4797
— Volat. siccum ex 2	
ungulis equi. 5	1.5093
— Vitrioli	1.900

Tables of Specific Gravities—Continued.

Sacch. Saturni	2.3953	Cor hominis ejusdem	1.01777
— albissimum	1.606	Tendo musculi homin. ejusd.	1.12621
Tartarus Crudus	1.849	Nervus, idem	1.125
— Cremor	1.900	Bezoar, occident.	1.500
— Emetic	2.246	— oriental	1.530
— Vitriolat	2.298	— alius	1.640
— alius	2.5904	— genuinus	1.6282
Vitriolum Britannic.	1.880	Calculus vesicæ human.	1.700
— album	1.900	— alius	3.664
— Dantzic	1.715	— ex renibus hominis	3.600
— Rubefact	1.900	— vesica fellis	1.220
— in Lapide	4.300	— alius ex ves. fel. }	
<i>Animalium partes.</i>		— Homin. recens, 50 years }	1.1346
Adipes, purified—viz.		— ex Lactibus Aselli	
Adeps, ex mustela putorio	0.9401	— majoris	1.1633
— Equina	0.9748	Corallia rubra	2.689
— bovina circa Renes	0.929	— alba	2.500
— bovina	0.955	Cornu Ariet. recens	1.24916
— ovilla circa Renes	0.9432	— Bovis	1.689
— ovilla	0.950	— Cervi	1.875
— suilla circa Renes	0.947	— Hædi recens	1.274
— sive lardum	0.954	— Rhinocerotis	1.242
— vitulina circa Renes	0.944	Lapis ex capite Bascia	
— humana frigens		(piscis Guineæ)	2.830
— gradu 31	0.9611	— Cobra di Capello uni-	
Aorta hominis, 50 annor	1.0714	— color.	1.90816
Musculus bovinus	1.075	— bicolor.	1.8148
— vitulinus	1.070	Unicornu	1.910
— ovillus	1.051	Pedro del porco Malaccensis	0.6208
— cuniculi	1.069	Tentacula Echini marini	1.041
— Perdricis	1.0575	Margarita orientalis	2.750
— Suis	1.060	Margaritifera Concha	2.480
— Hominis 50 an.	1.0559	Cochleæ Concha	2.520
Cerebrum Hominis adulti	1.0310	Muricis Concha	2.590
Cutis Suis	1.090	Ostreæ Concha	2.892
— Hominis 50 annor.	1.00846	Pectunculi testa alb. ex lit-	
Cartilago ex Sterno hom.		— tore Holland.	2.857
— 50 an.	1.13636	— cærulea	2.826
Dens Hippopotami	2.040	— nigra	2.888
— Rosmari (Walrus)	1.933	— fusca	2.888
— Balæna (Cajelot)	2.0444	— ex alb. et	
— Ebur	1.825	— cærul. varieg.	2.771
— molaris Elephanti	2.22137	Ovum Gallinaceum	1.090
Lien hominis 50 annor.	1.060	Mel vulgare	1.450
Ren bovis	1.059	— aliud	1.500
— vituli	1.053	Cera flav. ex Muscovia	0.965
— ovis	1.0526	— Dania	0.952
— cuniculi	1.109	— Frisia	0.965
Hepar bovis	1.0744	— Holland	0.960
— vituli	1.1029	— alba, puriss. ex Holland	0.9663
— ovis	1.0937	— mixt. ex Muscov.	
— cuniculi	1.080	— et Hol.	0.9648
— Gallinæ	1.077	— ex mari Baltic	0.8204
— Hominis 50 years	1.05263	— mixt. cum adipe	
Ventriculus Gallinæ	1.070	— ovilla	0.9506
Pancreas hominis 50 years	1.10294	— viridis ex Myrto Brabant.	1.0088
		Oculi Cancror. veri	1.890

Tables of Specific Gravities—Continued.

Oculi Cancror. spurii . . .	2.480
Ossa ovis recentia . . .	2.222
— bovis sicca . . .	1.656
— petrefacta . . .	1.895
Phosphorus urinæ Anglicus	1.7143
Sed mult. differt. ☞	

Fluida.

Aër. prope solum, ab. 0.001 $\frac{2}{3}$	
ad. 0.001 $\frac{1}{4}$	
Aqua pluvia . . .	1.000
— distillata . . .	0.997
— — alia . . .	0.993
— marina . . .	1.030
— — alia . . .	1.0211
— putealis . . .	0.999
— fluviatilis . . .	1.009
— Fortis vulgaris . . .	1.300
— — optima . . .	1.409
— Regia . . .	1.234
— Spadana . . .	1.000
Acetum Cerevisiæ . . .	1.034
— vini . . .	1.011
— — distillatum . . .	1.030
Ammoniaci Gum. Tinct. . .	0.899
Antimonii Butyrum . . .	2.470
— Tinctura . . .	0.866
Bals. Tolu . . .	0.896
Benzoini Tinctura . . .	0.9005
Bilis Bovina . . .	1.0246
— vitulina . . .	1.0072
— ovilla . . .	1.0072
— humana . . .	
Cortic. peruv. Tinct. . .	0.900
Lac Asininum . . .	1.021
— Bubulum . . .	1.030
— Caprinum . . .	1.009
— Humanum . . .	
Lactis Bovini Serum . . .	1.016
Laudanum liquid. (Sydenham)	1.024
Lixivium Tartar. . .	1.550
— Cineris Clavellati . . .	1.5713
— aliud . . .	1.5634
Salis marin. solut. saturat. in aq.	1.244
Urina humana . . .	1.016
— — alia . . .	1.030
Urinæ Spiritus . . .	1.100
— recent. Spirit. rectific. . .	1.102
— putrefact. Spiritus . . .	1.018
Oleum, Ambra . . .	0.978
— Amygd. dulc. . .	0.928
— Anethi . . .	0.994
— Aurantiorum . . .	0.888
— Athanasia . . .	0.946
— Carui . . .	0.940
— Campechia . . .	0.931
— Caryophyllor. . .	1.034
— Cera . . .	0.831

Oleum, Cinnamomi . . .	1.035
— Citri stillatitum . . .	0.842
— Cumini . . .	0.975
— Feniculi . . .	0.997
— Gagati nigri . . .	1.000
— Hyssopi . . .	0.986
— Juniperi . . .	0.911
— Kennekemalo . . .	0.9458
— Lini . . .	0.932
— Mentha . . .	0.975
— Nucis express. . .	0.934
— — Moschat. . .	0.948
— — aliud . . .	0.958
— Olivarum . . .	0.913
— Origani . . .	0.940
— Petrolii vel naphtha . . .	0.708
— Pulegii . . .	0.978
— Quercus . . .	0.929
— Raparum . . .	0.853
— Rorismarini . . .	0.934
— Rutæ . . .	0.975
— Sassafras . . .	1.094
— Sabinæ . . .	0.986
— Spicæ . . .	0.936
— Succini . . .	0.978
— Tanaceti . . .	0.946
— Tart. per deliq. . .	1.550
— Terebinthinæ . . .	0.792
— Vitrioli vulgar. . .	1.700
— — concentrat. . .	1.827
— — aliud . . .	1.877
Sanguis humanus . . .	1.040
— alius spissior . . .	1.056
— — venosus . . .	1.0623
— a quo secessit serum . . .	1.084
Sanguinis human. serum . . .	1.027
— — aliud . . .	1.030
— — cuticula . . .	
— — alba . . .	1.056
— — porcinus . . .	1.057
— — hujus serum . . .	1.035
— — agninus . . .	1.060
— — hujus serum . . .	1.019
— — caninus arteriosus . . .	1.082
— — venosus . . .	1.062
— — vaccinus . . .	1.058
— — hujus serum . . .	1.042
Spiritus Ambra . . .	1.031
— anisi . . .	0.9938
— oryza (arrack) . . .	0.9405
— cortic. citri . . .	0.870
— cornu cervi . . .	1.073
— — a Gau- . . .	
— — bio pp. . .	1.0634
— Frumenti præcurrens . . .	0.9527
— ditto . . .	0.9855
— Mellis . . .	0.895
— Juniperi . . .	0.9856
— Nitri communis . . .	1.315

Tables of Specific Gravities—Continued.

Spiritus Nitri alius . . .	1.410	Spiritus, Ros Solis dictus . . .	1.0087
— alius . . .	1.458	— Vini rectific. . .	0.866
— rectific. cum		— Gallic. vulgar. . .	0.9874
Nit. sic. . .	1.475	— Alcohol . . .	0.815
— Hermeticus . . .	1.610	— Æthereus . . .	0.732
— cum oleo		— Vitrioli . . .	1.203
Vitrioli a	1.495	Tr. Antimonii . . .	0.866
Gaubio par-		— Chalybis Minsyht. . .	0.853
ratus		— Chinæ . . .	0.900
— rectific. . .	1.583	— Gum. Ammoniac . . .	0.899
— dulcis . . .	1.000	Vinum alb. Gallic. vulgare . . .	1.020
— Bezoardic. . .	1.315	— moschar-	
— Salis ammon. cum		dinum . . .	1.000
cinere	1.120	— Frontignanum . . .	1.0086
clavel.		— Burgundicum . . .	0.953
— calce . . .	0.952	— Aurelianense . . .	0.996
— alius . . .	0.890	— Campienum . . .	0.962
— Marini cum bolo . . .	1.202	— rubrum Laurentii . . .	1.00513
— alius . . .	1.130	— Pontacq. . .	0.993
— alius . . .	1.037	— Hispan. Tintilla di	
— dulcis . . .	0.951	Rota . . .	1.0303
— alius . . .	0.890	— ex Malaga . . .	1.0159
— cum Ol. Vitriol. . .	1.146	— ex Xerez . . .	0.998
— alius . . .	1.154	— Canariense . . .	1.033
— Ol. V. bis		— Hispan. Malvasinum . . .	1.008
rectific. . .	1.118	— Mosellanum . . .	0.916
— Serici . . .	1.145	— aliud . . .	0.902
— Succini . . .	1.030	— Rhenanum . . .	0.9995
— Sulphuris . . .	1.019	— rubrum, Cape of	
— Terebinthinæ . . .	0.874	Good Hope . . .	1.018
— Tartari . . .	1.073	— album do. do. . .	1.039

☞ Specific gravity varies in bodies, both solid and fluid, in winter and summer: for all bodies are rarefied by the summer's heat, and condensed by the cold of winter. Nor is this change equal, but of great difference. Fluids expand more by the same heat than solids—and those, most so, that imbibe heat and retain it best, &c.

This is proved by the experiments of Homberg and Eisenschmidius—in which the weight of the substance, = to a Paris cubic inch, was employed; but the degree of Heat and Cold is not stated.

ÆSTATE	3	3	grs.	HYEME	3	3	grs.
Mercurius	7	1	66	—	7	2	14
Ol. Vitriol	0	7	59	—	0	7	71
Sp. Vitriol	0	5	33	—	0	5	38
— Nitri	0	6	24	—	0	6	44
— Salis	0	5	49	—	0	5	55
Aqua fortis	0	6	23	—	0	6	35
Acetum	0	5	15	—	0	5	21
— distillat.	0	5	11	—	0	5	15
Sp. vini	0	4	32	—	0	4	42
Lac Bubulum	0	5	20	—	0	5	25
Aq. fluviatilis	0	5	10	—	0	5	13
— putealis	0	5	11	—	0	5	14
— distillata	0	5	8	—	0	5	11

*Specific Gravities of the Elastic Fluids, that of air being taken as unity.**

<i>Names of The Elastic Fluids.</i>	<i>Densities determ'd. by experiment.</i>	<i>Densities by calculation.</i>	<i>Names of the Observers.</i>
Air	1.0000		
Vapour of iode . .		8.6195	Gay Lussac, Ann. de Chim. v. xci. p. 17.
Vap. of hydriodic ether	5.4749		Gay Lussac.
Vap. of essence of tur- pentine	5.0130		Gay Lussac.
Hydriodic gas . . .	4.4430	4.4288	Gay Lussac, Ann. de Chim. v. xci. p. 16 & 17.
Fluo-silicic gas . . .	3.5735 (1)		J. Davy, Phil. Trans. 1812, p. 354.
Chloroxycarbonic gas		3.3894 (2)	J. Davy, Phil. Trans. 1812, p. 150.
Nitrous acid gas . .		3.1764 (3)	Gay Lussac.
Vapour of sulphuret of carbon	2.6447		Gay Lussac.
Vap. of sulphuric ether	2.5860		Gay Lussac.
Chlorine	2.4700	2.4216 (4)	Gay Lussac and Thenard.
Euchlorine		2.3144 (5)	Gay Lussac.
Fluoboric gas	2.3709		J. Davy, Phil. Trans. 1812, p. 366.
Vap. of hydrochloric ether	2.219		Thenard, Soc. d'Arc. v. i. p. 121.
Sulphurous acid gas	2.1930	2.2072	Davy, Bibli. Brit. v. lv. p. 114.
Chlorocyanic vapour		2.1113	Gay Lussac, Ann. de Chim. v. xcv. p. 210.
Cyanogen	1.8064	1.8011	Gay Lussac, Ann. de Chim. v. xcv. p. 177.
Vap. of absolute alcohol	1.6133	1.6030 (6)	Gay Lussac.
Protoxide of azote . .	1.5204	1.5209 (7)	Colin.
Carbonic acid	1.5196		Biot & Arago, Mem. de l'Inst. 1816, p. 320.
Hydrochloric gas . .	1.2474	1.2505 (8)	Biot & Arago, Mem. de l'Inst. 1806, p. 320.
Hydrosulphuric gas .	1.1912	1.1768 (9)	Thenard & Gay Lussac, Reserch. Physico-Chim. 1. p. 191.
Oxygen gas	1.1036		Biot & Arago, Mem. de l'Inst. 1806, p. 320.
Deutoxide of azote . .	1.0388	1.0364 (10)	Berard.
Percarbureted hydro- gen gas	0.9784 (11)		Theodore de Saussure, Ann. de Chim. v. lxxxix. p. 283.
Azotic gas	0.9691		Arago & Biot, Mem. de l'Inst. 1806, p. 320.
Gaseous oxide of car- bone	0.9569	0.9678	Cruikshanks.
Hydrocyanic vapour	0.9476	0.9360	Gay Lussac, Ann. de Chim. vol. xcv. p. 150.
Phosphureted hydro- gen	0.870		Davy, Phil. Trans. 1812, p. 408.
Vap. of water (steam)	0.6235	0.6250 (12)	Gay Lussac.
Ammoniacal gas . . .	0.5967	0.5943	Biot & Arago, Mem. de l'Inst. 1806, p. 320.
Protocarbureted hy- drogen gas	0.5550	0.5624 (13)	Thomson, Bibli. Brit. v. lv. p. 123.
Arseniated hydrog. gas	0.5290		Tromsdorf.
Hydrogen gas	0.0732		Arago & Biot, Mem. de l'Inst. 1806, p. 320.

* Extracted from the Annals of Chem. 1816, vol. 1, p. 218, by Gay Lussac.

Observations.

(1) Mr. Thomson (Bibl. Brit. vol. 55. p. 114) gives a different result, to wit, 2.990; but Mr. John Davy, having ascertained that an empty vase acquired an augmentation of weight of 10.2 grs. when filled with air, and an augmentation of grs. 36.45 when filled with fluo-silicic gas, finds that $\frac{36.45}{10.2} = 3.5735$.

(2) The chloroxycarbonic gas is formed of a combination of one volume of chlorine, 2.4216, and one volume of the gaseous oxid of carbon 0.9678 condensed into one.

(3) The density of the nitrous acid that is given in the table, is taken from the observation that I have made, that this acid is formed of two volumes of the deutoxide of azote and one volume of oxygen condensed into one. There exists another nitrous acid composed of 4 volumes of the deutoxide of azote and 1 volume of oxygen; but it has never been obtained pure.

(4) M. Thenard and myself had found (Rech. Phys. Chem. vol. 2, p. 125), that chlorine weighs 2.470. Mr. Thomson has found it 2.713 (Bibl. Brit. vol. 45, p. 118); nevertheless, I think that these results are too large. Mr. Davy has found it only 2.395; and as it is, moreover, very certain that one volume of chlorine and one volume of hydrogen make exactly 2 volumes of hydrochloric gas; one can obtain the density of the chlorine by subtracting the half of the density of the hydrogen 0.0366 from that of the hydrochloric gas 1.2474, and then doubling the difference: thus we shall have 2.4216 for the density of the chlorine, and I believe it very exact; because we know with much precision the density of the hydrogen gas, and that of the hydrochloric gas.

(5) What we are to understand here, by Euchlorine, is a gas composed of 2 volumes of oxygen and one volume of chlorine, reduced to 2 by combination. This gas is obtained by decomposing the chlorate of potash, by strongly concentrated sulphuric acid. Mr. Davy says, that by decomposing it over mercury, he had obtained for two volumes of the gas, nearly two volumes of oxygen and one of chlorine. I have made the analysis by a particular process, exempt from every source of error, and have found that it contains, exactly, two volumes of oxygen, and one of chlorine condensed one third. It is from these results that the density is found 2.3144. The first compound that Mr. Davy has described under the name of *euchlorine*, appeared to be, according to him, a mixture of this latter gas and chlorine.

(6) The vapour of absolute alcohol may be considered as composed of one volume of olefiant gas, and one volume of the vapour of water, condensed into one. It is from this consideration that we find for the density of the vapour of alcohol 1.6030.

(7) The density of the protoxide of azote has been taken by M. Colin in the laboratory of the Polytechnic school. It is a long time since I have fixed it by calculation at 1.5209, because I knew that the protoxide of azote is formed of one volume of azote and half a

volume of oxygen, condensed into one, (*Société d'Arcueil*, vol. 2. p. 252).

(8) The calculated density that I give here, for hydrochloric gas, is obtained, by admitting that one volume of chlorine and one volume of hydrogen produce two volumes of the hydrochloric gas, and that the proportional number of chlorine is 44, and that of hydrogen 1.3265.

By calling D the density of the hydrochloric gas, and by taking 0.0732 for the density of the hydrogen, we have $2 D = 0.0732 : 0.0732 :: 44 : 1.3265$, and D is found equal to 1.2505.

(9) The calculated density of hydro-sulphuric gas has been obtained, by admitting, that hydrogen, in combining with sulphur, makes no change of volume, and that the proportion of these two substances in weight is that of 20 to 1.3265.

(10) The calculated density of deutoxide of azote is obtained from the consideration, that one volume of azote and one volume of oxygen, make two volumes of the deutoxide of azote.

(11) Mr. Henry had found that the density of olefiant gas is 0.967 (*Bibl. Brit.* vol. 41, p. 324) : but M. Saussure, from the consideration that this gas contains twice its volume of hydrogen, and that it produces by its combination with oxygen two volumes of carbonic acid gas, fixes it at 0.9784; which differs but little from the result of experiment.

(12) The calculated density is obtained from the consideration that two volumes of hydrogen and one volume of oxygen, yield two volumes of the vapour of water.

(13) The calculated density has been obtained from the consideration that proto-carburetted hydrogen gas contains two volumes of hydrogen, and that it gives one volume of carbonic gas in combining with oxygen.

There is found in the 45th vol. of the *Bibliotheca Britannica*, p. 114, a table of the densities of the gases, made by Mr. Thomson.

We dispense with the report here, because there are a great number of the densities that are not exact; such are those of the fluo-silicic acid gas, of nitrous acid gas, of Euchlorine, of the vapour of ether, of the vapour of alcohol, of the protoxide of azote, and of the vapour of water. Many others are taken from the same sources with our own, and we have availed ourselves of those which to us appeared to merit the most confidence. G. L.

DESCRIPTION OF THE PLATES.

PLATE I.

FIG. 1. (*a*) *A plain retort*, the neck of which is shown introduced a proper length into the mouth of a plain receiver *b*. The dotted lines at *c* show the receiver with the addition of a tubulure, into which either a stopper, or bent glass tube, may be occasionally fixed.

FIG. 2. *A glass alembic*; *a* the body, and *b* the head, which are ground so as to fit accurately, and may be separated when necessary. The head *b* is so shaped, that any liquid, which may be condensed, collects into a channel, and is carried by the pipe *c* into the receiver.

FIG. 3. *A separator*, for separating liquids of different specific gravities. It is furnished with a ground stopper at *a*, and a glass stop cock at *b*. The vessel is filled with the liquids that are to be separated (oil and water for example), which are allowed to stand till the lighter has completely risen to the top. The stopper *a* is then removed, and the cock *b* opened, through which the heavier liquid descends; the cock being shut, as soon as the lighter one is about to flow out.

FIG. 4. A glass vessel, termed a *matrass*, useful for effecting the solution of bodies, which require heat before they can be dissolved, or long continued digestion, see p. 8. The upper extremity of the long neck generally remains cool, and allows the vessel and its contents to be shaken occasionally.

FIG. 5. A glass bottle with a very thin bottom, and a projecting ring round the neck for suspending it over a lamp. These are useful for effecting *solutions* on a small scale.

FIG. 6. An apparatus contrived by Mr. Pepys, for ascertaining the quantity of carbonic acid discharged from any substance by the addition of an acid. It consists of a bottle closed by a ground stopper. This stopper is perforated, and forms the lower part of a tube, which is twisted into the shape of a still-worm. In this worm, any water that escapes along with the gas, is condensed, and falls down again into the bottle. The experiment is made precisely as described, p. 208: and the loss of weight is determined at the close of the effervescence.

FIG. 7. Mr. Leslie's *differential thermometer* described, p. 54.

FIG. 8. (*a*) *An air thermometer*, for ascertaining the temperature of liquids. It consists of a bottle, partly filled with any coloured liquid, and partly with air, a glass tube of small bore, open at both ends, being either cemented or hermetically sealed into the bottle, so that its lower extremity may nearly touch the bottom of the bottle. The expansion of the included air, on the application of heat, drives the coloured liquid up the tube, and to an extent which may be measured by the application of a scale. The fig. *b* is another variety of the same instrument, described p. 54.

FIG. 9. The original *air thermometer of Sanctorio*; see p. 54.

FIG. 10. A bent funnel for introducing liquids into retorts, without soiling their necks.

FIG. 11. *An adopter*. The wider end admits the neck of a retort; and the narrower is passed into the mouth of a receiver.

FIG. 12. A section of an evaporating dish of Wedgwood's ware.

FIG. 13. (a) *A tubulated retort* luted to (b) *a quilled receiver*, the pipe of which enters the neck of a bottle (c) supported by a block of wood.

FIG. 14. Different forms of jars for precipitations, with lips for conveniently decanting the fluid from the precipitate.

FIG. 15. A tube, blown in the middle into a ball, for dropping liquids. The ball is filled by the action of the mouth applied to the upper orifice, while the lower one is immersed in the liquid. To the former the finger is then applied; and, on cautiously removing it, the liquid is expelled in drops.

FIG. 16. *A bottle for ascertaining the specific gravity of liquids*. When filled up to a mark in the neck, with distilled water of a given temperature, it should hold 1000, 2000, or any even number of grains. The quantity which it is found to contain, of any other liquid of the same temperature, shows the specific gravity of the latter. For example, if it hold 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the latter is to that of water as 1850 to 1000.

PLATE II.

FIG. 17. An apparatus for procuring gases, without the possibility of their escaping into the room during the process, a circumstance which is of considerable importance, when the gas has an unpleasant smell or deleterious properties. Suppose that sulphuretted hydrogen gas is to be obtained from sulphuret of iron and diluted sulphuric acid. The sulphuret of iron, in coarse powder, is put into the body of the gas bottle *c*, with a proper quantity of water. The acid holder *a* is filled with diluted acid, the cock *b* being shut, and is then fixed into the tubulure of the gas bottle, to which it is accurately adapted by grinding. The bent tube *d* being made to terminate under a receiver filled with, and inverted in water, the perforated cock *b* is gradually opened, in consequence of which the acid descends into the gas bottle; and acts on the sulphuret of iron. If it be found necessary to renew the acid, without disturbing the apparatus, this may be done as follows. The cock *b* being shut, the stopper, which closes the acid holder, may be removed, and fresh acid be poured in, through the aperture. This may be repeated as often as is found necessary. The acid holder may be advantageously adapted, also, to a retort for certain distillations, such as that of muriatic acid.

FIG. 18. A plain gas bottle with sigmoid tube, the end, which is received into the bottle, having a ground stopper accurately fitted to the neck. For ordinary purposes (such as obtaining hydrogen

gas from diluted sulphuric acid and iron filings) this apparatus answers perfectly well, and is much less costly. It is frequently made with a tubulure and glass stopper, and is then called a tubulated gas bottle.

FIG. 19. A gas funnel, useful in transferring any gas, from a wide-mouthed vessel into a jar of narrower diameter, or into a bottle. When employed for this purpose, it is held inverted, as shown by the figure, the pipe being admitted into the aperture of the bottle or jar, which is filled with and inverted in water, and the gas being made to pass into it in bubbles.

FIG. 20. Dr. Hope's Eudiometer. The manner of using it has already been described, p. 107.

FIG. 21. A modification of Dr. Hope's Eudiometer described, p. 107.

FIG. 22. A gas receiver, into the neck of which is cemented a brass cap, with a female screw for receiving a stop-cock. The vessel *b* is a glass flask, which may be made to communicate with the interior of the jar *a*, by opening the cock. When the apparatus is used, it is necessary to employ two stop-cocks, and not one only, as represented by the figure. Supposing that the weight of any gas is to be ascertained, the flask *b* is exhausted, by screwing it on the transfer of an air-pump; and, if great accuracy be required, it is proper to enclose a gage in the vessel. Let the flask be weighed when exhausted; then screw it upon the top of the receiver containing the gas which is to be weighed; and open the communication, observing, by using a graduated jar, how much gas has been admitted. Suppose this to be 50 cubic inches. By weighing the flask again when full, we determine the weight of 50 cubic inches of the gas under examination. The experiment should be made when the temperature of the room is 60° , and when the barometer stands at 29.8.

FIG. 23. A plain jar for receiving gases, with a ground stopper.

FIG. 24. An eudiometer for trying the purity of a mixture of gases containing oxygen gas, by means of nitrous gas. The process has already been described, p. 266. The instrument should be accompanied with a phial, holding, when completely full, precisely a cubic inch.

FIG. 25. A wire stand, with a leaden foot, for the purpose of raising, above the surface of water within a jar, any substance which is to be exposed to the action of gas.

FIG. 26. An apparatus for showing that caloric exists in gases in a latent form. The application of it has been already described, p. 95.

FIG. 27. An apparatus for drying precipitates by steam, described, p. 8.

FIGS. 28 and 29. Tubes for exploding mixtures of hydrogen and other inflammable gases with oxygen gas, commonly termed the Eudiometer of Volta; see p. 110.

PLATE III.

FIG. 30. The common form of a Woulfe's apparatus. In this figure the retort *a* is represented plain, but it is better to employ a tubulated one. The use of this apparatus has already been described, p. 5.

FIG. 31. A modification of the apparatus, which has been already described. In this figure, the mercurial trough is shown with a jar standing inverted in it, for the purpose of receiving any gas that may escape condensation by water.

FIG. 32. Mr. Pepys's improvement of Woulfe's apparatus described, p. 6.

PLATE IV.

FIGS. 33 and 34. Cuthbertson's apparatus, for exhibiting the composition of water, with the substitution of gazometers for the receivers originally employed by him. The apparatus has been described, p. 117. FIG. 33 is an enlarged view of the conical brass piece, which is cemented into the bottom of the receiver, and through which the gases are conveyed.

FIG. 35. A gazometer of the most simple and common construction; see p. 87.

FIG. 36. A gas holder, described, p. 88.

FIG. 37. A galvanic trough; see p. 131. The tube *b* shows the arrangement for decomposing water. The upper wire may be hermetically sealed into the tube, and the lower one passed through a cork, which should have a small slit cut in it, to allow the water to escape in drops as the gas is produced.

FIG. 38. The manner in which a candle may be burned in oxygen gas; see p. 97.

FIG. 39. The combustion of iron-wire in oxygen gas.

FIG. 40. Apparatus for decomposing water over red-hot iron or charcoal; see p. 120.

FIG. 41. An apparatus for showing the diminution effected in the volume of hydrogen and oxygen gases by their slow combustion; see p. 111.

FIG. 42. A very simple and cheap contrivance for freezing quicksilver by muriate of lime and snow. The outer vessel of wood may be twelve and a half inches square, and seven inches deep. It should have a wooden cover, rabbeted in, and furnished with a handle. Within this is placed a tin vessel *b b*, standing on feet which are one and a half inch high, and having a projection at the top, half an inch broad, and an inch deep, on which rests a shallow tin-pan *c c*. Within the second vessel is a third *d*, made of untinned iron, and supported by feet two inches high. This vessel is four inches square, and is intended to contain the mercury. When the apparatus is used, a mixture of muriate of lime and snow is put into the outer vessel *a a*, so as completely to surround the middle vessel *b b*. Into the latter, the vessel *d*, containing the

quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow and muriate of lime, previously cooled to 0° Fahrenheit, by an artificial mixture of snow and common salt. The pan *cc* is also filled with these materials, and the wooden cover is then put into its place. The vessels are now left till the quicksilver is frozen. A more elegant, but more expensive apparatus, by Mr. Pepys, intended for the same purpose, is figured in an early volume of the Philosophical Magazine.

FIG. 43. A wire stand, consisting of an interior circle, and three straight pieces of wire proceeding from it in the same plane. Its use is noticed, p. 99.

FIG. 44. Sir H. Davy's apparatus for the analysis of soils described in his paper, which is copied into the third part of this work.

PLATE V.

FIG. 45. Pictet's arrangement of an apparatus for showing the radiation of caloric, unaccompanied by light; see p. 60.

FIG. 46. An oval copper boiler, for exhibiting the most important facts respecting latent caloric. The size of its different parts (except the width, which is 4 inches) may be learned from the scale affixed to the plate, which is abundantly sufficient to enable any intelligent workman to construct the apparatus. The collar joint and stuffing box, however, it is indispensably necessary to describe, especially as the former article of apparatus is generally constructed on a bad plan.

FIG. 47 is a section upon a larger scale, of the collar joint at *b* (fig. 46), made for the convenience of screwing together long or crooked metal tubes, without turning them round: *a* is a section of the end of one of the tubes, and *b* that of the other which is to be attached to it; *c* is a collar which turns loose upon the shoulder of *a*, and screws upon *b*. By screwing this collar upon *b*, the end *cc* of the tube *a* is brought to press upon the part *dd* of the tube *b*, without turning round either of those tubes. If upon *d* be laid a ring of linen cloth soaked in boiled linseed oil, the joint, when screwed up (if tolerable well made), will be impervious to steam as well as to water or air. The projection at *d* is for preserving the ring of cloth from being displaced, and for guiding the ends of both tubes, so as to meet properly.

FIG. 48 is a section of a socket, for fixing the stem of a thermometer into a boiler or a digester, where there is much heat and pressure; *b* is a socket fixed on the outside of the boiler or digester, having a hole through it large enough to admit the bulb of the thermometer; *a* is a plug which screws into *b*, having a hole through its centre large enough to admit only the stem of the thermometer; *cc* is a loose round plate, concave on the upper side, having a hole through its centre just sufficient also to admit the stem of the thermometer. When the instrument is to be inserted, the plug *a*, and the plate *c*, must both be taken out of the

socket. The bulb is then passed through it. The plate *c* is next slipped over the stem, and dropped into its place. Some flax, soaked in linseed-oil, must next be wrapped round the stem, so as nearly to fill the socket. The plug *a* must then be screwed in, till the flax be compressed so as to make the whole sufficiently tight. The opposite surfaces of the plate *c*, and the plug *a*, are made concave, for the purpose of compressing the flax round the stem of the thermometer.

PLATE VI.

FIGS. 49, 50, 51. Sections of crucibles.

FIG. 52. A muffle; see p. 4.

FIG. 53. Stands for raising the crucible above the bars of the grate; *a* one adapted to Mr. Aikin's blast furnace; *b* one of the common form.

FIG. 54. A skittle-shaped crucible.

FIG. 55. Mr. Aikin's portable blast furnace. It is composed of three parts, all made out of the common thin black-lead melting pots, sold in London for the use of the goldsmiths. The lower piece *c* is the bottom of one of these pots, cut off so low as only to leave a cavity of about an inch, and ground smooth above and below. The outside diameter over the top is five and a half inches. The middle piece, or fire-place *a*, is a larger portion of a similar pot, with a cavity about six inches deep, and measuring seven and a half inches over the top, outside diameter, and perforated with six blast holes at the bottom. These two pots are all that are essentially necessary to the furnace for most operations; but when it is wished to heap up fuel above the top of a crucible contained within, and especially to protect the eyes from the intolerable glare of the fire when in full heat, an upper pot *b* is added, of the same dimensions as the middle one, and with a large opening in the side, cut to allow the exit of the smoke and flame. It has also an iron stem, with a wooden handle (an old chisel answers the purpose very well) for removing it occasionally.

The bellows, which are double (*d*), are firmly fixed, by a little contrivance which will take off and on, to a heavy stool, as represented in the plate; and their handle should be lengthened so as to make them work easier to the hand. To increase their force on particular occasions, a plate of lead may be firmly tied on the wood of the upper flap. The nozzle is received into a hole in the pot *c*, which conducts the blast into its cavity. From hence the air passes into the fire-place *a*, through six holes of the size of a large gimlet, drilled at equal distances through the bottom of the pot; and all converging in an inward direction, so that if prolonged, they would meet about the centre of the upper part of the fire. Fig. 56 shows the distribution of these holes in the bottom. The large central hole is intended to receive the stand *a*, fig. 53, which serves for supporting the crucible.

No luting is necessary in using this furnace, so that it may be

set up and taken down immediately. Coak or common cinders, taken from the fire when the coal just ceases to blaze, sifted from the dust, and broken into very small pieces, forms the best fuel for higher heats. The fire may be kindled at first by a few lighted cinders, and a small quantity of wood-charcoal.

The heat which this little furnace will afford is so intense, that its power was, at first, discovered accidentally by the fusion of a thick piece of cast iron. The utmost heat procured by it was 167° of Wedgwood's pyrometer piece, which was withdrawn from a Hessian crucible, when actually sinking down in a state of porcelainous fusion. A steady heat of 155° or 160° may be depended on if the fire be properly managed, and the bellows worked with vigour.*

By a letter from Mr. Aiken, I have learned, also, a convenient way of exhibiting, in a lecture, and performing at other times, the process of cupellation, by means of this furnace. It consists in causing a portion of the blast to be diverted from the fuel, and to pass through a crucible in which the cupel is placed. This arrangement supplies air; and the whole may be seen by a sloping tube, run through the cover of the crucible. Fig. 57 shows the furnace when used for this purpose; *a a* the furnace; *b* the perforated stopper for the central blast; *c c* a portion of earthen tube, through which the air passes, and is heated during this transit; *e* a piece of soft brick perforated to admit the earthen tube *f*, which may be kept open for inspecting the process. No luting is required, except to join *f* to *e*.

FIG. 58. Knight's portable furnace,† composed of strong iron plate lined with fire lute, the inside diameter six inches: *a* shows the grate; *b* the ash pit door; *d* the door of the fire-place when used as a sand-heat; *e e* two holes opposite to each other for transmitting a tube; *g* an opening for a retort neck, when used for distilling with the naked fire.

FIG. 59. A different view of the same furnace; *a* the grate; *c* the register to the ash pit; *f* a small door, with a contrivance for supporting a muffle. The other letters correspond with the explanation of the preceding figure.

For this furnace the proper fuel, when it is used as a wind furnace, is wood-charcoal, either alone, or with the admixture of a small proportion of coak. For distillation with a sand heat, charcoal, with a little pit coal, may be employed.

PLATE VII.

FIG. 60 represents a fixed furnace, which I find very useful, because it may either be employed as a wind furnace or for distillation with a sand heat. Its total height outside is thirty-three inches, and the outside square is eighteen inches, or two bricks laid lengthwise. The thickness of the sides of the furnace is the breadth of

* See Philosophical Magazine, vol. xvii. p. 166.

† This furnace is also described in p. 2.

a brick, or four and a half inches; but whenever there is room, it is better to make them nine inches in thickness. From the top of the furnace to the grate, *b*, which is moveable, and supported by two bearers, the height is thirteen inches; and at *c* is a double Rumford door; or, in preference, a hole closed by a moveable earthen stopper, for introducing fuel. The ash pit should have a register door. The chimney is four inches wide by three high, and may either be furnished with a damper or not. On the top of the furnace a cast-iron ring is fixed, ten inches inside diameter, three inches broad, and half an inch thick. It is secured in its place by three iron pins, passing through three equidistant holes in the ring, and bent at the distance of nine inches at a right angle. These serve the purpose of binding the ring firmly into the brick-work. The sand pots are of different sizes; and a variety of them may be made to fit the same ring, by varying the breadth of their rims, as shown fig. 71. The brick should be cemented together, at least for the inner half of their breadth, by loam, or by a mixture of Stourbridge clay, with two or three parts sand, and a proper quantity of water.

When this is used as a wind furnace, the opening in the side is to be closed by its stopper; or, if a Rumford door be employed, it must be defended from the fuel by a fire tile. The fuel (coak) is introduced at the top, which is occasionally covered by a fire tile. When distillation with a sand heat is performed, the sand pot rests on the iron ring, and the fuel, which may be common pit coal, is added through the opening in the side. It may be proper to state, that, in order to receive a sand pot of as large a size as possible, the upper course of bricks should be bevelled within the furnace; and the width at the top may exceed a little that at the grate.

The best Stourbridge or Newcastle-on-Tyne fire-bricks are necessary in constructing this and the following furnaces.

FIG. 61 is a longitudinal section of a wind furnace, invented by Mr. Knight, with an additional chamber for applying the waste heat to useful purposes; *a* the internal cavity, which is square, for containing the fuel and the crucible: *b* the flue passing into a hot chamber *c*; an appendage particularly useful for drying luted crucibles, or bring them to a proper temperature for the furnace; for roasting ores and various other purposes: *d* the flue connecting it with the vertical chimney *e*; which, to produce a strong heat, should never be less than thirty or forty feet high: *f f* covers, consisting of twelve-inch Welsh tiles, with handles: *g* the stoke hole, through which no more of the fire is seen than what appears between the grate and the bearing bar *h*. This space is left for the double purpose of raking the fire, and occasionally taking out the bars: *k* the ash pit, which is sunk below the level of the ground, and is covered, where it projects at *l*, by an iron grating.

The best situation for this furnace, is an angle of the laboratory, the chimney being in the corner, as represented in the sketch. By this arrangement, the operator is spared the disagree-

able necessity of scorching his legs, by standing opposite the stoke-hole, while the backs of his legs are exposed to a current of cold air rushing to the furnace.

FIGS. 62 and 63 are different views of a furnace invented by Mr. Knight, and convertible to various purposes.

The inside of this furnace is nine inches square, and sixteen inches deep from the top to the grate. The face of the opening at *g* rises at an angle, which makes the back part five inches higher than the front. This contrivance enables us completely to cover a large retort with fuel, without obstructing the passage of the air, and also relieves partly the weight of the cover, when it requires to be moved. The walls of the furnace are at least a brick and a half thickness, and as much more as local convenience will allow. By sinking the ash pit below the level of the ground, at *i*, the height of the furnace needs not exceed eighteen inches, which renders the management of the fuel much more easy, and subjects the face and hands less to the action of the heat. The ash pit *a*, must be at least eighteen inches deep, below the surface of the ground, and more if convenient. It must have an opening, projecting from it three or four feet, to be covered with boards, and with an iron grating next the furnace. This preserves the legs of the operator from the action of the fire.

The grate *b* is formed of separate bars, each of a triangular shape, three fourths of an inch apart, and resting on two bearers. In the front of the furnace, an iron bar is to be placed to support the brick-work, and to leave an opening, through which the bars may occasionally be drawn out, and the fire raked and cleared of the slag. The chimney *c* is two and a half inches from the top, and four and a half wide by two and a half high.

To fit this furnace for occasional distillation with the naked fire, an opening, *d*, fig. 62, is left on one side, which is filled up, when not wanted, by five pieces of soft fire-brick, cut to a proper shape, and secured by a clay lute. It is proper, also, to be provided with other pieces, having arched openings for transmitting the neck of a retort. One of these pieces may have a round hole for occasionally transmitting a tube, and a corresponding hole, *h*, fig. 63, must then be made in the opposite side of the furnace, to be closed, when not wanted, with a stopper.

FIGS. 64 and 65 represent a sand heat, for containing flat evaporating vessels; the depth from back to front two feet; the width, agreeably to the scale, six feet. At the front is a rim four inches deep, consisting of a piece of iron plate, which is fastened at each end into the wall. The floor or bottom, *ee*, is formed of cast-iron plates, which rest upon each other in corresponding rabbets. The advantage of several small plates, over one large one, is the cheapness and facility, with which they are replaced, if cracked by the heat, an accident of not unfrequent occurrence. The joints are secured by a fire lute, which effectually prevents the sand from falling through. The fire place is shown by *b*; at the bottom it has a grate ten inches long, by eight wide. The flame and smoke circulate first through the flue *c*, and then through the re-

turning flue *d*, which conveys the smoke to the chimney *g*. In constructing the flue beneath the grate, a row of bricks, set edge-ways, answers the purpose, and serves also to support the inner edge of the plates.

It is advisable to cover the sand heat with a sloping roof, which may be formed of lath and plaster, and supported by side walls. The lowest part of the roof may be foremost, and about three feet above the edge of the iron plates. It is, also, necessary to have an air flue, nearly at the top of the back wall, under the dome or roof, to be closed occasionally by a door. This must open into the chimney, in which case it serves the purpose of carrying off noxious vapours.

PLATE VIII.

FIGS. 66, 67, 68, are the section and plans of a reverberatory furnace for experimental purposes. In this furnace, the fuel is contained in an anterior fire-place; and the substance to be submitted to the action of heat, is placed on the floor of another chamber, situated between the front one and the chimney. The flame of the fuel passes into the second compartment; by the form of which it is concentrated upon the substance exposed to heat, which is not confined in a separate vessel or crucible, but placed on the floor of the furnace. When reduced to a state of fusion, the melted mass is allowed to flow out through a tap-hole at *h*. The dimensions of this furnace it is scarcely possible to state, as they vary so considerably in different parts of it; but they may be ascertained by referring to the figures, and by the application of the scale. In all three figures, *a* represents the ash pit; *b* the grate composed of moveable bars; *c* the door at which the fuel is introduced; *d* a door in the side of the chamber, for the purpose of inspecting the process; *e* the floor of the furnace which descends, and is gradually contracted towards the back part; *f* another door for introducing and stirring the materials; *g* the back part of the furnace, immediately under the chimney; *h* the tap-hole; *i* the chimney.

FIGS. 69 and 70, exhibit a cupelling or enamelling furnace. The form of this should be an oblong square; its dimensions being regulated by that of the muffle, which should go home to the back, its front edge lodging on the mouth of the furnace. On each side of the muffle, two inches and a half must be left, to let the fuel pass readily underneath, where there should also be a similar space. A stoke-hole must be left on the other side, but the situation of the view will not admit of its being shown. Before the muffle, is a projecting ledge or shelf, shown at *e*, which is intended to support any thing that is to be put into the muffle. Two twelve-inch tiles, worked in along with the bricks, will answer this purpose. In both figures, *a* shows the ash pit; *c* the grate; *d* the muffle; *e* the opening for introducing the muffle; *f* the chimney, and *g* the cover.

FIG. 71. Sand pots with rims of different sizes.

FIGS. 72, 73. Dr. Black's portable furnace, made of sheet

iron lined with fire clay. Its dimensions, as they vary in almost every part, will best be learned from the scale; *a* the fire place; *b* the chimney; *c* the ash pit; *d* the door of the ash pit; *e* a register for regulating the quantity of air admitted to pass through the fuel.

FIG. 74. Mr. Chenevix's wind furnace. This is rudely sketched in Nicholson's Journal, from which the more accurate figure in plate viii. is taken. This furnace Mr. Chenevix describes as follows: "I have constructed a wind furnace, which, in some respects, is preferable to the usual form. The sides, instead of being perpendicular, are inverted; so that the hollow space is pyramidal. At the bottom the space is twelve inches square, and at the top only eight. The perpendicular height is seventeen inches, from the top to the grate. This form unites the following advantages. 1. A large surface is exposed to the air, which having an easy entrance, rushes through the fuel with great rapidity. 2. The inclined sides act as reverberators. 3. The fuel falls of itself, and is always close to the grate."

In the figure, *a* represents the grate; *c c* are two bricks which can be let in at pleasure, to diminish the capacity; *b* is another grate which can be placed on the bricks *c c*, for occasional purposes; *d d* are bricks, which can be placed on the grate *b*, to diminish the capacity of this part of the furnace; *e* the cover. Both sets of bricks should be ground to the slope of the furnace.

In the construction of every furnace, which is intended to produce a strong heat, lime or mortar should be avoided, and the bricks should be set in loam, or Stourbridge clay, worked up with water and sand, inserting occasionally pieces of sheet iron, bent twice in opposite directions at right angles. The furnace should be allowed to remain some weeks, after setting up, before it is used; and before raising a strong heat, a gentle fire should be sometimes kindled in it, the strength of which may be gradually increased. When a strong blast is expected, it is necessary to bind the brick-work together, externally, by strong iron bars and plates, kept in their places by screws. The chimney should be nine inches wide, and raised to as great a height as circumstances will admit.

The coak of pit coal is the only fuel fitted for exciting an intense heat, and should be used in all cases, except in the reverberatory, and in distillations with the sand bath, when pit coal may be employed. The charcoal of wood is adapted principally to portable furnaces.

PLATE IX.

FIG. 75. The galvanic battery called *couronne de tasses*, described p. 132.

FIG. 76. Apparatus for obtaining the elements of water in separate tubes; p. 136.

FIG. 77. The pile of Volta; see p. 131.

FIG. 78. Section of a galvanic trough, to explain the theory of the excitation of galvanic electricity; see p. 145.

FIG. 79. Apparatus for obtaining oxygen and hydrogen gases, from separate quantities of water not in contact with each other; see p. 137.

FIG. 80. Two agate cups connected by moistened amianthus; see p. 138.

FIG. 81. Two gold cones similarly connected, *ibid.*

FIG. 82. Agate cups similarly connected with an intermediate vessel *i*; see p. 139.

FIG. 83. Apparatus for procuring potassium from potash and iron filings, described p. 154.

FIG. 84. Apparatus for firing gases by electricity, or submitting them to electrical discharges, p. 89.

FIG. 85. Pepys's improved gas-holder: *a* a small iron retort placed in the fire with a jointed conducting tube *b*, which is admitted into the vessel at *c*. This is shown on a larger scale in a different part of the plate. The letter *d* is placed on the body of the reservoir, and near the central pipe, which descends from the cistern *e* to nearly the bottom of the vessel. At *f* a glass tube is fixed, which shows the height of the water within the vessel. When a jar is intended to be filled with gas from the reservoir, it is placed, filled with water and inverted, in the cistern *e*. The cocks 1 and 2 being opened, the water descends through the pipe attached to the latter, and the gas rises through the cock 1. By raising the cistern *e* to a greater elevation, any degree of pressure may be obtained; and a blow-pipe may be screwed on the cock at the left side of the vessel.

PLATE X.—(ADDITIONAL.)

FIG. 1. A view of Glauber's apparatus for distillation, referred to in the note at p. 6.

a. The ash-hole of the furnace.

b c. The door of the furnace.

d. An opening for a sand bath.

f. A pipe, going from the distilling vessel.

g. The first crooked pipe, fitted to the pipe *f*.

h. A receiver fitted to that pipe, and set in a tub of water, for accelerating the operations: which receiver hath a cover with two holes, through the first whereof goeth a single crooked pipe, and through the other two crooked pipes, whereof one goeth into the receiver, as did the single, and the other out of the receiver *h*, into *h h*; *i* the tub of water, *m* a third pipe. By this way flowers are sublimed, and spirits distilled speedily, and in great quantity.

FIG. 2. Mr. William Hembel, jr's. improved apparatus for distillation—referred to in the note, p. 6.

"A Woulfe's apparatus (says this gentleman, in the note he has given in the American edition of the New Edinburgh Encyclopædia, vol. 5, p. 802) with tubes of safety may answer very well

for demonstrations at a public lecture : but, for processes in which considerable quantities of gas are evolved, and the saturation is to be effected under great pressure, they are totally inadequate. If the lower orifice of the tube is much immersed below the surface of the liquid, the accumulated gas will act similar to condensed air in the experiment of the hydrostatic fountain, and force the liquid out of the bottle until the orifice of the tube is exposed ; then the gas will also escape ; thus occasioning a double loss of products, and that whether straight or Welters tubes be used.

"Plate CXLII. No. 2. fig. 4. represents our method of connecting any number of bottles, by which tubes of safety are superseded ; yet the liquid can be saturated with gas, by as much pressure as the tenacity of the glass will resist : with the further advantage of being able to change the surface of the liquid at pleasure, without injury to the product.

"The apertures of the tubes *h, k, m, o*, merely perforate their respective corks ; whilst the tubes *i, l, n*, &c. descend *very near* the bottoms of the bottles. Into the bottle *c*, a small quantity of water is introduced, to engage the impure gas which may come over. The bottles *e* and *g*, contain the liquid to be saturated with the gas ;—a similar arrangement of long and short tubes are to be used for any additional number of bottles.

"On introducing into the retort, the substance from which the gas is to be extricated, and adding an acid, an action will take place. The evolved gas will pass through the liquid in the bottles as usual. When the gas ceases to be further evolved, a condensation will take place in the retort ; then the liquid in the bottle *c*, *e* and *g*, will yield to the pressure of the incumbent atmosphere, (acting through the aperture of the tube *o*,) and pass into the bottles *b, d* and *f*. But, as the apertures of the short tubes *h, k* and *m*, terminate with the lower surface of their respective corks, and the liquid in the bottles does not reach those apertures, the liquid can pass no further.

"It will then be only necessary to excite a fresh action by adding more acid in the retort, when the gas will accumulate in the receiver and empty part of bottle *b*. When the elastic force of the accumulated gas is sufficient to support a column of the liquid, equal to the height of one leg of the tube *i*, the liquid will rise and pass into the bottle *c*, the gas will follow and pass in the bottle *d*, and by pressing on the surface of the contained liquid will force it over into the bottle *e*, after which, the liquid in *f* will be forced in *g*, when the process of saturation will go on as before.

"There will be a great economy of acid, if the subsequent additions are not added until after an absorption has taken place, as the surface of the liquid will thereby be frequently changed, and the absorption of gas considerably accelerated.—For saturating water with muriatic and ammoniacal gas, or preparing hyper-oxy-muriate of potash on a large scale, demijohns may be substituted for the bottles *d, e, f*, &c."* HEMBEL, jun.

* It may not be improper here to remark, that the above description is rendered useless in the Encyclopædia, owing to the engraving of the apparatus

FIG. 3. Dr. Wollaston's cryophorus—see p. 78.

FIG. 4. Apparatus for impregnating water with oxymuriatic acid gas—see note at p. 295.

FIG. 5. Apparatus for extricating phosphureted hydrogen gas—see p. 324, note.

a Is a block of wood, shaped as in the engraving; the inclined plane of which is hollowed out in the middle, to receive the neck of the retort; *b b* strings, or other contrivance for fastening down the retort, after the materials are introduced. The figure sufficiently explains the other intentions to be answered in the operation.

FIG. 6. A very convenient table furnace, which was omitted to be mentioned in the notes on that part of the work.

It is simply a large earthen pot, such as is in constant family use, turned upside down. Before the pot is baked, an opening is cut in its side, as represented in the plate; another opening (circular) is made in the bottom (the top of the furnace), and several smaller ones near the bottom, for permitting the smoke, &c. to escape. Such a furnace can be readily procured for 25 or 30 cents of any potter; and is an excellent substitute for those of a more costly nature. It may be used for a great variety of purposes, requiring only a lamp heat. It will answer for the purposes of analysis; for distilling most of the acids, and indeed for almost every common occasion. Two or three of different heights, and with holes of various sizes at the bottom, will be found adapted for nearly every purpose.

PLATE XI.

*Account of Dr. Wollaston's Scale of Chemical Equivalents, from Thomson's An. of Philos. vol. 4, p. 176.**

This scale is of so much convenience to the practical chemist, that I seize the earliest opportunity to make it known to my readers in general. It gives the composition of any weight whatever of any of the salts contained on the scale, the quantity of any other salt necessary to decompose it, the quantity of new salt that will be formed, and many other similar things, which are perpetually occurring to the practical chemist, and cannot be answered without an arithmetical calculation. I have used such a scale for above six months, and found it attended with numberless advantages. I cannot undertake to explain the instrument, either more clearly, or in fewer words, than Dr. Wollaston himself has done in his own paper. I conceive, therefore, that the best thing I can do is to present my readers with the following extract from that paper, which contains the most material part of it, as far as the explanation of the instrument is concerned:—

being defective in the letters of reference—and it would be obviously judicious in the editors to cancel the present plate and replace it by one more perfect. C.

* Dr. Wollaston's paper is published in the Philosophical Transactions for 1814, part i.

"It is not my design, in the table which follows this paper, to attempt a complete enumeration of all those elements or compounds which I suppose to be well ascertained, but merely to include some of those which most frequently occur. I do not offer it as an attempt to correct the estimates that have been formed by others, but as a method in which their results may be advantageously applied in forming an easy approximation to any object of our inquiries.

"The means by which this is effected may be in part understood by inspection of the Plate [II.], in which will be seen the list of substances intended to be estimated, arranged on one or the other side of a scale of numbers in the order of their relative weights, and at such distances from each other, according to their weights, that the series of numbers placed on a sliding scale can at pleasure be moved, so that any number expressing the weight of a compound may be brought to correspond with the place of that compound in the adjacent column. The arrangement is then such, that the weight of any ingredient in its composition, of any re-agent to be employed, or precipitate that might be obtained in its analysis, will be found opposite to the point at which its respective name is placed.

"In order to show more clearly the use of this scale, the Plate exhibits two different situations of the slider, in one of which oxygen is 10, and the other bodies are in their due proportion to it, so that carbonic acid being 27.54, and lime 35.46, carbonate of lime is placed at 63.

"In the second figure, the slider is represented drawn upwards till 100 corresponds to muriate of soda; and accordingly the scale then shows how much of each substance contained in the table is equivalent to 100 of common salt. It shows, with regard to the different views of the analysis of this salt, that it contains 46.6 dry muriatic acid, and 53.4 of soda, or 39.8 sodium, and 13.6 oxygen; or if viewed as chloride of sodium, that it contains 60.2 chlorine, and 39.8 sodium. With respect to re-agents, it may be seen that 283 nitrate of lead, containing 191 of litharge employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead, and that there would then remain in solution nearly 146 nitrate of soda. It may at the same time be seen, that the acid in this quantity of salt would serve to make 232 corrosive sublimate, containing 185.5 red oxide of mercury, or would make 91.5 muriate of ammonia, composed of 6 muriatic gas (or hydro-muriatic acid), and 29.5 ammonia. The scale shows also, that for the purpose of obtaining the whole of the acid in distillation the quantity of oil of vitriol required is nearly 84, and that the residuum of this distillation would be 122 dry sulphate of soda, from which might be obtained, by crystallization, 277 of Glauber salt, containing 155 water of crystallization. These and many more such answers appear at once by bare inspection, as soon as the weight of any substance intended for examination is made by motion of the slider correctly to correspond with its place in the adjacent column.

"With respect to the method of laying down the divisions of this

scale, those who are accustomed to the use of other sliding-rules, and are practically acquainted with their properties, will recognise upon the slider itself the common Gunter's line of numbers (as it is termed), and will be satisfied that the results which it gives are the same that would be obtained by arithmetical computation.

"Those who are acquainted with the doctrine of ratios, and with the use of logarithms as measures of ratios, will understand the principle on which this scale is founded, and will not need to be told that all the divisions are logometric, and consequently that the mechanical addition and subtraction of ratios here performed by juxta-position, correspond in effect to the multiplication and division of the numbers by which those ratios are expressed in common arithmetical notation.

"To others who are not equally conversant with the nature of logarithms, and consequently have not so correct a conception of the magnitudes of ratios, some further explanation of the mode in which the scale of equivalents is constructed, will, I presume, be acceptable.

"They will observe, that the series of natural numbers are not placed at equal intervals on the scale; but that at all equal intervals are found numbers which bear the same proportion to each other. In fig. 3, some of the larger intervals alone are represented on a line similarly divided. The succession of intervals, marked A, B, C, D, E, are all equal, and at these points of division are placed numbers 1, 2, 4, 8, 16, which increase progressively by the same ratio. And since the series 3 : 6 : 12 : 24 increase in the same ratio of 1 to 2, these intervals *a, b, c, d, e*, are the same as the former. At another succession of different yet equal intervals, marked F, G, H, I, are placed numbers 1, 3, 9, 27, which increase regularly by an equal ratio of 1 to 3; and by means of a pair of compasses it would be found that the interval from 2 to 6, or from 6 to 18 (which are the same ratio of 1 to 3), is exactly equal to F G, the interval between 1 and 3. As any single space represents any one ratio, so the sum of any two or three equal spaces represent a double or triple ratio. If 1 be increased three times by the ratio of 1 to 2, it becomes 8, which bears to 1 triple the ratio of 2 to 1. This ratio is therefore represented by A D, which is the triple of A B.

"The distances of the intermediate numbers 5, 7, 10, 11, 13, &c. from 1 are likewise made proportional to the ratios which they bear to 1, and are easily laid down by means of a table of logarithms; for as these are arithmetic measures of the ratios which all numbers bear to unity, the spaces proportional to them become linear representations of the same quantities.

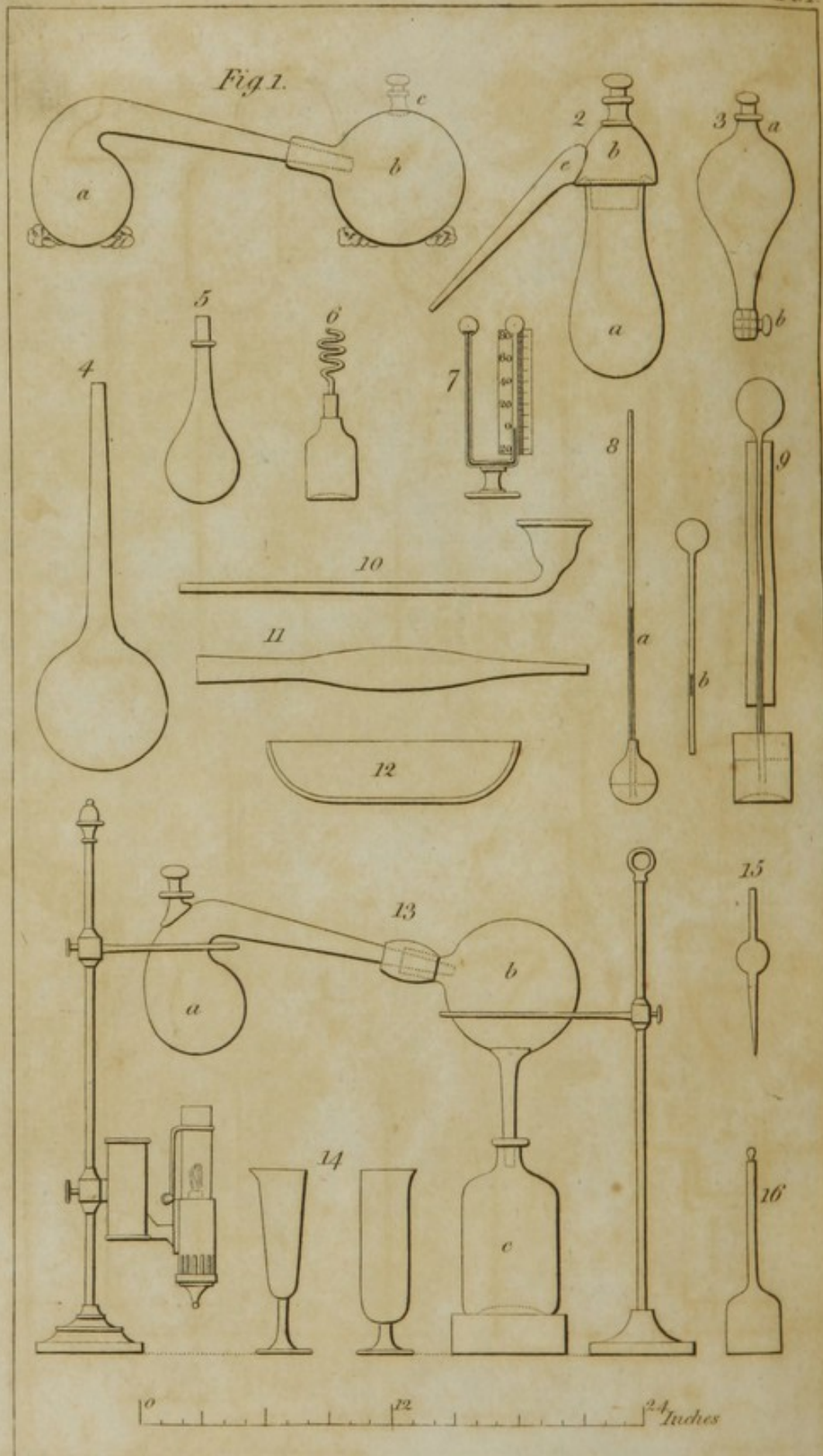
"As the entire spaces A D, A E, represent the ratios of 8 and of 16 respectively to 1, so the difference D E represents the ratio of 8 and 16, which stand at D and E, to each other. And in the same manner any other space, *k l*, represents correctly the ratio of 7 to 13; so that the measure of a fraction expressed by quantities that are incommensurate is rendered as obvious to sight as that of any simple multiple. And if a pair of compasses be opened to this interval, and transferred to any other part of the scale, the points of the com-

passes will be found to rest upon numbers bearing the same proportion to each other as those from which the interval was transferred.

"It is exactly in this manner that the various points in the column of equivalents indicate the several quantities sought in any given position of the slider. The relative distances, at which the articles are placed, represent so many different openings of the compasses rendered permanent and presented to view at once. In the table, which I shall place at the end of this communication, the relation of the various substances enumerated to each other is expressed by numbers.* In the engraved scale of equivalents, the ratios of these numbers are represented by logometric intervals at which they are placed, their several positions being determined by those of their respective numbers on the slider, which is logometrically divided. Consequently all the several points in the column of equivalents will indicate numbers in the same due proportions to each other, whatever part of the scale may be presented to them. Those who seek information may obtain it by inspection; those who already possess it may be able to correct the positions of some articles by direct comparison with the best analyses upon record, in whatever numbers the results of those analyses may happen to be expressed."

* This has reference to the Philosophical Transactions. Dr. Thomson has not introduced the table in his Annals. C.

Fig 1.



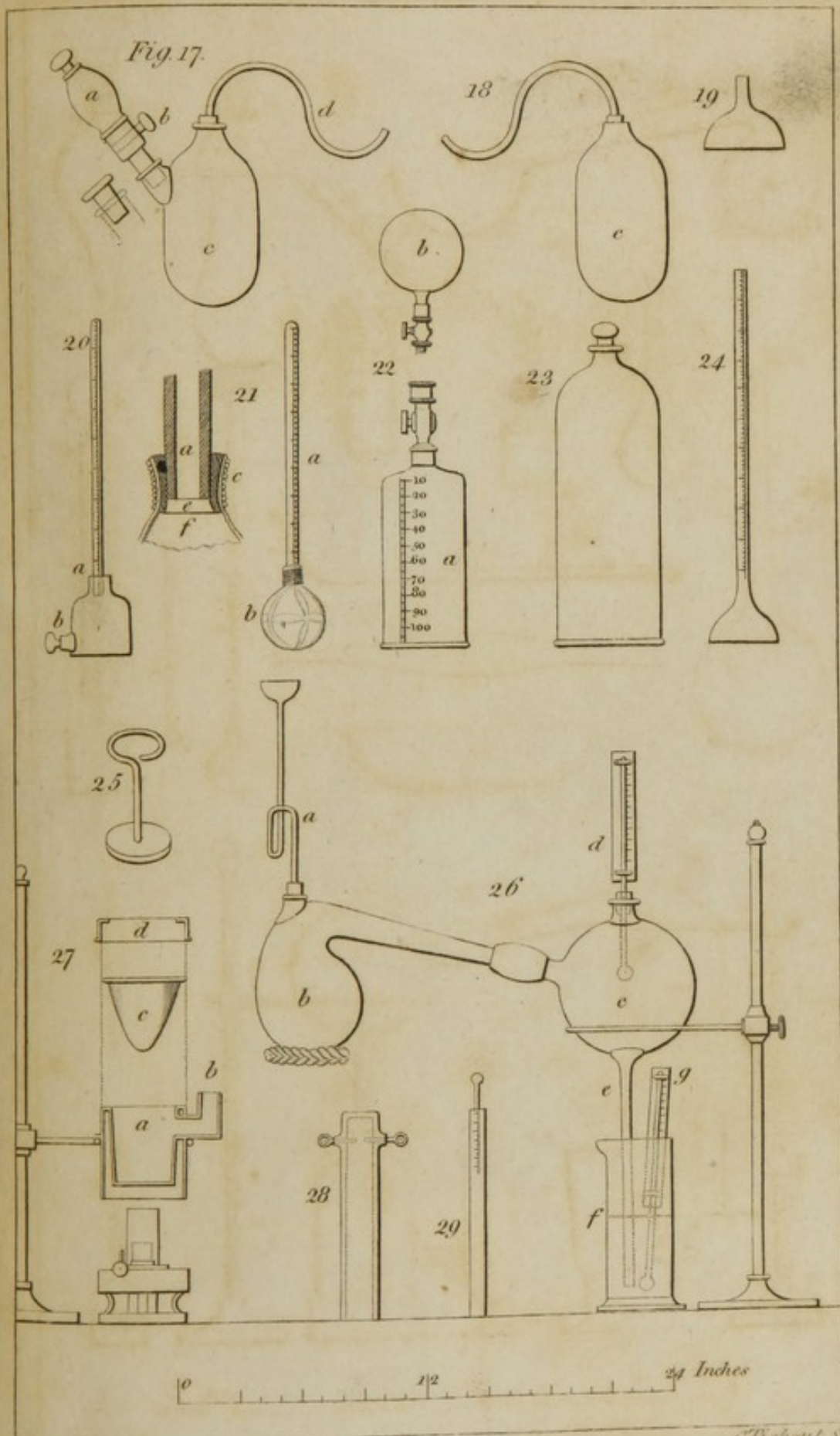
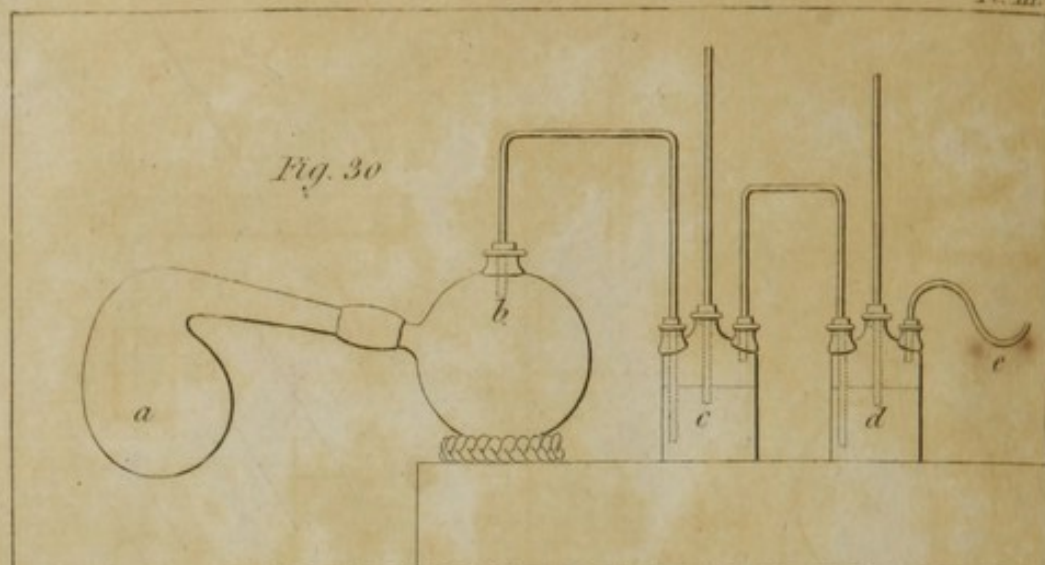
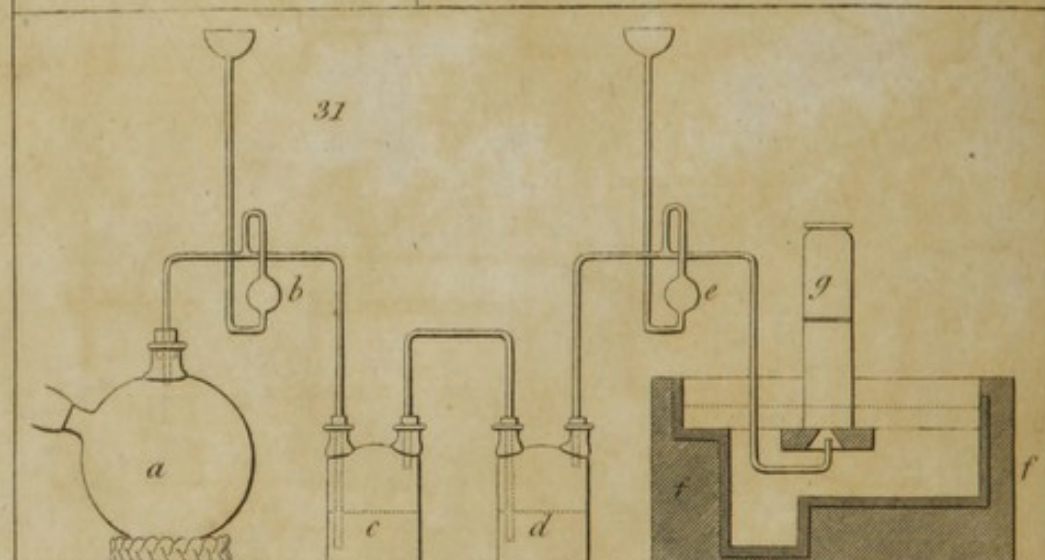


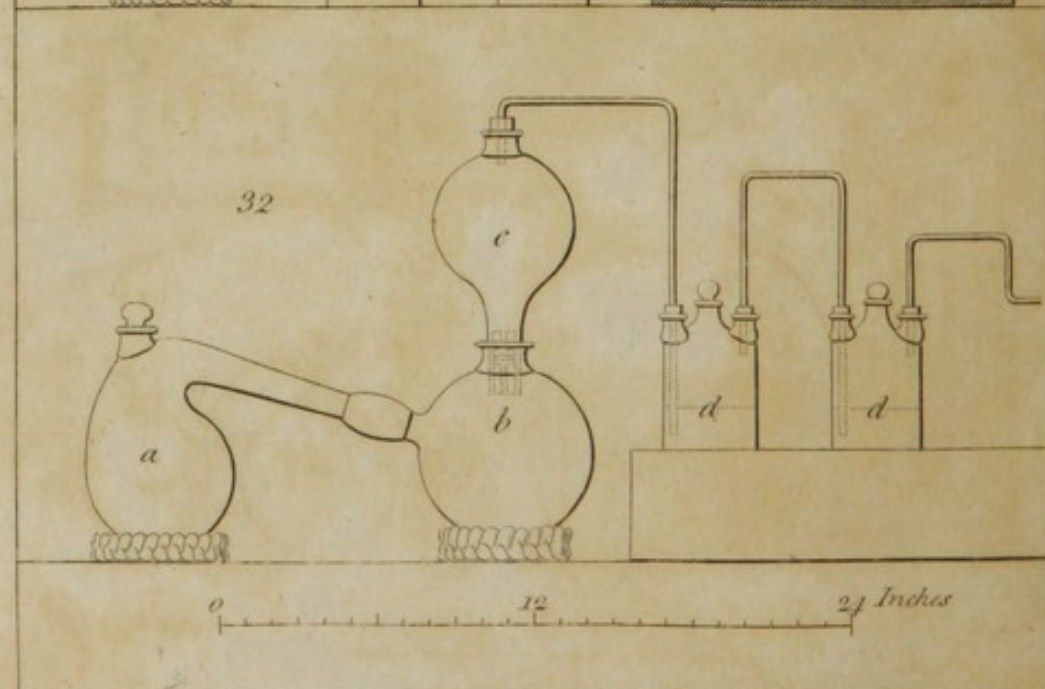
Fig. 30



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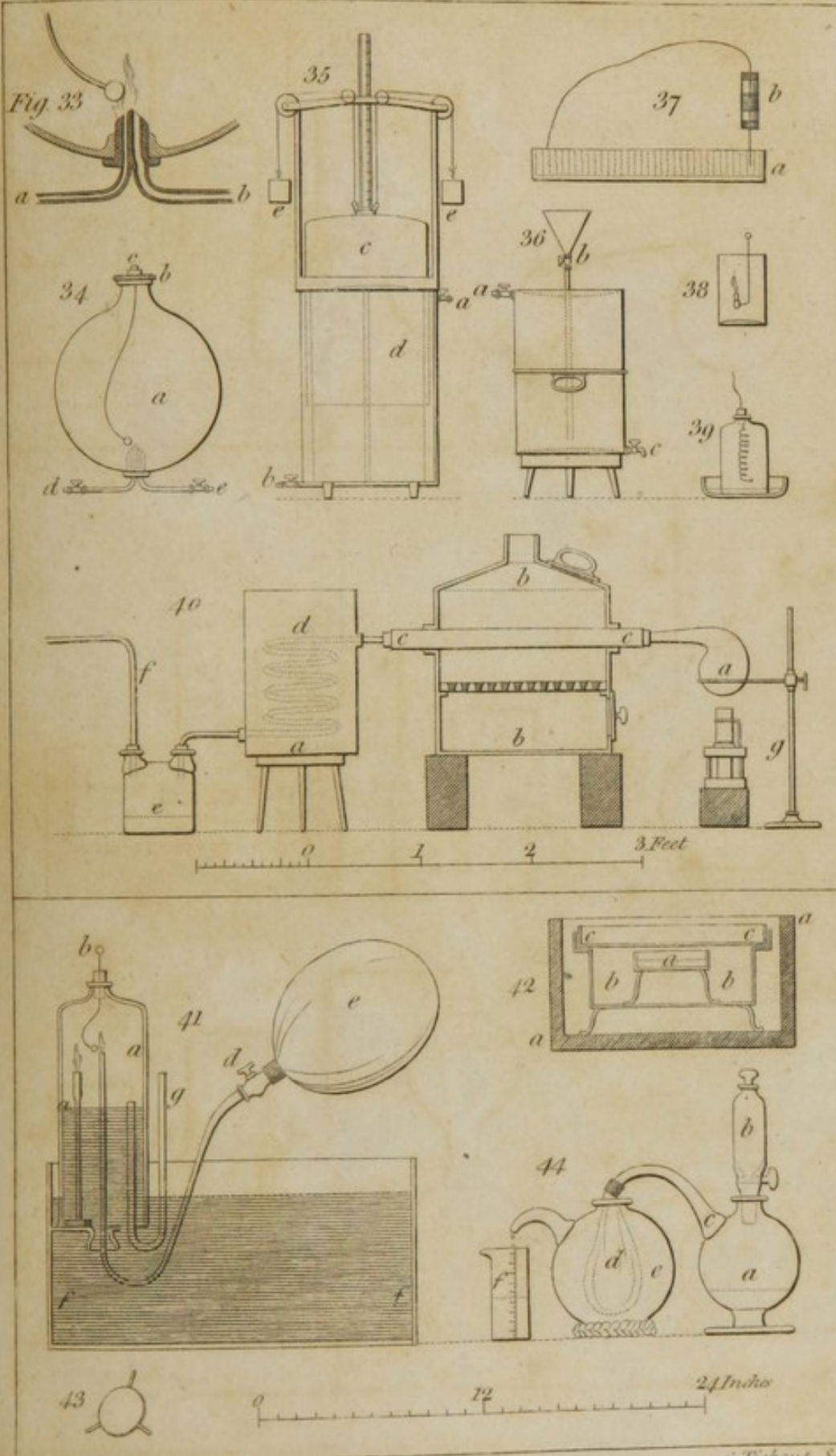


Fig. 45.

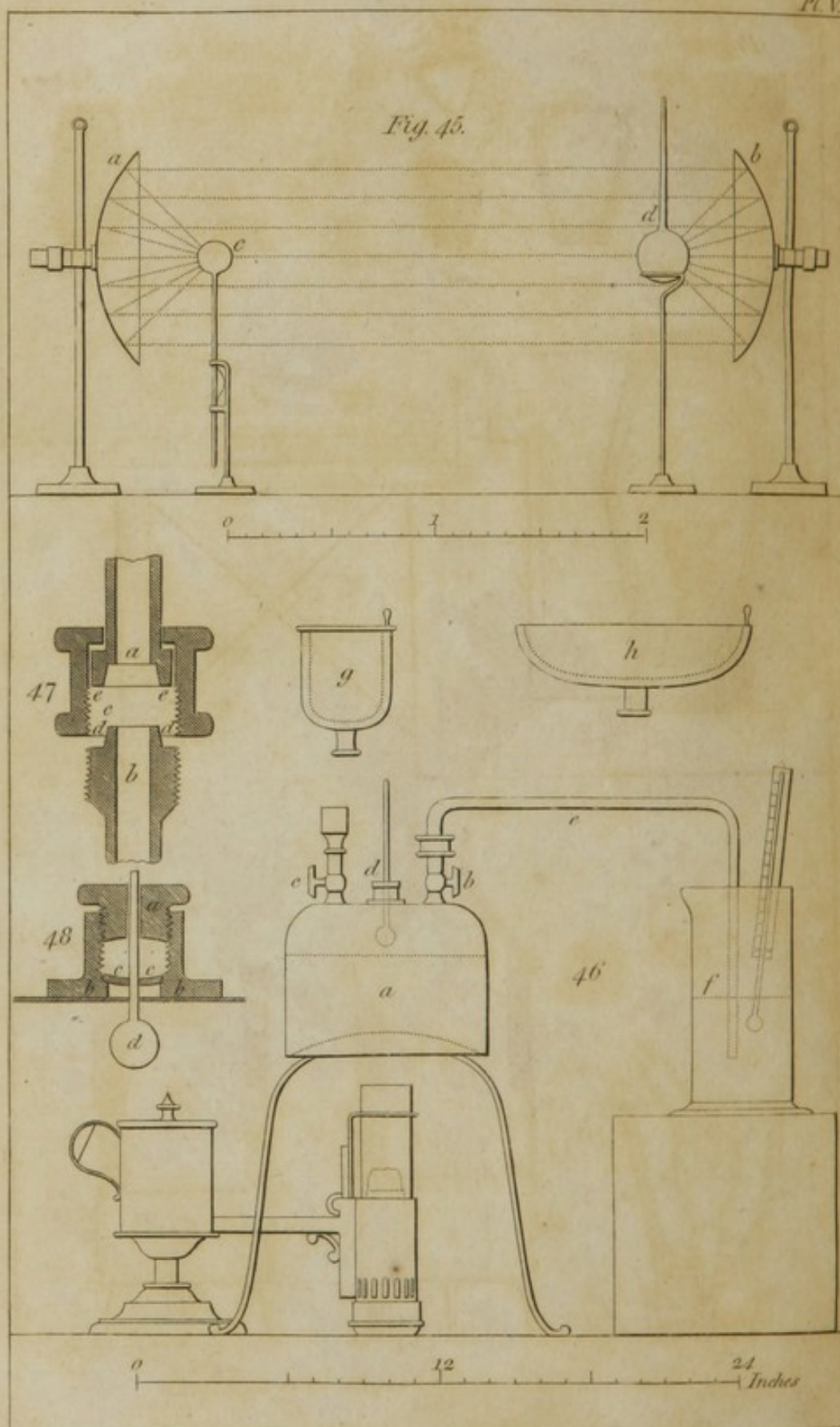


Fig. 49.

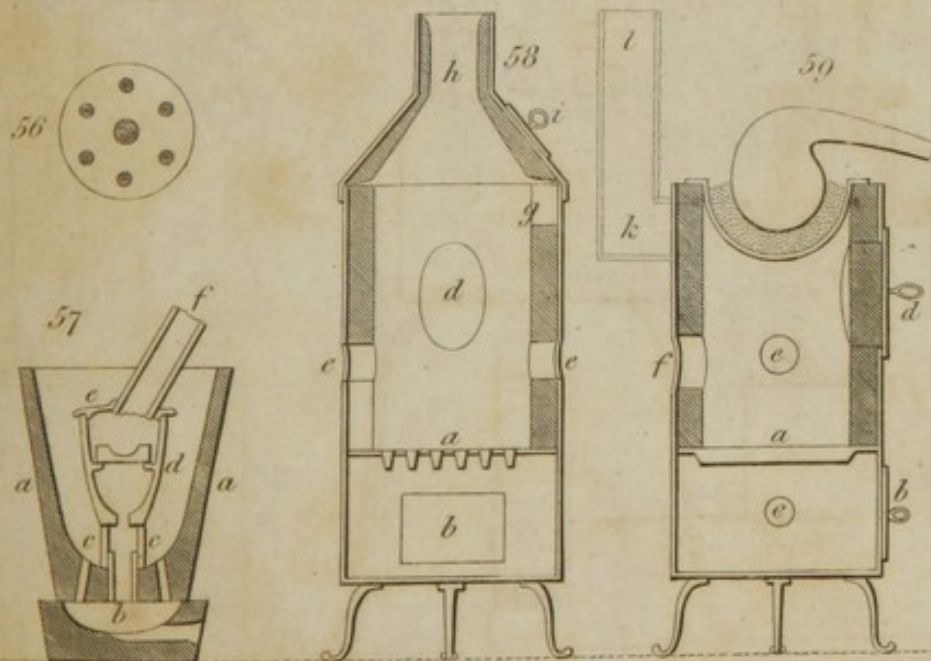
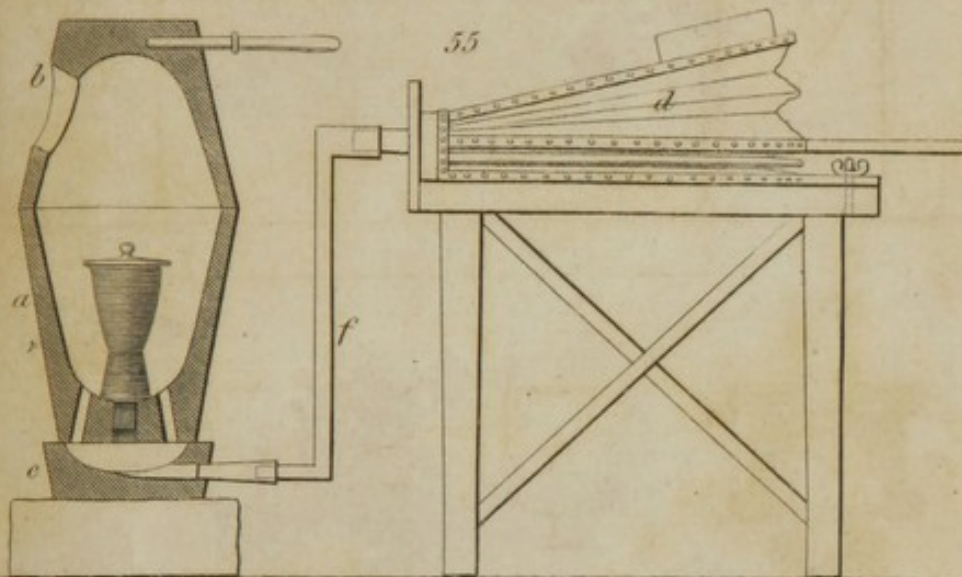
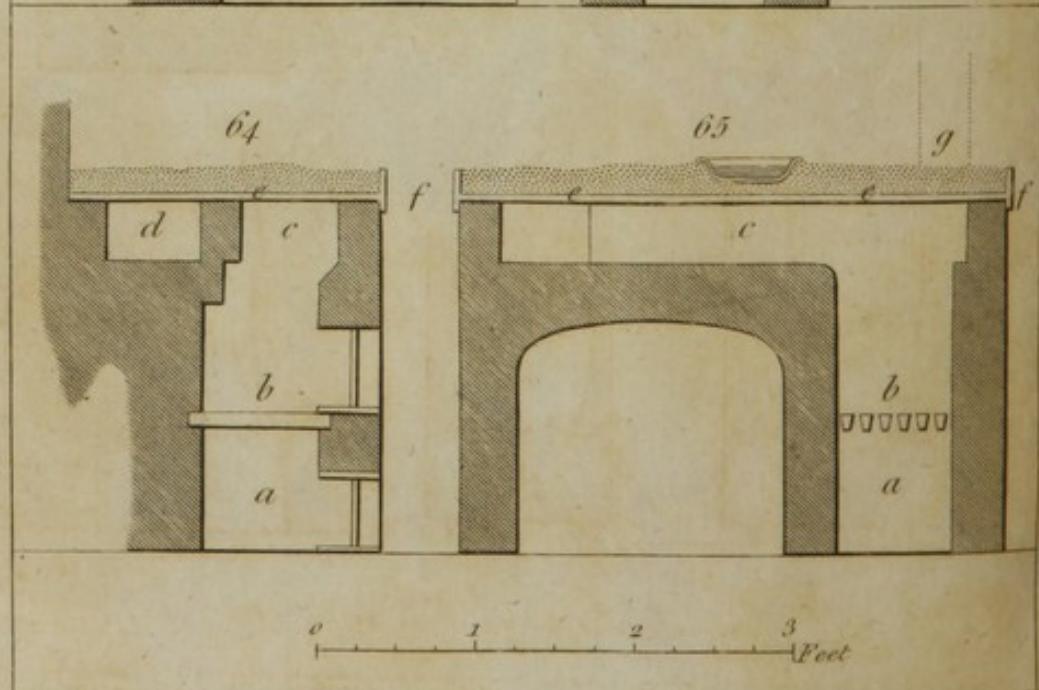
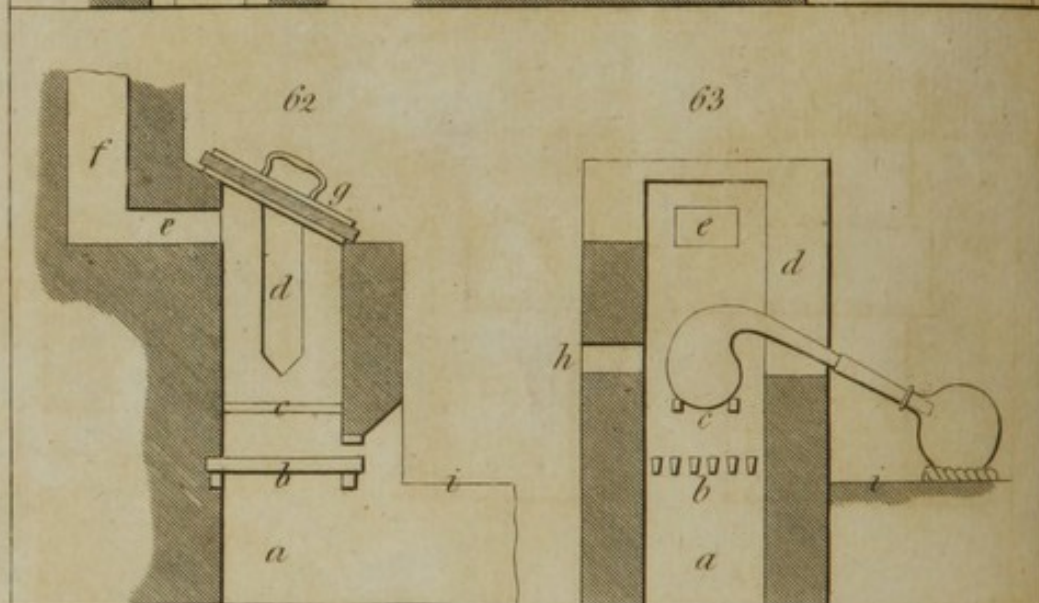
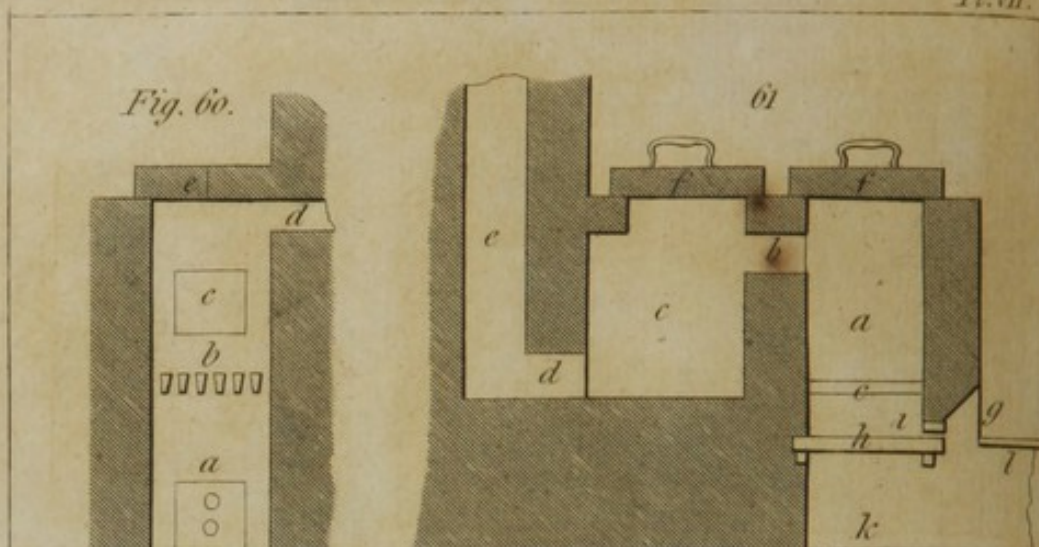
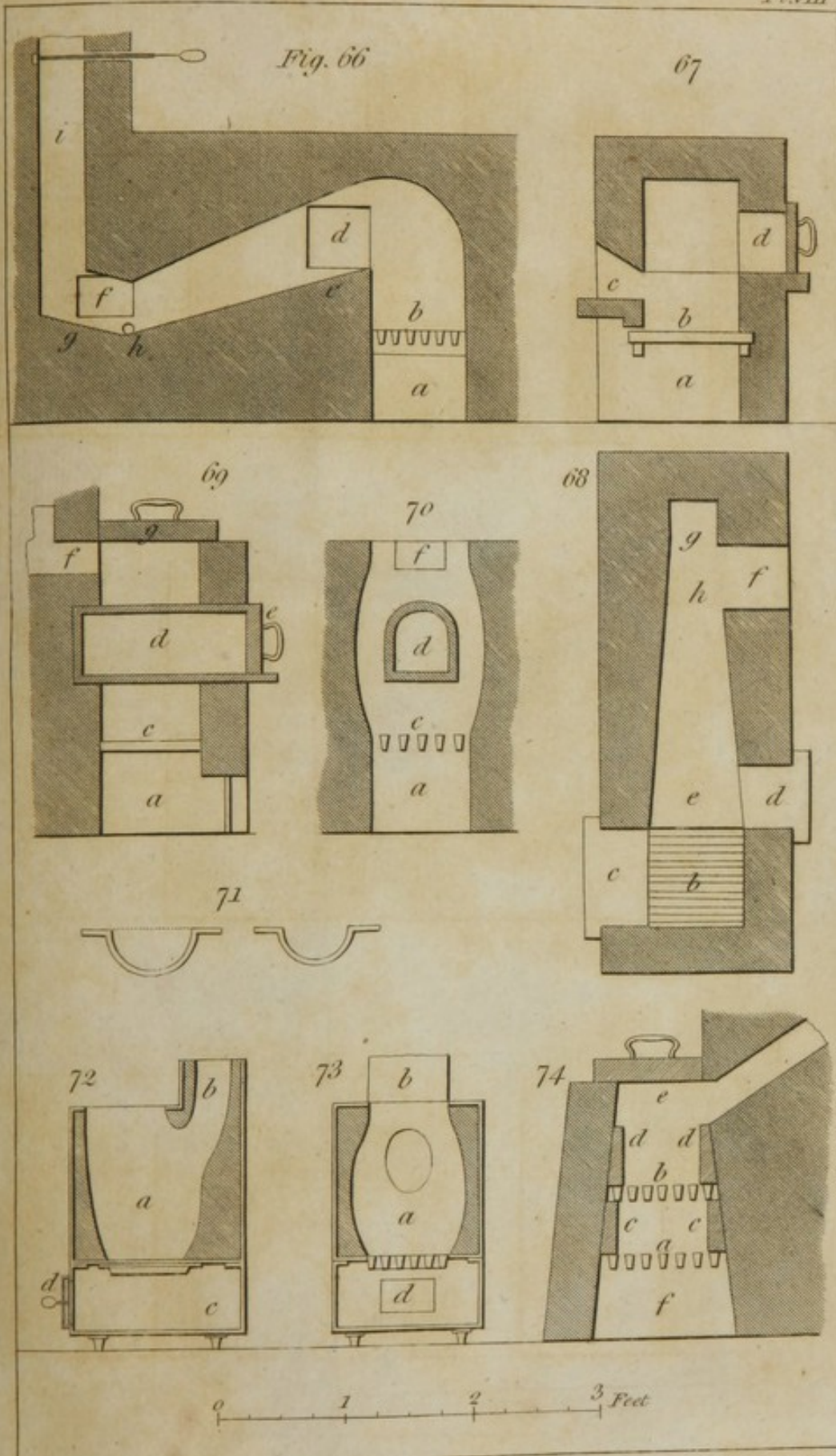


Fig. 60.



0 1 2 3 Feet



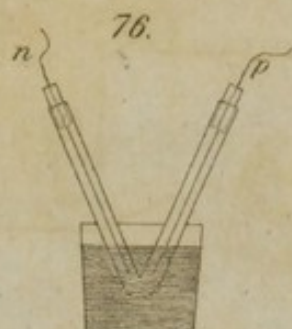


Fig. 75.

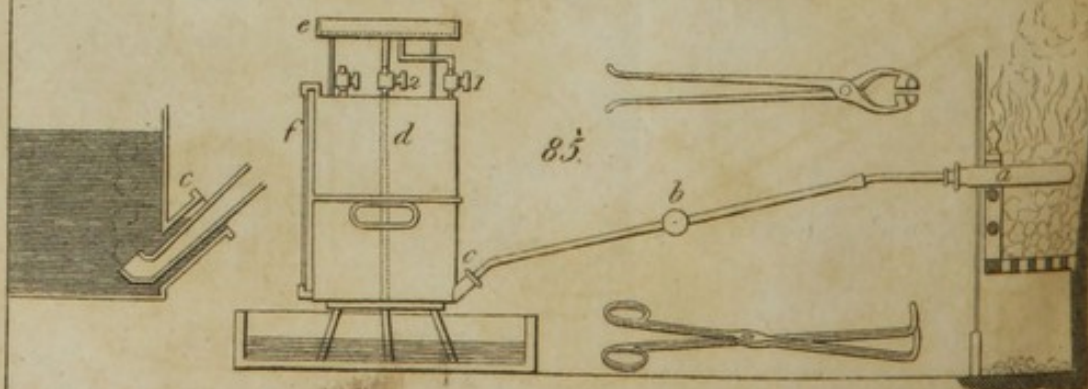
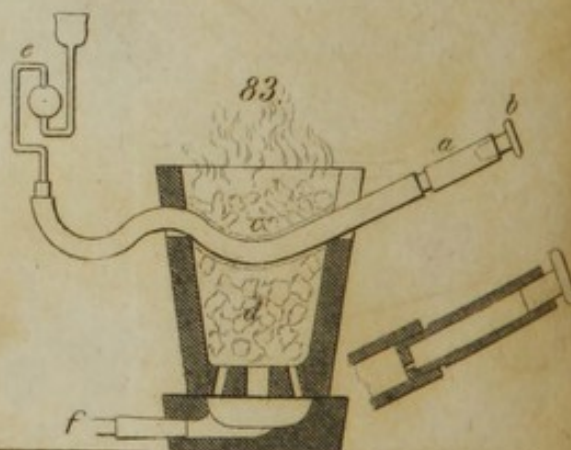
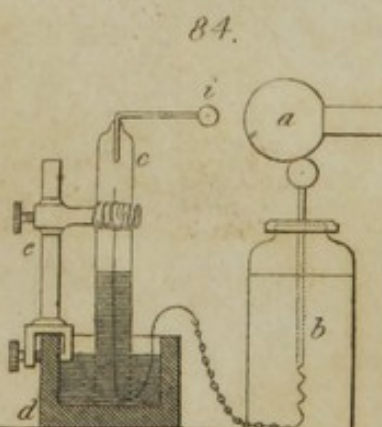
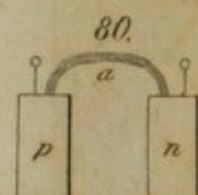
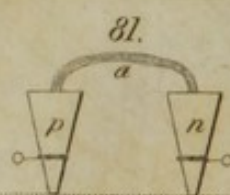
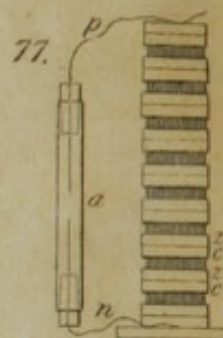
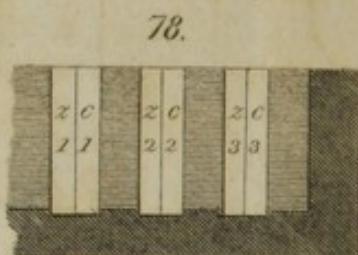
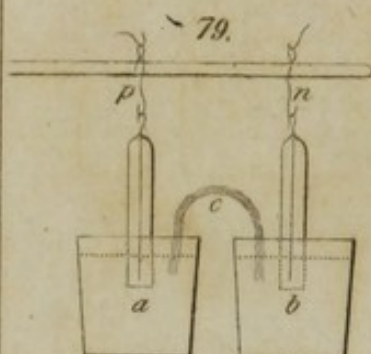
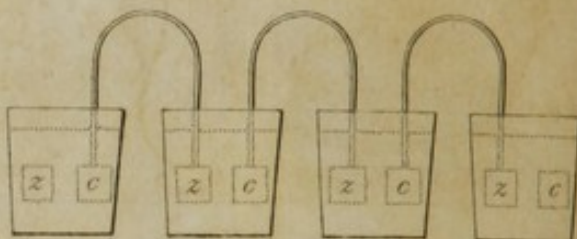
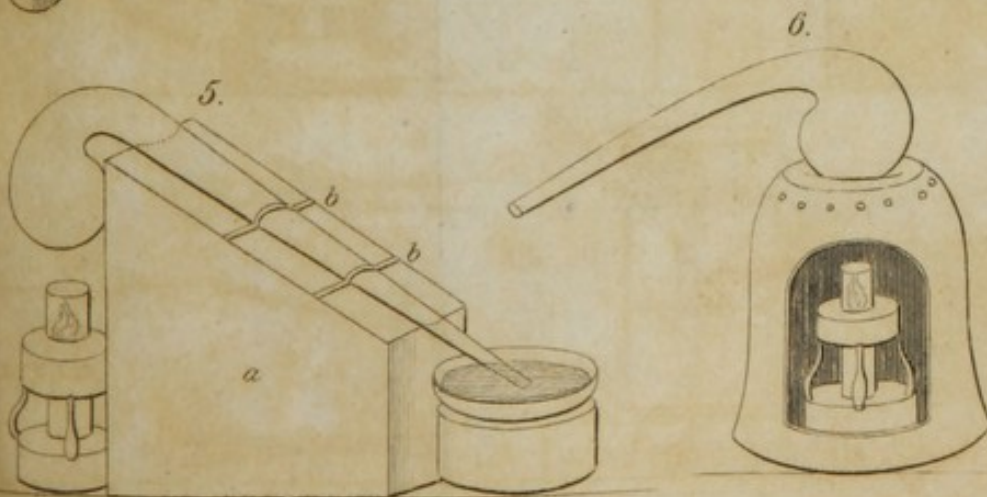
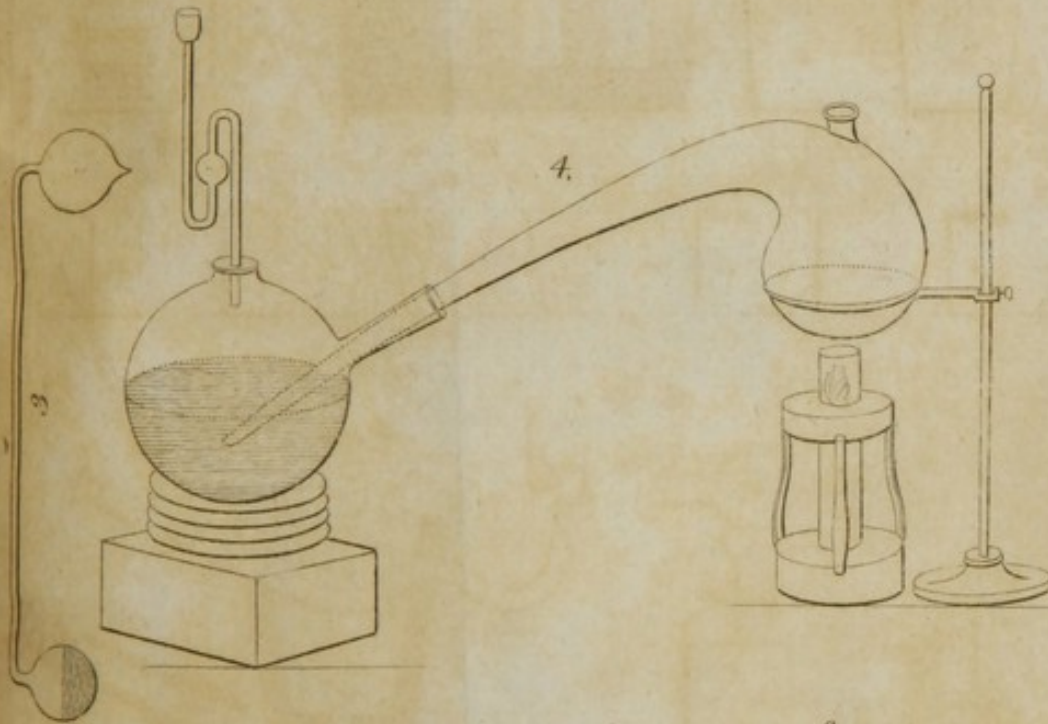
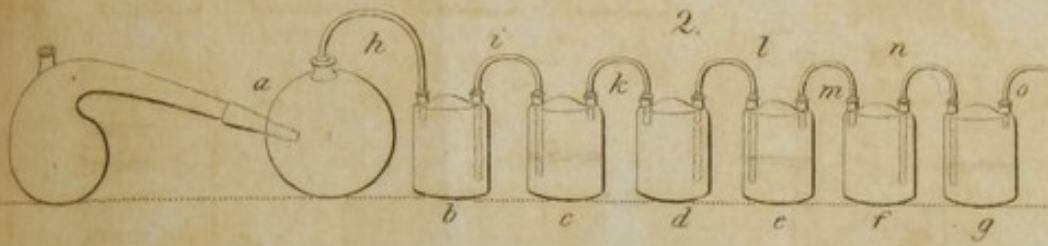


Fig. 1.



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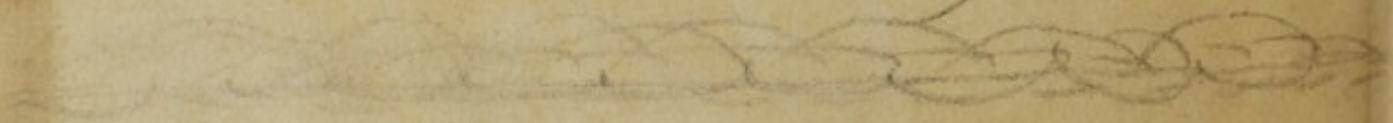
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