Chemical manipulation; being instructions to students in chemistry, on the methods of performing experiments of demonstration or of research, with accuracy and success / By Michael Faraday.

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Faraday, Michael, 1791-1867.

Publication/Creation

London : W. Phillips, 1827.

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CHEMICAL MANIPULATION;

BEING

INSTRUCTIONS

TO

STUDENTS IN CHEMISTRY,

ON

THE METHODS OF PERFORMING EXPERIMENTS OF DEMONSTRATION OR OF RESEARCH, WITH ACCURACY AND SUCCESS.

BY

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London:

PRINTED AND PUBLISHED BY W. PHILLIPS, GEORGE-YARD, LOMBARD-STREET;

SOLD ALSO BY W. TAIT, EDINBURGH;

AND HODGES AND M'ARTHUR, DUBLIN.

1827.

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Ce n'est pas assez de savoir les principes, il faut savoir MANIPULER.

Dictionnaire de Trevoux.



TO

HIS GRACE THE DUKE OF SOMERSET,

PRESIDENT,

TO

THE VICE-PRESIDENTS,

MANAGERS,

VISITORS, AND MEMBERS,

OF THE

Royal Institution of Great Britain,

THIS CONTRIBUTION TO THE SCIENCE,

WHICH HAS BEEN SO EMINENTLY PURSUED IN THEIR LABORATORY AND THEATRE,

IS RESPECTFULLY INSCRIBED

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CHEMICAL MANIPULATION.

INTRODUCTION.

Chemistry is necessarily an experimental science: for as facts are the data from which its conclusions are drawn, and the evidence by which its principles are supported, a constant appeal to them is necessary; and yet so small, comparatively, is the number of these necessary elements presented to us spontaneously by nature, that were we to bound our knowledge by them, it would extend but a very small distance indeed, and that even in an uncertain manner. To supply the deficiency, new facts have been created by *experiment*, the contrivance and hand of the Philosopher having been employed in their production and variation. In reference to the varieties of inert matter, all their possible forms, states, and properties, and the powers which influence them, Chemistry, if occupied only in the observation of such phenomena as are presented by nature, would do little more than record a state of things approaching to quiescence, which has resulted from the active exertion of the inherent powers of matter; and the Chemist would have but little opportunity of observing substances in their energetic state, or of witnessing the actual exertion of the powers inherent in them. Even when such appearances might naturally be presented, either their vastness, their complication, or their rarity, would in many cases prevent the deduction of correct conclusions.

Hence the importance of multiplying facts by every means in our power whilst engaged in the pursuit of this science. If it were our object to learn as much as possible of the nature of a substance taken at random from the surface of the earth, how slight would be the amount of information derived from a consideration of it in its natural state;—we

should be able to decide perhaps that the air did not affect it, that light did not sensibly injure it, that the rain or dews did not dissolve it, that the difference between summer and winter did not apparently alter it, that the ground beneath was not affected by it, and perhaps some other points respecting its nature might be ascertained: but what are these compared to the knowledge gained by submitting it to a high temperature, either alone or in contact with other substances; by subjecting it to the action of other bodies as solvents under peculiar circumstances, and operating upon it in the numberless ways which art and experience may dictate to us. Unaltered as it appeared before, it may now change its form, yield new substances and enter into new combinations, and instead of being the inert lump it appeared, may prove an active and powerful agent in many of the purposes of civilized life.

Such then are the advantages which result from experiment; nor is the case at all exaggerated, for in Chemistry it may safely be stated that more than nine-tenths of the facts upon which the science is founded are thus evolved by artificial means. Without indeed the great body of truth thus furnished, the science could not have existed; for though it is not exclusively, it is preeminently experimental, being in this respect strikingly distinguished from Astronomy, Botany, Zoology, and other sciences, which have regard to appearances and phenomena presented by nature. Hence it derives many of its peculiar charms.

These considerations are abundantly sufficient to shew the intrinsic importance of experiments; and when to them are added those which arise from the great extent and dominion of the science itself over the powers and properties of all matter, and its influence in administering to the wants, comforts and pleasures of life, little need be urged in extenuation of an attempt to facilitate the acquirement of the art of making experiments by students in Chemistry.

Experiment has two principal objects; the extension of our present knowledge, and the proof or demonstration of knowledge previously acquired; in both of which it is essentially necessary to the progress of chemical discovery.

There are also two parts in an experiment; first, it has to be devised; its general nature and principles are to be arranged in the mind, and the causes to be brought into action, with the effect to be expected, properly considered; and then it has to be performed. The ultimate objects of an experiment, and also the particular contrivance or mode by which those ultimate results are to be produced, being mental, there remains the mere performance of it, which may properly enough be expressed by the term *manipulation*.

Notwithstanding this subordinate character of manipulation, it is yet of high importance in an experimental science, and particularly in Chemistry. The person who could devise only, without knowing how to perform, would not be able to extend his knowledge far, or make it useful; and where every doubt or question that arises in the mind is best answered by the result of an experiment, that which enables the philosopher to perform the experiment in the simplest, quickest, and most correct manner, cannot but be esteemed by him as of the utmost value. It is indeed to him like the external senses to the mind, a channel of information by which things before unperceived are made known, and for which he has continual use.

There are many experiments, and even whole trains of research, which are essentially dependent for success on mere manipulation; such for instance are various analytical processes, in which the principles of the process and the modes of detecting and separating the substances being well known, the accuracy with which they are successively separated, and their quantities correctly ascertained, depends entirely upon manipulation. Such is the case in most of the analyses of ordinary siliceous, calcareous, or aluminous stones: such is also the case in the analysis of organic substances by any of the processes recommended in chemical works: it is the same with the manufacture of many chemical preparations; and the separation of four or five gases, a problem of frequent occurrence, is to the chemist who has made but moderate progress even in his studies, a matter entirely of manipulation.

By accurate and ready manipulation, therefore, an advantage is gained independent of that belonging to the knowledge of the principles of the science, and this is so considerable, that of two persons having otherwise equal talents and information, the one who manipulates best will very soon be in advance of the other; for the one may obtain satisfactory results from his experimental enquiries, while the other is left in doubt or led astray by his imperfect reasonings. This advantage may be illustrated by the use of the tinder syringe, a small instrument consisting of a cylinder about half an inch in diameter, and three or four inches in length, closed at one end and fitted with a piston, to the extremity of which a piece of amadou is fastened: by forcing the piston down and compressing the air *suddenly*, so much heat is evolved as to fire the tinder. Some persons cannot perform this simple experiment, whatever may be the strength or alertness which they endeavour to bring into action, whilst others with a very slight force and the mere approach of their hands towards each other in the air, will in every instance obtain the effect desired and produce the required ignition. Were this a new experiment to the persons making it, the object being by its institution to prove whether air when highly compressed gives out much heat or not, the first person would either come to a wrong conclusion, or, if he doubted the success of his experiment, would arrive at none at all, whilst the second would be enabled to form a correct and affirmative conclusion, and thus would have added an important fact to his previous knowledge.

In other cases where the appearances may be such that we have no method of anticipating, or when produced, of correcting them, as in the habitudes of an unknown substance or its action upon other bodies, then careful manipulation is of the utmost importance: without it the appearances produced may arise or be modified by extraneous substances present, or by other causes overlooked; and the conclusions may be erroneous at the time when it is most important they should be correct, because the subject is new, and because from its novelty but a small proportion of previous knowledge

will bear upon the point and help us to correct the error. Nor is the tyro alone thus liable to be misguided; for it would not be difficult to point out instances where the most acute minds have in this way been led to false conclusions.

Another consequence of skilful manipulation is, that by its means a train of research may frequently be carried much farther than its first object, and in two ways. In the first place the occurrence of clear and distinct phenomena, besides proving satisfactorily the direct object of inquiry, frequently suggests to the mind collateral views which, pursued and extended, terminate in additional chains of information and discovery; whereas if the experiments be less clear, though sufficient may be distinguished to satisfy the mind on the subject in question, nothing more is done and no new object or view arises. In the second place the operations may be performed on comparatively very minute quantities, and that which in the hands of one person had hardly sufficed to supply very general information of its nature, may in those of another be made to yield matter for a full and minute investigation, terminating in the developement of its nature and habits, with a perfection equal to that obtained with the largest quantities. Frequent illustrations of the importance of manipulation in thus effecting all that can be desired with small quantities, is afforded in the occasions that arise juridically in testing for arsenic; for the fractions of a single grain, will in the hands of some persons afford the most striking and convincing proofs, whilst many grains will in the hands of others present no satisfactory conclusion.

When the substance under examination is rare, and that is frequently the case both in natural and artificial productions, the facility of working with small quantities is of the highest importance, as otherwise the opportunity of gaining information may be entirely lost, or if preserved is retained only at a great expense. There existed in the British Museum a small fragment of a black stone, the source and history of which was unknown; it was unique, no other specimen being in the Museum or known to be in existence; yet as it presented some peculiar characters, Mr. Hatchett

was induced to examine it, and working with a portion of the stone weighing not more than 200 grains, he was enabled to discover in it a new metal, which he distinguished by its various characters from all those previously known, and which he named Columbium. Ekeberg afterwards discovered a metal which he named Tantalium, conceiving it to have been observed and distinguished for the first time by himself; but Dr. Wollaston, who examined it and compared it with Columbium, was able to identify it with that metal, although he had not more than five grains of the stone from the British Museum upon which to make his experiments.

Finally, habits of correct and delicate manipulation very much facilitate experimental enquiries at all times. It is not in difficult researches only that it is desirable, but even in such common operations as testing for lime, or iron, or sulphuric acid, its advantages become manifest; for either time is shortened, or the apparatus considered as necessary is diminished, or effectual substitution is made for those that may be wanting, and thus the experiment becomes easy, where otherwise it would be considered impossible. Besides facilitating such inquiries, it also diminishes the expense both in materials and apparatus, and it produces beneficial habits in the mind by exercising it both in invention and perception, even in this subordinate part of its operations. "Nothing," as Dr. Johnson observes, "is to be considered as a trifle by which the mind is inured to caution, foresight, and circumspection. The same skill, and often the same degree of skill, is exerted in great and little things."

The importance of instruction in manipulation has long been felt by the author during his professional experience as a public and private teacher of Chemistry in the Royal Institution; and the deficiency existing in the means of teaching it, induced him to think he might perform an acceptable service by putting together such information on the subject as there was reason to suppose would be generally useful to the student. No book contains those minute directions which are necessary in the present extensively cultivated state of the science, nor can verbal instruction

teach that perfection of manipulation which is only to be gained by constant operation; but there is so much that can be taught, so much that can be suggested by such instruction, that it seems extraordinary that not one of the many treatises upon Chemistry has been devoted to this subject, especially when it is considered that of the great numbers who now desire, or are assumed to have some knowledge of Chemistry, very few have access to competent practical sources. Lavoisier's elements is the work which appears to the author to contain the best general directions, but every pupil to whom it has been shewn, has found it to fall far short of his necessities.

Such are the considerations which have given rise to the present work, and under their influence it has been composed. The object of the volume is to facilitate to the young chemist the acquirement of manipulation, and by consequence, his progress in the science itself. It does not attempt to inculcate the *principles* of the science, but the *practice*; neither does it claim to teach *a habit of reasoning*, but has solely in view the *art of experimenting*; and though sometimes it may be necessary to speak of the properties of bodies, or to draw conclusions, it will always be done in subordination to the main object. The volume indeed is not intended to supply the place, or imitate in its nature, any one of the numerous and useful works on Chemistry now extant, but to be rather an accompaniment to all of them, supplying that portion of knowledge which however essential to the learner, was not of a nature to consort with their more scientific contents.

In the pursuit of this object it is intended to describe

The conveniences and requisites of a laboratory.
Chemical apparatus and its uses.
The methods of performing chemical operations.
The facilities acquired by practice, and
The causes which make experiments fail or succeed.

Although a laboratory will be described in a complete state, well appointed, and with all the conveniences that the

author is acquainted with, yet it is intended that the directions shall be such as to enable the experimenter to perform the operations, when desirable, with the smallest number of requisites; for though many may wish to be made acquainted with all that is useful, yet to far more a knowledge of the few essentials are of the greatest consequence. To omit the description of a complete laboratory in a work devoted to chemical experiment would of course be erroneous; but it would certainly be a much greater error to omit shewing, as far as the author's knowledge will serve him, how many things may be dispensed with in cases of necessity, and how few are the absolute requisites for the greater number of operations. The general principles upon which apparatus is formed will be inculcated for the purpose of leading the student to the *ready substitution* of one thing for another, and to that *contrivance*, by which the wants of the operator may be obviated; and therefore *small*, *temporary*, and *generally useful* apparatus, will be pointed out as often as possible.

It is not intended to describe processes particularly, such as the preparation of each of the acids, or of the alkalies, or of other important substances; or such as are numerous in the chemical arts, though reference will probably be frequently made to them. The work is intended principally to assist in obtaining a knowledge of the chemistry of research, and not the chemistry of the arts, or rather, not of the ultimate and refined processes of chemical preparations; otherwise than as, the principles being the same, the instruction which is advantageous in the one case will be useful in the other. The book is principally for beginners, but this will not induce the author to reject as improper any information he may have to give relative to the facilities of making experiments, though they may relate to the production of refined and abstruse results. Lastly, it may be remarked, that it is intended for a country where most of the requisites are supplied in trade.

Professedly disclaiming a scientific character, the arrangement of the volume is one of mere convenience, but it has not been adopted without considerable thought. As the

work was not intended to teach the principles of Chemistry, but to be a useful laboratory companion, that arrangement was considered as best, which though not scientific, seems most convenient for including the different parts of manipulation, without any great violence to the relation of the whole subject. It has therefore been divided into *Sections*, or principal divisions; the object of each, however, has not always been strictly adhered to alone, since it has often been found convenient and useful to include information on other points, which nevertheless have always some degree of connexion with the subject under consideration. Those who may read the work for instruction will probably not find many difficulties in the arrangement, particularly as they will be aided by a copious index.

Such are the objects of the present book, and the means by which their attainment has been attempted. That it is faulty the author has no doubt; indeed he is thoroughly convinced it cannot be otherwise. It contains little more than the experimental practices and methods of one person; and though in the more ordinary operations of chemistry the author's may resemble those of most other chemists, and therefore be well adapted for general adoption, yet in those peculiar facilities that others may have attained by operating, it must necessarily be imperfect. Acquisitions of this kind made by any chemist must be in relation to his particular trains of research; and as there are but few who possess the power of ranging through the whole of this extensive science, it cannot be expected that every one should have perfect knowledge of the facilities belonging to all departments of experimental chemistry. The author has been anxious that omissions of importance should be as few as possible.

Finally, he has to observe with reference to the pupil's expectations in consulting this book, that even supposing it were perfect, it could still only point out the methods for him to *practise*, and thus, aided by the principles of the science detailed in other works, and the experimental directions in the present volume, he must perfect his knowledge by study and the labours of his own hands.

SECTION I.

The Laboratory.

1. INASMUCH as the Laboratory is a spot where every chemist will pass a great portion of his time, it is natural that its arrangement and furniture should at first claim much of his attention; for being the place peculiarly fitted up for the performance of chemical experiments, fitness for that purpose must have material influence over the facilities to be found in those practical exercises, which by their results are so important in the formation and correction of his opinions.

It is however very curious, and at the same time instructive, to remark the different views taken by chemists as to the essentials and requisites of a laboratory. Some will not think it approaches to perfection unless it consists of a large room on the ground floor, well stocked with tables, cupboards, furnaces, and various other etceteras which may be judged to be convenient; and having in connection with it a second room, dry, comfortable, and fit for the reception of the balance, air pump and similar apparatus, and a third apartment, which however may be a kitchen, or even a cellar, intended to contain moveable furnaces, bricks, tiles, sand, and the numerous rough materials which are now and then required; whilst others will be satisfied with a small cupboard, and think *that* sufficient to contain all that is requisite for their operations. Much of this variety of opinion depends upon the difference in the pursuits of the persons. He who studies chemistry by microscopical experiments, testing the qualities rather than ascertaining the quantities of matter, may find a cupboard abundantly sufficient for his operations, or may even pack all his requisites on a tray; whilst the person who is engaged in metallurgical processes, in extensive experiments on gaseous matter, or in the applications

of chemistry to the arts, will find a laboratory essential to his progress. Part of the difference in opinion is founded however on mere matter of taste and inclination, and those who love the science, and are in circumstances to pursue it liberally, will probably never think a damp kitchen or a small attic sufficient for their purpose. It was in a spirit of this kind that the late Dr. Marcet, when he purchased a house on the banks of the lake of Geneva, which unfortunately he did not live long to occupy, appropriated one of the best rooms in it to the purposes of a laboratory, not knowing, as he himself said, why he should not do what he could to make that a pleasant place where he found so much pleasure.

When the laboratory is attached to a public institution, where it is devoted to the progress and teaching of the science, and where it is intended to facilitate the researches of two or three persons at the same time, it must necessarily be of a large size, possessing the accompaniments of an apparatus and a store room, and all the facilities which have been found useful in variety of research and in extensive operations.

Hence it may be observed that in various circumstances, the place may be either large, of a moderate size, or small, and yet not in the first case exceed, or in the last fall short, of what is required. In a volume like the present it will be proper that a good and convenient laboratory should be described with all its requisites and accompaniments, the whole being adapted according to the convenience of the person who may for the first time be forming his chemical establishment.

2. If equally convenient it is generally better that the room to be converted into or built for a laboratory, should be on the ground or basement floor, as water is then easily laid on, the foul water from the sink can be readily conveyed away, and coal, carboys, and other dusty and heavy articles more conveniently carried into it. The size, as has been before intimated, may vary very much, but a room of from 20 to 24 feet by 16 or 18 feet, will well answer the purpose. Where however it is otherwise unimportant, the size

of a laboratory intended to be actively used, should be as large as possible, otherwise when chemical apparatus accumulate, and several sets of experiments are in progress at once, it may be found that confusion and error arise solely from the want of room.

3. If the place is to be built for the purpose, then no difficulty will arise in the construction and arrangement of the flues and lights, which, though of great importance, cannot usually be introduced or altered easily in a room already finished. Where the opportunity occurs, the place should be furnished with several flues, and an advantage is gained if their terminations in the room are separated by some little distance from each other. Sometimes it is easy to spread these over one side or wall of the room, the stack in which they unite being carried up immediately in their neighbourhood. One flue is essentially necessary for the draught of the furnace, which will be lighted daily for ordinary operations, and the ventilation and warming of the place. Another is in many cases essentially requisite for the construction of a wind furnace; another or two are desirable to serve as vents for the conveyance of fumes, or at other times to be connected with moveable furnaces. The lower extremity of each is generally best terminated by a stone in the wall having a round aperture: when out of use this is to be closed by a stopper; when in service the stopper is to be withdrawn, and the flue continued by a piece of funnel-pipe fitted loosely into the hole, the pipe being continued to the furnace in operation, or otherwise terminated according to the use to which the flue is to be put. All of them should have dampers, that perfect government of the draught may be obtained. If but one flue can be had, it must be turned to account in the best way possible, either by making it divide and terminate below in two or three places, using brick-work or funnel-pipe as may be convenient, or by supplying the place of furnaces and apparatus requiring flues, by substitutes in which they are dispensed with, in the manner hereafter to be described. When necessary a brick flue may be altogether omitted, and its

place supplied by funnel-pipe, but the arrangement is almost always uncomfortable and inconvenient.

4. It is generally a matter of indifference, or at least of taste, whether a laboratory have sky-lights or windows, but it is always an advantage to have it well lighted. Sky-lights throw the light very agreeably over sand-baths and furnaces, and are exceedingly convenient in crucible operations, in consequence of the manner in which the light falls into the vessels. One side-light should however in all cases be provided, for the purpose of observing most advantageously the action of reagents. Where upon the addition of test solutions only faint opalescence or colour is produced, considerable management is at times required for its observation in the most advantageous way, and in these cases, and generally indeed in testing, a side or window light is by far the best. There is another point relative to the admission of light to a laboratory, which in the present state of chemical science is worthy of consideration. The solar rays have been found highly influential in causing chemical change: they effect combinations and decompositions in a manner unattainable by any other agent, and are now frequently resorted to, not merely in the preparation of peculiar substances, as phosgene gas, chloride of carbon, &c. but also in the processes of analysis, as where chlorine is an agent used, and likewise in new experimental researches. It would be well therefore in the construction of a laboratory, to provide if possible for the direct admission of solar light, and this is the more desirable inasmuch as, were it always attainable, chemists would more frequently try the chemical powers of this peculiar agent, at present but little known, and would probably add rapidly to the comparatively small stock of knowledge we possess concerning it.

5. The mode of lighting a laboratory is to a considerable extent connected with its ventilation, and the necessity of rapidly changing the air of the place, when required, should be kept in view; for though much may be effected by means of hoods and flues, yet it is impossible at all times to prevent the contamination of the atmosphere by the general diffusion

of deleterious vapours or gases through it to such an extent as to render an immediate change of the whole very necessary.

6. There are several large articles of great utility in a laboratory which may be almost considered as fixtures, and which require consideration in the first place, on account of the comparative permanency of their arrangement. Of this kind is the general furnace, the tables, the sink, the cupboard, the shelves, &c. The first of these, or *a general working furnace*, is in my opinion very important from the extreme facility which, when conveniently constructed or arranged, it gives to every ordinary operation. Its use is partly domestic, partly chemical; for it has to warm and air the place, occasionally to heat water, as well as to supply the means of raising a crucible to ignition, or of affording a high temperature to flasks through the agency of a sand bath. These objects are best obtained by those furnaces which are built with a table top. The fire place itself is constructed of brick work with iron front and fittings, and the flue being carried horizontally for three or four feet, is afterwards carried off to and connected with the main flue existing in the wall. The fire place and horizontal flue are covered with a large plate of cast iron of from two to three feet in width; this is formed in the middle, over the heated part, into sand baths; a round moveable one over the fire itself, and a long fixed one over the flue. The sand baths supply every gradation of heat, from dull redness if required down to a temperature of 100° or lower, whilst on each side of them exists a level surface, which answers every purpose of an ordinary table, and supplies extraordinary facilities to experiments going on in the sand bath or furnace. Nor are these advantages gained by any serious sacrifice of heating power in the furnace itself, for it is easy so to construct it as to make its ordinary combustion not more rapid than that of a common fire, and yet by closing the fire door and opening the ash pit to obtain a heat that will readily melt gold, silver, or cast iron.

A furnace like this is best placed in the middle or towards one end of the laboratory independent of the wall, for then it most effectually warms the air of the place, and there is

working room all round it; the flue may then either descend and be carried off for a short distance under ground, or it may be connected by funnel-pipe with the upright draught chimney. But if more convenient, either as occupying less of the room of a small laboratory, or for other reasons it may be placed with advantage against one side, and where the laboratory is made out of a room previously built, the best situation is generally against the fire place, and the flue of the furnace is then easily connected with the chimney previously existing.

7. When a furnace of this kind stands against the wall, it is frequently advantageous to construct a wooden hood over the sand bath, to receive the fumes evolved during the digestions and solutions made upon it, and conduct them away to the chimney. An extensive hood however requires a separate flue, or it will injure the draught of the fire; and if the furnace be in the middle of the laboratory, a fixed hood of any kind interferes with its convenient use. It is generally better in these cases to adopt the temporary hood and contrivances which will be described hereafter. A particular description of the construction of the furnace itself will also be given under the head of furnaces.

8. The *tables* are most important parts of laboratory furniture; they should be as extensive as the room will admit of, and be so placed as to allow of ready access; hence a large one, or two placed towards the middle of the room, and in such a situation as to be well lighted, are very useful. They should be made strong, and be furnished with drawers, unless indeed one be closed in by doors, so as to form cupboards having shelves within to hold rough articles; and if such a one could have a situation given it near the sink, as a kind of cleansing and washing table, its advantage would soon be experienced. The table appropriated to testing operations and experiments with corrosive fluids, as acids and alkalies, is sometimes covered with lead, or even with earthenware, glazed tiles being very convenient for the latter purpose.

9. There are some things which necessarily have their appropriate and constant place on the tables. The *filtering*

stands are of this kind, and are thus raised to a convenient height for operations: they should have a situation chosen for them, which though convenient for use and close to the table to be kept clear for general purposes, should not be in the way of the constant operations going on there. A drawer or other dry place in the immediate neighbourhood of these stands, should be appropriated to filtering paper. The mercurial trough is another apparatus which should have its assigned place upon the tables, and the particular table upon which it stands, or upon which mercurial operations are generally performed, should have a groove cut round it near to the edge, with a hole in one place for the facility of collecting the scattered mercury. Any of the metal which may be spilled is swept or wiped into the groove, and thence into a hole, and thus collected and preserved.

10. A *sink*, with an abundant supply of water, is very important, and although it is possible that a jug, with a large leaden funnel and a pan beneath, might suffice, yet so advantageous is the unlimited use of water, and a regular sink with its drain, that much should be done to secure them. The water should be laid on from a cistern that contains a never failing supply; and the sink should be made of strong wood work lined with lead, for though that metal is liable to the action of mercury and some metallic solutions, yet on the whole it is less subject to chemical action than any other substance ordinarily placed in a similar situation. The sink should be made as large as convenient, not exceeding 30 inches by 42, and should have a drain which will freely carry off all the slops and water that are likely to be thrown down. An iron stink trap should be placed at the commencement of the drain, not merely for the purpose of preventing unpleasant smells, but for the retention of the mercury that is gradually washed away, and which in an active laboratory of research amounts to no small quantity in two or three years. A sink is useful not only for washing bottles, glasses, jars, &c. but for many chemical operations, such as filling airholders, washing minerals, preparing gluten, &c. and should be made convenient for all these purposes. It will of course be placed in a corner, and as much out of the way as is consistent with

its free use, a place in the immediate neighbourhood being appropriated to its cleansing accompaniments, pails, pans, brushes, brooms, &c.

11. *Cupboards* are very useful, and at least one large one with shelves inside ought to be provided. In these are to be kept clean test glasses, jars, measures, retorts, flasks, receivers, &c. for here they are preserved from the dust and dirt which is constantly moving and settling in the laboratory itself. The shelves should be placed at different intervals, so as to receive glasses of various sizes; and one or two of them should have a number of round holes cut out from an inch to four inches in diameter to receive the necks of retorts, flasks and receivers. Between the shelves should be fixed various hooks and nails to hold and retain tube apparatus, such as syphons, detonating tubes, tubes of safety, &c. One cupboard shelf should be particularly appropriated to receive products of experiments in progress which have to be preserved for a few days; or things which being valuable are but rarely required, as potassium, &c.

12. All parts of the walls of the laboratory within reach and conveniently situated, should be fitted up with shelves in a firm manner to receive bottles and jars. These must vary in strength, size and interval, according to their intended uses; such as are to hold the bottles containing the usually extensive and continually accumulating series of chemicals, need seldom be of greater height or depth than to receive a six or eight ounce phial standing close against the wall. Those intended for the jars of the pneumatic trough, must be wider and at greater intervals, and those again which are intended to hold the stock bottles must be considerably stronger, in consequence of the weight to be borne by them. In arranging the shelves it will be proper to pay attention to their situation; the first series for instance containing the chemicals and tests in constant use, should be near the table upon which operations are most generally carried on, whilst the stock bottles may be put upon shelves considerably out of the way. A shelf near the sink, with holes in it, upon which apparatus which have been washed and rinced may be placed to drain, is very useful,

and two or three others in the same neighbourhood, or somewhere out of the way, supply places for chemical lamps, oil cans, and other dirty articles that cannot but exist in a laboratory.

13. Analogous in its office to the shelves is the tube rack; it is intended to hold pieces of glass tube from one to three or four feet long, and generally consists of a shelf about three feet long and from six to eight inches wide, having a piece fastened on so as to form a raised edge about an inch high: or it might be made with some advantage by driving three or four long pins or holdfasts into the wall in a line, the end of each being turned up: no wooden bottom is in this case used, and the piece of glass tube required is more readily selected from among the rest, than when upon a rack of the other kind; the smaller pieces are, however, apt to fall through.

14. A part of the wall should be selected to be furnished with long spikes, either by driving them into the brick work or fastening up a board to which they are attached. These serve to hold retort and flask rings, and large bent tubes, such as syphons, curved pieces, &c.; smaller spikes will answer a similar purpose for the numerous coils and pieces of wire that are continually required for use.

15. One or two large wooden blocks will be found useful in a laboratory; they may serve as bases on which to put heavy mortars, and one of them will form a good support for a spike or anvil. They should have their appointed situations on the floor.

16. A set of ten or twelve small blocks of wood, about four inches square and of different thicknesses, from half an inch to three inches, are also of great service in supporting parts of apparatus at different heights.

17. Some consideration must be given in appointing the places of the various pieces of apparatus and furniture in most common use; and their relation to the tables, the bottles, and each other, must be taken into account. The pneumatic trough is in constant service, and must not therefore be far from the centre of activity, or situated in a dark place: access to it should be ready, and communication

from other parts open and free. The jar shelves should if possible be placed near. The mercurial trough already mentioned as standing upon the table, should be similarly circumstanced. The table blow-pipe is a very essential article, and in continual use: it should have a place against the wall near to its appendage, the tube rack. The dirty, but useful coal box, should have a convenient but low and unobtrusive situation given to it, that it may fully perform its part without interfering with the uses or advantageous situation of other things. It can hardly be imagined without experience how much is gained by an attention to these details; for though an operation may, either from its desultory nature or its subordinate character be of little consequence when considered separately, yet when it has to be repeated again and again, and from its recurrence is continually entering into the business of the day, it attains a degree of importance which makes its ready and accurate performance of the greatest consequence.

18. The necessity of such things in the laboratory as flasks, retorts, receivers, bottles, phials, mortars, &c. will be evident, but any information respecting them will be most advantageously given as we advance. They are better supplied as they are wanted, rather than by a previous order, and in that way the accumulation of what is unnecessary, is to a great extent avoided.

19. But there are other things, properly denominated tools, which being always useful, should be immediately procured. Amongst these, an anvil, or spike, with its foot-block, should stand on the ground, and a vice should be fixed against one of the tables. Two or three hammers, including one intended for mineralogical purposes, some cold chissels, a screw-driver, a saw, cutting chissels, gimblets, brad-awls; half-round, flat, and small three-square files; half-round, flat, and rat-tail rasps; pincers, pliers, forceps, a trowel, a soldering iron with its appendages, a glue-pot, are the tools which, with a collection of nails and screws, will be found necessary: and to these may be added a saw-knife for cutting soft brick, coarse spatulas, either of wood or bone, or made from iron hoop, and a cork-screw.

20. There are several articles which may be considered as materials in a laboratory. Bricks are often wanted to build up temporary furnaces, or to form supports: mortar is consequently useful; sea-sand is required for sand-baths and other purposes, and is readily obtained from the bricklayer. Corks are useful in a thousand ways, and should be provided of good quality, and of all sizes, from a large bung downwards: old cards are extremely convenient. Matches, string, and bladder, are also necessary.

21. Many of these useful articles are best preserved in drawers, and hence the necessity of a number of these receptacles in a laboratory. If the tables do not supply enough of them, it will be desirable to have a strong rough set exclusively for these purposes. The appropriation of drawers requires some method; one should be appointed to receive fragments of glass tubes too small to remain in the tube-rack; another should be kept exclusively for the reception of those useful laboratory vessels, glass tubes of various sizes closed at one end; another, from containing corks, will be the cork drawer; another, the tool drawer; the files and rasps, however, being from their quantity and general use, worthy of a drawer to themselves; the valves or glass plates, stirrers and tapers, used in the laboratory, will also occupy a drawer; string, with bladder, and sand-paper, another; and tow, with dusters, another; drawers being the most convenient places for these things. One drawer should be divided within into various compartments intended for different small apparatus, as blow-pipes, forceps, a scratching diamond, platina foil and wire, &c.

Besides drawers, a few small strong wooden boxes are convenient in a laboratory for containing lime, lute, manganese, sand, &c. and a few wooden trays are exceedingly serviceable for removing apparatus.

22. Distilled water must be included among the chemist's requisites, and so much advantage is gained by its abundant supply that any accessible source should be eagerly sought. Distilled water in large quantities is by no means uncommon in towns, for in consequence of the nu-

merous applications of steam the opportunities of collecting it are frequent. Wherever steam is used for the conveyance of heat through pipes, the condensed water may by a very little contrivance be collected in abundance, by placing a clean cask or vessel under the place where it issues forth. Such water must of course be tested to prove its purity, that being rejected for laboratory use, which from any derangement in the pipes or other circumstance is found to be impure. Where the laboratory cannot be supplied in this way, the water must either be bought or distilled; the furnace before described (6.) is extremely well adapted for the application of a still for this purpose. Distilled water is best preserved for table use in a bottle holding about a quart, or three pints, which should be quite distinct in its form or appearance from any other bottle in the laboratory, so that no mistake may at any time arise.

23. A flint and steel, with matches, or what is a far better thing, an eupyrion, should always be conveniently placed in the laboratory, and near to it a candle and candlestick. The little apparatus, called Hertner's Eupyrion, is now so well known in most towns that no difficulty will exist in obtaining it. To those who do not know the instrument, it may be as well to observe, that it consists of a very small bottle half filled with asbestus, rather closely pressed, and moistened with very concentrated sulphuric acid, the quantity being such that though it thoroughly wets the asbestus it cannot flow amongst it or upon the sides of the bottle; the bottle is closed by a good tight cork, and should never be opened except when a match is to be introduced, and immediately the latter is withdrawn, it should be closed again. The matches are small slips of wood tipped with sulphur in the usual way, but they are then again tipped over the sulphur by being dipped for the eighth of an inch into a mixture of three parts by weight of chlorate of potash, and two parts of starch or sugar, mixed with a little vermilion to give it colour, and water enough to make it into a thin paste: this is allowed to dry thoroughly. One of these matches suddenly dipped into the bottle so as to touch the sulphuric acid and snatched out

again, will immediately inflame. For the eupyrion may be substituted the phosphorus bottle, made by stirring a piece of phosphorus about in a dry bottle with a hot wire; the phosphorus undergoes slight combustion, and forms a highly combustible coat over the interior: a common sulphur match rubbed against the inside of the bottle and drawn out into the air, immediately inflames; or if it should not do so, a second stir with the hot wire, or two or three days rest, will generally render the bottle a good one. It should be closed by a glass stopper so as to prevent access of air, except at the short momentary intervals when it is in use. Both this and the eupyrion are to be preferred to flint and steel.

24. There remains little besides to perfect the preliminary furniture of a laboratory. A blank writing paper book should be upon the table, with pen and ink, to enter immediately the notes of experiments. A chair may be admitted, and one will be found quite sufficient for all necessary purposes, for a laboratory is not the place for persons who are not engaged in the operations that are going on in it.

25. Having thus described the laboratory, it will easily be understood that great advantages would arise from the association of another room or two with it, which nevertheless may be dispensed with. A good balance is a very delicate piece of apparatus, and is soon injured and deranged if exposed to the attacks of the damp and corrosive vapours that are continually floating about in the laboratory, in which it should be allowed to remain as little as possible, and yet from its constant use should not be far removed. If there be a small dry room at hand, therefore it is very convenient generally to keep the balance in it; and there the air pump and its receivers, the electrical machine, Leyden jar, and a quantity of delicate apparatus, will usually be its companions.

26. On the other hand, such things as lute sand, charcoal, coke, bricks, crucibles, voltaic troughs, carboys, &c. do not require a dry place, and would even cause injury if kept in the same room with the balance; yet it is advantageous if otherwise convenient, to remove them from the laboratory

into a separate place, that the former may be left unembarrassed and clear for operations. These therefore would go very properly into a dry cellar or covered shed, or any place that would suit as a rough lumber room. Still it may be observed, that these places are not essential, and where the laboratory establishment is but small, all the delicate apparatus may be put into a dry cupboard, and the other things find their situation in the laboratory itself.

27. It was at first intended to annex a plan of a convenient and complete moderately-sized laboratory, but the idea was resigned in consequence of the difficulty of exhibiting the essential parts in more than one case out of ten. There will scarcely be two of these chemical workshops which may not advantageously differ in the arrangement of some of their essential points, as well as in the extent of their different parts; some being extensive in one department, others in another. A notion of the most necessary furniture of a small laboratory, or of one to be comprised in cases of necessity on the surface and within the drawers of a single table, may easily be gathered from the manipulatory parts of the present work. If the want of time, or if other circumstances should necessarily limit the pursuit of chemical research, the author would advise one so situated to begin by providing a spirit lamp, a blow pipe, a pair of pliers, some platina foil and wire, a platina capsule, a few Florence flasks, a chemical lamp, a few evaporating basins, a few pieces of quill glass tube, and two or three dozen bottles; with some of the most useful chemicals, as the acids and alkalies, and six or eight of the most important tests; and to purchase all other things as the necessity for them may arise.

SECTION II.

Balance, Weighing, &c.

28. On entering upon a part of this work which relates more directly to manipulation than the matter of the preceding pages, it may be proper to state very distinctly, that the object is not to give information relative to the nature or construction of chemical apparatus in general, but to teach its simplest, most effectual, and accurate use. It will be the endeavour of the author to keep all in strict subordination to this object, and when he enters into the construction and principles of an instrument, it will be solely with a view to the clear comprehension of the manner of using it. Hence a reason for the apparent disproportion which will now and then appear in the details of this subordinate and descriptive part: for whatever the pupil or chemist can himself do towards the correction or construction of an instrument will be fully described, whilst that which must of necessity be done by the workman, will be passed over in silence. To teach a person how to make balance, or to inform him how it is made, is not the object of the writer, whilst, on the contrary, its use is the very point in view: whatever therefore facilitates the latter, or can be done by one who is not a workman, to correct slight derangement, ought now to claim our attention.

29. A chemist cannot do without a delicate balance; it is absolutely necessary to his repetition of the most important experiments of others, or to his own independent progress. If he be an active operator, he will require two or three balances; for the weights with which it is necessary to work being very various, they are almost without limit, and cannot be estimated by the same instrument. Large quantities, if weighed in balances competent to shew minute differences in small weights, would infallibly injure or even destroy them, by flexure of the beam or change in the points of support; and small weights cannot be appreciated in scales intended for

great quantities, because of the strength it is necessary to give the instrument, and the consequent weight, and comparative roughness of the parts. One pair of scales should therefore be provided that will weigh from one ounce up to three or four pounds, or even more, and be so constructed as to turn with two or three grains, when loaded with their greatest weight. They can, when required, be made very delicate and correct, but except in particular cases that is not necessary. Another pair of scales, calculated to weigh from half a grain to two or three ounces with considerable accuracy, and turning with about half a grain when fully loaded, should be kept for laboratory purposes. They will be intended for common use, and should be substituted as often as possible, for the best balance, especially in cases which require the balance in the laboratory: the object being to save the superior instrument from injury by too frequent use, and to preserve it from exposure to the vapours which are constantly evolving in the progress of operations, or from the bottles. The choice instrument should be sufficiently delicate to weigh from 600 to 1000 grains and downwards, indicating distinctly and certainly differences equal to the $\frac{1}{5000}$ or $\frac{1}{6000}$ part of the weight in the scale.

The materials and construction of balances vary so much, as also do the circumstances which influence their purchase, that no general directions on this point can be well given. Whether large or small they are best on fixed supports, and not suspended loosely, although very good ones of this construction are made. They should be preserved from all damp and vapours, and the beam of the large one, if its construction will admit of it, and even of the next pair, frequently oiled and wiped. The more delicate instruments should be cleaned by the maker: much harm is sometimes produced by rough and hasty cleansing, and if, when about to be used, it is seen that a spot arising from rust, or corrosion, or any other cause, exists on the beam or pan of a delicate balance, it is better to compensate for the difference of weight arising from it, by adding a temporary counterpoise to the pans, than to try to remove it previous to the operation. If the balances are so constructed as to pack

into boxes or cases, they should be kept in such cases when not in use. Delicate instruments are always enclosed in cases, and are so fixed in them as to require and admit of their use without removal. When not in use, the cases should always be closed. A loose green baize or linen bag to throw over the balances when in the laboratory and not in use, is serviceable, and whenever of necessity the delicate balance is brought into the laboratory, it should be returned to its proper situation immediately that it is done with. The instrument itself is so expensive, so soon suffers injury, and then has its value and use so rapidly diminished, that every care should be taken of it.

30. The weights for these balances are as various as the instruments themselves. They will be wanted from 3 lb. down to the hundredths of a grain, and will form at least two sets, the one consisting of avoirdupois pounds, ounces, and drachms, and the other of grains, from 1000 down to the minutest fractions. It is usual to construct these weights in sets containing as few as possible in each. Thus 4 weights of 1, 2, 3, and 4 grains, are sufficient to weigh from 1 to 10 grains, and with similar weights of 10, 20, 30, 40, 100, 200, 300, and 400, will weigh up to 1000 grains. The weights might be still further diminished in number by using such as are expressed by the following series, 1, 3, 9, 27, 81, 243, and a series of ten so constructed would weigh any number from 1 to 88,573. But this is not at all desirable in practice, and several of each particular weight, or several sets of weights, should be in use at once.—This will not be necessary with the pounds, ounces, and drachms, because they are comparatively but seldom used in the laboratory, but with the grain weights it is required: for it is desirable, in all possible cases, to refer to the same kind of weights for simplicity of calculation and comparison, and grain weights being those generally and conveniently referred to, it follows necessarily that such are in constant use; this being the case, all delay or difficulty arising from a deficiency of weights should be avoided by an abundant supply. It frequently happens that in the estimation of a loss or gain of weight, or in taking specific

gravities, two or more weights of the same value are wanted, and this, together with occasional losses, will render it evident that there should be a liberal extra quantity. For this reason a small box, divided into compartments, containing a variety of grain weights, from a tenth up to 1000 grains, and intended to accompany the balance ordinarily in use, is exceedingly convenient. It is well to have a perfect set, from 500 downwards to the hundredths of a grain, to be always kept with the best balance, there being two or three sets of the fractions of a grain. Repetitions of those above a grain are in this case not required, but may be supplied when wanted from the laboratory box.

31. These weights are sometimes made of brass, the smaller ones however are commonly of platina. The fractions of a grain should always be of platina, and it would be much better if that metal were constantly used for weights not surpassing 10 grains. Perhaps its expense for heavier weights would sometimes be objectionable, but this is fully compensated by the unchangeableness in weight either from oxidation or corrosion, and the facility with which they are cleaned from ordinary dirt, either by slight wiping or momentary exposure to the flame of a spirit lamp. Where expense is no object, all the weights should be of platina; their permanent correctness compensating abundantly for the increased cost.

Next to platina there is probably no common metal better than brass, of which to construct weights; the larger grain weights, and also the pound series and its divisions, may be made of this alloy. It is of course liable to be affected very materially by the laboratory fumes, and in consequence small weights constructed of it are often rendered useless in a very short period. Keeping them in a close box, retards to a certain degree this kind of injury. The pound and ounce weights are frequently constructed in sets, each weight being hollow, having the form of a truncated cone, and fitting into the others, so as when arranged together to form a solid mass. Such weights are very convenient in arranging counterpoises, the cup form enabling

the largest weight used, to receive all the additional matter added to make the counterpoise accurate, as will be seen in the practice to be described hereafter.

32. The laboratory box of grain weights should include a pair of small brass pincers or forceps, for the handling of the divisions of a grain. The latter are too minute to be moved expeditiously and safely by the hand, and unless the weights be comparatively large, the handling of any of them is liable to communicate extraneous matter, and thus render them more or less inaccurate.

33. Associated with the weights should be some convenient substances for the purpose of counterpoising crucibles capsules, tubes, &c. A little box of clean shot of different sizes mixed together, answers this purpose in part very well; and its contents may be completed by a few pieces of thin sheet lead or tin foil.

34. The balance and weights should be carefully examined at intervals, to ascertain their accuracy, for if they involve unnoticed errors, all the experiments made with them may be worse than useless. Some curious conclusions, tending to subvert most important chemical truths, might be quoted as having arisen solely in this way.

35. The theory of the balance is so simple, that the tests of its accuracy will be easily understood, and as easily practised.* It may be considered as an uniform inflexible lever, supported horizontally at the centre of gravity, and supporting weights of equal distances from the centre, by points in the same horizontal line with the centre of gravity. If the weights be equal, the one will counterpoise the other, if not the heavier will preponderate. In the balance as usually constructed, there are certain departures from the theory as above expressed, some from the impossibility of execution, and others in consequence of their practical utility, and a good balance may be said to consist *essentially* of a beam made as light as is consistent with that inflexibility which it ought to possess, divided into two arms of equal weight and length, by a line of support or axis, and also

* See Nicholson's or Ure's Dictionary of Chemistry, article *Balance*.

terminated at the end of each arm by a line of support or axis intended to suspend the pans. These three lines of support should be exactly parallel to each other in the same horizontal plane, and correctly perpendicular to the length of the beam; and the plane in which they lie, should be raised more or less above the centre of gravity of the beam, so that the latter should be exactly under the line of suspension. It will be unnecessary in this place to speak of the coarse faults which occur in the ordinary scales, these will easily be understood; and from what may be said of the examination of the most delicate instrument, the impossibility of avoiding them without incurring an expense inconsistent with their ordinary uses, readily appreciated.

36. It will be easily understood that a beam constructed with knife edges, resembles the one before mentioned, and supported on horizontal planes by the central line of suspension, as is generally the case, will take a horizontal position, in consequence of the situation of the centre of gravity. The addition of the pans causes no change in this ultimate position of the beam, because they are of equal weights. The delicacy of a balance depends very materially upon the relative situations of the centre of gravity, the central fulcrum, and the lines of suspension. If the centre of gravity be considerably depressed below the fulcrum, then upon trying the oscillations of the balance by giving it a little motion, they will be found to be quick, and the beam will soon take its ultimate state of rest; and if weights be added to one side, so as to make it vibrate, or turn as the expression is, or else to bring it to a certain permanent state of inclination, the quantity required will be found to be comparatively considerable. As the centre of gravity is raised, the oscillations are slower, but produceable by a much smaller impulse, the beam is longer before it attains a state of rest, and it turns with a smaller quantity. When its situation coincides with the fulcrum or centre of oscillation, that being also in the line joining the two extreme points of suspension, then the smallest possible weight will turn the beam (supposing the knife edge and suspending plane perfect), the oscillations no longer exist, but one side or the

other preponderates with the slightest force, and the valuable indication which is furnished by the extent and velocity of the vibrations, is lost. The case where the centre of gravity is above the fulcrum, rarely if ever occurs; such a balance when equally weighted, would set on the one side or the other, that side which was in the slightest degree lowest tending to descend still lower, until obstructed by interposing obstacles; unless indeed the fulcrum was placed considerably above the line joining the extreme points of suspension, in which case the weights in the pans might counteract the effect dependant upon the elevation of the centre of gravity. In balances intended to carry large quantities, it is necessary to place the centre of gravity lower than in those for minute quantities, that they may vibrate regularly and readily, and hence one cause why they are inferior in delicacy, for as a consequence they will not turn (or indicate) except with a larger weight.

37. The vibrations of a balance vary with the quantity of matter with which it is loaded, and the more the weight in the pans, the slower their occurrence. These should be observed, and the appearances retained in the mind, in consequence of the useful indications they afford in operations of weighing. A certain extent and velocity of vibration would, in some degree, indicate to the person used to the instrument, nearly the weight required to produce equilibrium; but the same extent and velocity with a weight much larger or smaller, would not be occasioned by an equal deficiency or redundancy of weight, as in the former case. The weight required also to effect a certain inclination of the beam or to turn it, should be known, both when it is slightly and when heavily loaded. If the instrument turns with $\frac{1}{100}$ of a grain when 600 grains are in each scale, or with $\frac{1}{60000}$ of the weight to be estimated, it may be considered as very good.

38. Balances are sometimes liable to *set*, as it is called, when overloaded. The effect consists in a permanent depression of that side which is lowest; thus if a balance be equally weighted in each pan but overloaded, it will, if placed exactly horizontal, remain so; but the slightest impulse or

depression on one side destroys the equilibrium, the lower side continues to descend with an accellerated force, and ultimately remains down, being to all appearance heavier than the other. Generally speaking, the more delicate a balance, the sooner this effect takes place, and hence one limit to the weight which it can properly carry. This setting of the balance, and the general diminution of delicacy by increase of weight, should be carefully kept in mind. The setting is considered as dependent upon the position of the fulcrum, *below* the line which joins the extreme points of suspension of the beam; the effect which would thus be produced being masked for a time by the centre of gravity in the beam falling below the fulcrum.

39. When the beam, freed from the pans, but supported on its stands, has been found to oscillate regularly and equally, and gradually to attain a horizontal position of rest, it should be reversed, that is, taken up and turned half way round so as to make that arm which before pointed to the right now point to the left. The beam should then again be made to oscillate, and if it performs regularly as before, finally resting in a horizontal position, it has stood a severe test and promises well. The faults which are likely to be disclosed in this way, depend upon imperfections in the work of the middle knife edge and the planes upon which it rest. This edge is made either of agate or steel, and should be formed out of one piece of matter and finished at once; every part of the edge being ground upon the same flat surface at the same time. In this way the existence of the two extreme or bearing parts of the edge in one line is insured; but when the two parts which bear upon the planes, are formed separately upon the different sides of a piece of agate or steel, or what is worse when they are formed on separate pieces, and then fixed one on each side the beam, it is scarcely possible they should be in the same line, and if not it cannot be correct. These knife edges usually rest upon planes or else in curves. The planes should be perfectly flat and horizontal, and exactly at the same height; the curves should be of equal height and their axis in the same line. If they are so and the knife

edge is perfect, then the suspension will be accurately on the line of the edge, and reversing the beam will produce no change.

40. When the pans are hung upon the beam, the balance should of course still remain horizontal. The lines of suspension for the pans are not so difficult to obtain correctly as that before spoken of, but they should be tried by changing the pans, then by reversing the beam, and afterwards by changing the pans again. The irregularities which may in this way be discovered in a balance, can be corrected only by the workman, and are always difficult points in the final adjustment. Faults may exist in a slight degree in a very excellent instrument, and the inaccuracies which might result from ignorance of them may be avoided when they are known, by attention to directions.

41. The length and the weight of the arms are proportionate to each other: the length of each is accurately the linear distance from the middle to the distant knife edges, all the edges being considered parallel to each other and in the same plane. The two arms should accord perfectly in this respect, but the weight is by no means necessarily subject to equality, though it is better that it should be so. One arm with its pan, may be considerably heavier than the other, but from the disposition of the weight in the lighter arm towards the extremity, or in the heavier towards the middle of the beam, the equilibrium may be perfect; and therefore no inaccuracy is caused thereby in the use of the balance. Instruments are usually sent home in equilibrium, and require no further examination than to ascertain that they really are in adjustment as to that particular point; and that after vibrating freely they take a horizontal position. If they should not do so the fault is easily corrected for the time by a small counterpoise.

42. Equality in the length of the arms is much more important, and may be ascertained in two or three ways. Suppose the balance with its pans to vibrate freely and rest in a horizontal position, and that after changing the pans from one end to the other, the balance again takes its horizontal state of rest. In such a case abundant proof

is obtained of equality in the length of the arms. They may however be equal, and yet this change of the pans from end to end may occasion a disturbance of equilibrium, because of the unequal distribution of weight in the beam and pans; but to ensure an accurate test, restore the pans, and consequently the equilibrium, to the first state; put equal or at least counterposing weights into the pans, loading the balance moderately, and then change the weights from one pan to another, and again observe whether the equilibrium is retained; if so the lengths of the arms are equal.

Tests of this kind are quite sufficient for the purpose of the chemist; who having ascertained that his balance, whether slightly or fully laden, vibrates freely,—turns delicately,—has not its indications altered by reversing the beam or changing counterpoising weights,—may be perfectly satisfied with it, and leave the fuller consideration of the difficult points and corrections to the instrument maker.

43. The weights should undergo an examination as well as the balance, and it is necessary to make this with reference to their accuracy when new, and also to their change by wear or corrosion. It is essential in the first place to set out with a good standard, and though this point is of necessity generally left to the workman, yet, when possible, it is very desirable that the 1, 10, 100, and 1000 grain weight should be compared with others of equal value and good authority. The most ready method of detecting errors in the subdivisions, is to make up equal quantities from different weights and compare them together in the balance, a large one being tried against eight or ten smaller, as the 100 grain weight against those of 40, 30, 10, 8, 5, 4, 2 and 1; and then again, from a quantity made up of several, to remove some and replace them by others, as for instance, for the 30 grain weight above, to substitute a 10 and four 5 grain weights. The fractions of the grain should be examined in the same manner, and if any material error exists it will thus readily be discovered. Should the balance in use be one which from accident or other circumstances is

affected in its indications by changing the weights in the pans, then in these trials all the changes should be made in one pan only, the weight in the other being considered as a mere counterpoise, and left undisturbed from first to last. The trials with those weights which accompany the best balance, and are intended exclusively for very delicate experiments, should be made with extreme care.

The examinations which are to take place at different periods to ascertain the continued correctness of the weights, are to be conducted in a similar manner, except indeed when there is reason to suspect the alteration of a particular weight, which will then of course be tried against one admitted to be correct. These trials should be more or less frequent, according to the exposure of the weights; those, which from being continually in the laboratory rapidly change their colour and appearance, will often require examination; but platinum weights are in this respect unalterable, and are liable to very little derangement of any kind from ordinary use.

44. The operation of weighing is very simple, and it is only because in the hands of the chemist it becomes one of extreme delicacy and frequency, that the facilities for its performance require to be mentioned. It should in the first place be ascertained before every operation, that the balance is in order, as far as relates to its perfect equilibrium, and to the freedom of vibration; and also that no currents of air are passing through the case, so as to affect its state of motion or rest; a situation being chosen where such influences may be avoided. If from any accidental cause it be not in equilibrium, it should be balanced by a fragment of paper, or a slip of tin or lead foil. If its vibrations are imperfect and impeded, the cause, whatever it be, must be discovered and removed, or a delicate operation cannot be performed.

45. When the substance to be weighed consists of one or a few pieces only, it is merely necessary to put it into one pan, and to add weights to the other, until the two are in equilibrium. A delicate balance is always furnished with means of supporting the pans, independently of the beam; and the beam itself is also supported when required, by

other bearings than its knife edges; and in such a manner as to admit of the rapid removal of these extra supports, that the instrument may be left free for vibration. This is done that the delicate edges of suspension may not be injured, by being constantly subjected to the weight of the beam and pans, and that they may suffer no sudden injury, from undue violence or force impressed upon any part of the instrument. When therefore a large weight of any kind is put into, or removed from the pans, it should never be done without previously supporting them by these contrivances; for the weight if dropped in descends with accellerated force highly injurious to the supporting edges, or if a large weight be taken out without first bringing the pans to rest, it cannot be done without producing a similarly bad effect. No weight heavier than a grain should be introduced without this precaution, which, besides being requisite for the reason described, is otherwise advantageous.

46. When a weight is put in which is assumed to be nearly equal to the substance to be weighed, the balance should be brought to a horizontal state of rest, this being usually done by the same means as those appointed to support the pans; it should then be liberated gradually, so as to leave the pans wholly supported by the beam. The whole being upon its true centres of suspension, it will be observed whether the weight is sufficient or not, and the rapidity of ascent or descent in the pan containing it, will enable a judgment to be formed of the quantity still to be added or removed. (37). Bringing the balance to a state of rest as before, such quantity should be added, and trial again made; and it is better to repeat this, for every required alteration of weight, however small it may be, than to endeavour to adjust the weight, whilst the whole is suspended from the knife edges, and the pans are swinging in the air.

47. As the weight approaches to equality with the substance to be weighed, the oscillations become slow, and the beam rests in a line more or less inclined, being the same with that above and below which the oscillations are made. The positions of this line may be judged of, therefore, whether the balance be at rest or in motion, and is a mate-

rial indication of the weight to be added or taken away; a person who from observation of the oscillations of a balance and the position of this line, is able to take advantage of the indication it affords, will effect the required equilibrium in three or four trials, when another person unobservant of these points, will not do it in less than ten or twelve.

48. The small weights should always be removed by a little pair of pincers, for when the fingers are used, at the same time that they may leave any thing adhering to them in the pan, they may brush out minute weights. The weights are safer too in pincers than in the fingers. It sometimes happens that the balance appears to vibrate with difficulty or to stick, though no sufficient cause can be discovered. On these occasions a slight tremor given to the instrument, by tapping on the case, or by a vibratory motion, will frequently assist the balance, and confer sufficient delicacy to allow of the operation being completed. The weight should always be estimated when the instrument is at rest, but it should be carefully ascertained by the freedom of vibration, that this rest is the consequence of perfect equilibrium, and not due to the want of delicacy in the instrument or to accidental obstruction.

49. When the balance has ultimately been brought into a state of equipoise, the weight is next to be estimated. The operator generally takes an account of the additions and subtractions as he proceeds, but the resulting quantity should be confirmed by inspection. Remove the weights therefore from the balance, and if there be many, and especially small ones, this is best done by slipping them all out of the pan together into a small basin, or upon a sheet of paper, and then by laying them out, their amount may be ascertained. To detect any error that may have arisen, either in calculation or otherwise, make up the quantity in other weights, the fewer the better, introduce these into the pan in place of the former, and see if they also accurately counterbalance the substance weighed, if they do, the accuracy of the weight is ensured, if not, the cause of the discrepancy must be sought for, discovered and corrected.

50. When the operation of weighing has to be repeated

frequently, as happens in certain parts of analytical processes, it economises time to have the smaller weights arranged in order before the balance; the hundredths together on the right hand, then the tenths, then the grains below ten, and ultimately the large weights.

51. In weighing substances that are hot, great attention should be paid to any effect produced by the ascending current of air, in elevating the pan containing the hot material, and thus giving erroneous results: a silver capsule, weighing 600 grains when cold, appeared to weigh less by seven tenths of a grain when heated by a spirit lamp, and again placed in the scale. If it had previously contained ten grains of a substance, to be subjected to such a temperature, a loss of 0.7 of a grain would have appeared to take place, when actually none might have been occasioned. Beside this probable fallacy, the introduction of a hot substance or vessel into the pan, is liable to affect the arm of the beam above, if delicately constructed, and cause derangement for the time merely by its expansion.

52. Although when the balance is in perfect order, it is indifferent which pan receives the substance and which the weights, it is advantageous always to use the same pan for the same purpose. Attention to this custom, is a correction to a certain extent for inequality in the length of the arms; for though in the latter case a difference must exist between the weight and its counterpoise to produce equilibrium, yet this difference is constant, and the quantities increased or diminished in equal proportions, will equally balance each other, so long as the contents of the pans are not changed. If then the weights are always put into one pan, the quantities weighed in the other, will be in the same proportion as the weights, though not exactly equal to them, and the products of an analysis estimated thus, would be as accurately known as if the balance had been perfect. But if on the contrary, the products were put first into one pan and then into the other, they would sometimes be over-rated, and sometimes under-rated, and would very soon, by accumulation, be irreferable either to the weights or each other.

Attention will be required in practising this rule in cases where frequent alterations in weight are taking place. Suppose carbonate of lime, in a crucible, had been weighed in the substance pan by weights in the weight pan; if it were heated violently it would become quick lime and lose in weight, but this loss could not be ascertained correctly by returning the crucible and lime into the same pan it was in before, and then adding weights to make up the deficiency, but must be done by removing weights from the weight pan; and if a second alteration were effected in the weight, as by converting the lime into a hydrate or sulphate, that must also be estimated by weights added to the weight pan, no weights ever being mingled in the same pan with the substance, but every change in the weight of the substance being estimated in the one pan by a corresponding change of weight in the other.

53. When weighing powders, or moderately divided matter, it is better not to lay them at once on the pan, but upon some interposed substance. For this purpose, two slips or pieces of glass, or two watch glasses of equal weight should be used, one in the weight scale and one in the substance scale. They may be kept clean, and are convenient in possessing the advantage of generally resisting chemical action, and permitting the substance to be washed off them without injury. Or in place of two pieces of glass, one piece, or a little Wedgewood's basin counterpoised, will answer the purpose. But two pieces of paper are generally more convenient, and there are few substances which may not be weighed upon them. Hot-pressed wove paper is the best; its smooth surface preventing adhesion even of the finest powders. It should not be torn but cut, for the fragmented edge would retain a portion of the powder when passing over it; and its form is given and its adjustment easily made by a pair of scissors. Its flexibility is very convenient in assisting to convey the powder into a flask, or other narrow-mouthed or small vessel. All these advantages are obtained by the use of a material, which has in addition those of being very cheap and clean, and the few cases in which it is objectionable, as where the substance to be weighed is moist or deliquescent, are easily distinguished, and its insufficiency then may be supplied by the use of glass or metal.

54. In transferring small quantities of powder from place to place, as for example into and out of the balance, and adjusting them, spatulas are very useful, and one of platinum for this and other purposes, is requisite in every laboratory. It may be about half an inch wide, at least three inches long, and so thick as to resist considerable force without bending; otherwise it will not be the generally serviceable instrument it ought to be. For those who are inclined to indulge in the luxuries of chemistry, a pocket knife with a platinum blade, is a very excellent tool, answering many of the purposes of the spatula above described. With reference to the removal of powders, ivory and bone spatulas answer the purpose well, but in case of the absence of all these, their place at the balance may be supplied by a slip of the same hot-pressed wove writing paper before mentioned, cut from the sheet with scissors. In effecting the ultimate adjustment of the quantity, the smallest portions may be taken by it from the heap in the scale, and by a slight lateral shake, the smallest quantity may be dropped from it into the pan: copper and platinum leaf do not make good temporary spatulas, unless bent down the middle, for they are apt to give way between the fingers, and by their elasticity to scatter the substance.

It is not necessary in weighing out given quantities of powder, 100 grains for instance, to bring the balance to rest every time a little of the substance is added or removed, inasmuch as by a short practice both may be done without communicating any other impulse to the instrument than that resulting from the alteration of weight.

55. In using the balance, the operation very often consists merely in counterpoising, no estimate of the quantity being required, but simply an accurate and temporary weight corresponding to that of the substance or vessel. Platina crucibles, capsules, glass tubes, &c. either alone or with their contents, very frequently require to have their weights thus compensated; for counterpoises should be considered as weights, and go into the weight scale. If but a small one be required, a slip of tin foil, leaf lead, or even of paper or card, will answer the purpose very well, the piece

being trimmed down by scissors till it balances the object in the other pan. If a larger one is wanted, a piece of plumbers's sheet lead is convenient, and may be accurately adjusted by a pocket knife. Besides sheet lead, shot of different sizes, (33) are often used for this purpose, being poured into the weight pan until there is nearly sufficient to balance the contents of the opposite scale, and the final adjustment made by a piece of lead, or tin foil, or paper. When shot are not at hand, the counterpoise may be nearly made up by large weights, and adjusted as before by metal foil. Where the whole consists of many parts, it is desirable that they should be preserved compactly together, lest any portion be dispersed, and inaccuracy introduced. The hollow weights (31) are for this reason very useful in counterpoising; the largest weight that is not too heavy, should be taken, and the requisite addition placed within it. If such a convenience be not present, then perhaps the best plan is to put a piece of clean smooth paper (writing paper if ready) of a few inches square into the pan in the first place, and add weights to complete the counterpoise; the ultimate adjustment can be made as before, or even upon the edge of the piece of paper; when that is done, enclose the loose portions of the counterpoise in the piece of paper, wrapping all up safely together, again see that it is accurate, and then set it aside in the drawer of the balance, or in the place appointed for such things until it is required. In consequence of the change in weight of paper, either by desiccation in a dry place, or the absorption of moisture in a damp one, a counterpoise so wrapped up should be kept in a place similar in dryness to that from whence the paper came, and the chances of change are diminished by any shortening of the time during which it is necessary to be preserved. When the mind is alive to this source of error, it is easily avoided, by keeping paper for the purpose in the place where counterpoises are kept, or by drying the paper and keeping the counterpoises also in a dry state.

56. Sometimes vessels or substances are to be weighed which will not conveniently rest in the pans without a little contrivance: tubes, if long, now and then interfere with the

case containing the balance, and flasks are liable to roll over, occasioning the loss of their contents. Tubes of moderate length, such for instance as are used in the processes of organic analysis, can often in these cases be weighed by the use of a small loose loop or ring of twine, which being slipped over the suspending wires of the balance pan, is to be raised nearly to the top, and then by passing the tube through it, the upper part will be supported, whilst the lower end rests in the pan, the whole being in a position approaching to the vertical. In this case it is necessary that the loop and tube be arranged so that the latter does not touch the beam, or in any way interfere with the free suspension of the pan supporting it.

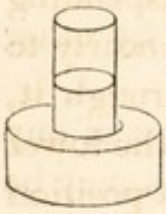


Such a loop is also very convenient in supporting flasks in the balance, for being allowed to descend upon the suspending wires of the pan, it prevents the neck of the flask from passing between them, and retains it in a position sufficiently vertical to avoid the loss of any of its contents.

57. Many balances, in order to facilitate their various uses, have a hook at the bottom of each pan: to this a thread or wire is readily attached, and being terminated beneath in one or more loops, is easily made to sustain a tube or other article to be weighed, which from its inconvenient shape will not lie safely in the pan itself.

58. When it is required to weigh liquids, they must of course be retained in some convenient vessel, the weight of the vessel being in the first place either known, or counterpoised, or ascertained by an after operation. Glasses, flasks, capsules, and small tubes, are all useful in turn to retain fluids. The glasses and capsules will stand readily in the pan, and the flask may be supported as before mentioned (56.) by the loop of twine, or by being placed upon a small wooden ring about two inches in diameter and an inch wide, covered with list, which serves as a temporary foot. The tubes will more frequently be required to contain scarce fluids, or perhaps such as have actually been formed in them during an experiment, and will often want supporting. It is for this and for many purposes of adjustment at the

balance, convenient to have two rings of good cork, about three quarters of an inch high, kept with it, fitting loosely into each other, and having for the internal diameter of the smaller, half an inch, and for the external diameter of the larger, two inches. These will support most tubes in a more or less inclined position; and in any case where they will not answer the purpose, a temporary stand is easily made out of a cork by piercing a hole through it with a rat-tail rasp, of the proper size to receive the tube.



59. The listed rings referred to above are exceedingly useful in the laboratory for the support of retorts, flasks, globes, receivers, and all vessels of a circular form. They are easily made out of a slip of thin pliant wood, or a piece of sheet copper, the rough ring being covered by rolling list round it. A number of them should be provided for laboratory purposes, from two to six inches in diameter, and of different heights.

60. Where a certain weight of fluid is wanted, its final adjustment is easily effected by several methods. If it be water or alcohol, or a substance that does not act upon paper, it is best to add a little over weight, and then to remove the excess by bibulous paper. If a piece of filtering paper be folded up several times in the same direction it will form a loose rod, the end of which being dipped into the fluid rapidly imbibes a quantity by its porosity and capillary attraction: when it has risen about an inch in the paper, which it will do instantly, if the moist piece be pulled off and the fresh end again immersed, a second portion will be taken up. Upon pulling off the moist end, especially if done by a hard pinch extending slightly over the dry part above, a ragged extremity is left, which by a little management in dipping the paper into the fluid obliquely, may have a pointed form given to it. This may be used in removing either large or small quantities, and is very convenient for the final adjustment of the weight: by allowing a few of the filaments only which remain to enter the fluid, the latter passes up slowly, and its quantity may be judged of by the gradual progress of the moisture above; so that with very

little trial the precise quantity required may be removed. Such at least is the case with water and most aqueous solutions. With alcohol, fixed and volatile oils, it is not so, because the imbibed part does not separate with particular facility from the dry portion, or leave the useful filamentous edge spoken of. The final adjustment is here however easily made by a slip of paper folded once or twice, or by other means to be described.

61. There is no difficulty in the rough adjustment of any fluid; for even when corrosive, the larger portions may be removed by dipping into it a small capsule, or a spatula: in these cases the final adjustment may be completed by taking up the small remaining excess by means of a glass rod. Upon dipping a rod into a fluid and withdrawing it rapidly, as much as would be contained in three or four drops may be readily and neatly removed; the rod being cleaned, more may be taken away by reapplying it: as the quantity removed is proportionate in some measure to the moistened surface of the rod, it is evident that by using one which is conical at the end, the smallest desired quantity can be taken up at once, and the adjustment accurately effected.

62. One other mode of adjustment it may be well to mention, leaving the many varieties which may be conveniently devised, as occasion may offer, for spontaneous suggestion. It is sometimes necessary to weigh out a certain portion of a fluid, which from being a new product or the result of a peculiar experiment, and small in quantity, will not admit of the slightest waste. A tube about the eighth or tenth of an inch in diameter, drawn out to a capillary termination, is then very convenient. If its fine extremity be immersed



in the fluid, which we will consider in excess in the balance, capillary attraction causes a portion of it to enter the tube; if enough be not removed, by inclining the tube, more will enter in consequence of the diminished perpendicular height of that within; if too much be removed by the second insertion, an elevation of the tube into a position more perpendicular will cause the passage of a portion from it into the vessel; and in this way more or less may be taken away and accurate adjustment obtained. Should the

fluid be tardy in its motion within, from the dryness of the interior or smallness of the lower aperture, it may be helped whilst passing in or out, by applying the mouth of the operator to the upper orifice; but this should be avoided generally, lest any portion of moisture be introduced. When it is necessary to lay the tube down, it may be placed in a position nearly horizontal across a glass or ring (59), or any ready support, the lower small extremity being out of contact with any other substance. When the operation is finished, the quantity which ultimately remains upon the tip of the tube, the only part that has at any time been immersed, is so small as to be no object, and this is the whole of the waste incurred. The portion remaining in the capillary tube is to be restored to what is left of the original quantity.

63. Peculiar management is required in estimating the weight of certain substances which rapidly undergo change, and are hence liable to alterations in weight during the time occupied in the performance of the operation. Suppose for instance it were necessary to weigh some hydrate of chlorine obtained by compressing the moist crystals produced at temperatures below 40° within folds of cold bibulous paper; or that the weight of hydrated chloride of calcium in crystals, and dried in the same manner, by compression, were required; the first would evaporate in the air, and not only injure the balance and neighbouring bodies, but also lose weight; and the latter, by deliquescing, would gain weight; both with such rapidity as entirely to prevent the attainment of accuracy. These effects will be completely avoided by transferring them not to the pan of the balance, but to a portion of water of known weight, and ascertaining the increase of weight so occasioned. In such a case, therefore, weigh or counterpoise a portion of water in a test glass or basin, and then, the crystals being prepared and dried by compression, transfer them rapidly to the water, and ascertain their quantity by the increase of weight; then proceed with the analysis or experiment, using the solution in place of the crystals. It is evident that an expedient of this kind has its limits, consisting in the nature of the experiment to

be made, and the action of the water on the substances; but it is often very valuable, and now and then removes a difficulty which could not otherwise be surmounted. The choice of the substance which is to receive the changeable body must depend upon circumstances, and sometimes alcohol, sometimes water, and sometimes an acid, alkaline, or neutral solution, is to be preferred.

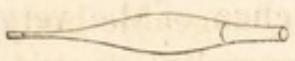
64. It may here be observed, that inasmuch as in many experiments one quantity is equally convenient with another, so that it be accurately known, we have the advantage in such cases of avoiding any trouble dependant upon adjusting accurately the quantity of matter, and obtain the same end by adjusting the weights, the matter itself being left undisturbed. Thus if it were wished to know how much chloride of silver would be furnished by a given weight of crystalline hydrated chloride of lime, 76.43, or any other number of grains would answer the purpose as well as an accurate hundred, and the facility of immersing the body into water as above described, is obtained. The particular cases where an opportunity of this kind, dependant upon the adjustment of the substance or the weight at pleasure, can be taken advantage of, must depend upon the judgment of the experimenter.

65. Similarly changeable products, the weights of which are required, are frequently produced in vessels, and especially in tube operations. In such cases the method will be to counterpoise or weigh the vessel and its contents, then to remove the substance, and cleaning the vessel, to ascertain the loss of weight; that being the weight of the substance. Wherever such a course is necessary, the use of vessels that may be cleaned without injury or change is evidently needful: hence a great advantage of tubes and vessels of glass, or platinum crucibles and capsules.

66. Substances which fume, and which may in consequence cause injury to the balance, should be weighed in close vessels. Of such kind are some of the acids, ammonia, and numerous mixtures.

67. Small capillary tubes, made by drawing out a piece of thin quill glass tube at the blowpipe, as hereafter to be

described (Sect. xx), are exceedingly convenient for the estimation of minute quantities of valuable liquid products, or moderately but not excessively volatile substances, such as ether, &c.: the tube may be of the general form of that depicted in the wood cut, and of the same size or larger, as may be convenient; having been counterpoised, it is to be charged with the fluid to be weighed, by dipping into it the smaller extremity, and inclining the tube. When a sufficient quantity has entered by capillary attraction, the tube is to be withdrawn, the small portion of external moistened surface wiped, and the whole weighed, care being taken that the end does not touch any substance, for then the fluid might be drawn out. In this way the quantity can be accurately ascertained, and then, that the experiment may include all weighed, it will be found of advantage that the tube, being of no consequence to the result, may consequently be thrown with its contents into the solvent, or added directly to the substance upon which the action is to take place: the tube itself being broken up and disregarded.



Sometimes it is desirable hermetically to close one end or even both ends of the tube charged as above; this is easily done by having it of the annexed form, the capillary termination being rather wider than the part a little above it. In this case, when the tube is filled as far as is desirable, by inclining or inverting it the surface in the narrow part will leave the extremity, and this being introduced for a moment into the flame of a spirit lamp, will be effectually sealed; this done, the fluid is to a great degree secured and rendered stationary in the tube, and, if required, it is easy by approaching the other end to a spirit lamp, to soften the glass, draw it out, and seal it, in the manner to be shewn hereafter.



68. Where in place of any particular weight, merely an equal, double or triple quantity of one substance is wanted to be added to another, a convenient quantity of the one most worthy of consideration may be put into one pan, and counterbalanced once, twice, or thrice, by the other. In mixing dry substances, or in making analyses with refer-

ence to the kind rather than the weight of bodies present, this comparative mode of estimation is frequently useful.

69. In most processes of weighing, the buoyancy of the air is overlooked, and though in consequence of the very superior density of solid and fluid matter generally, as compared to the atmosphere around us, errors thus introduced are usually unimportant, yet the chemist should be aware of its influence, and alive to its possible interference. From the manner in which gases are usually weighed, the error does not then exist, but it is sometimes more considerable than would be expected in experiments made with substances, at one time in the gaseous state, and at another in the liquid or solid form. The production of water, for instance, from the combination of oxygen and hydrogen, is an important experiment, and has been often repeated; the weight of the water should accurately correspond with the weights of the gases combined. The weights of the gases are in the usual method correctly ascertained, but the weight of the water estimated in the usual way is diminished by the buoyancy of the air, which in this case amounting to about $\frac{1}{820}$th part, would introduce an error to that extent, were this effect not to be taken into account.

70. The determination of Specific Gravity is of constant occurrence with the chemist, and though it resembles the general operation of weighing, it has peculiarities connected with it which require attention. It is not intended here to go into a consideration of the general process, but leaving that to be obtained from elementary works, only to notice those things which are liable to occasion errors, or are necessary to correct results. If the substance be a solid, the well-known process of weighing it first in air and then in water, and dividing the first weight by the loss in the second, is to be followed; and though here again minute errors are introduced in consequence of the buoyancy of the air in the first weighing, they are not of a nature to require attention in this place.

71. Balances are expressly furnished with contrivances to facilitate the immersion of the body in water when required, so that its weight may be ascertained in that posi-

tion. The substance which passes the surface of the water, supporting the immersed body and connecting it with the scale beam, is generally a horse hair, and for common purposes, it is perhaps the best. When however a hydrostatic balance is not at hand, and an ordinary balance is to be used for the purpose, the suspending link has frequently to be selected from several substitutes which present themselves in the laboratory. It should not be penetrable or alterable by the water; it should not be thick; it should not be weak. If it be the first, as a piece of thread for instance, the quantity of water in it undergoes continual variation in consequence of the difference of immersion as the balance vibrates, and thus a change of weight is occasioned in that which ought to be constant. If it be the second, as a piece of string, it introduces errors of two kinds, one dependent on the buoyant power of the water over the part which is sometimes immersed and sometimes not, and which if the same point were not always brought to the surface of the water would act upon it, as it would upon the stem of the hydrometer; the other dependent upon the capillary attraction of the water, which, within certain limits, would cause a larger elevation of the fluid round the string when thick, than if it were small, and add a proportionate weight to it. If it were the third, it would present an obstacle to the correction of the faults last mentioned, inasmuch as it would not admit of being made thin for want of strength.

72. These errors become serious when they affect a small body, a gem for instance, and in such cases, or wherever the weight will admit of its application, a filament of unspun silk is probably the best substance that can be used. It is unaffected by the water, has scarcely any weight, so minute is its bulk, or any buoyancy given to it by immersion in the fluid; it does not cause any elevation of fluid round it where it cuts the surface of the liquid; and retains no air bubbles. It has but little strength in consequence of excessive tenuity, and therefore must not be pulled hastily or subjected to sudden snatches.

When a silk fibre will not answer the purpose or cannot be obtained, a fine wire will very conveniently supply its

place, and it is only in cases of necessity that recourse should be had to thread, fine twine, or any substance made up of many fibres. But if some of the latter must answer the purpose, then silk thread is better than any other, because of its strength; and what is called thrown silk, which consists of a few fibres only, twisted together, is, when strong enough, almost unobjectionable. In all these cases of substitution, take that substance which, being of sufficient strength, is the thinnest and most compact, and in all cases it is desirable that the mass of which the specific gravity is to be taken should be as large as the line will safely support; for if a coarse suspending thread be used in taking that of a small fragment, the errors relating to the thread, which are several in number, affect the result much more importantly than if the operation had been performed upon a large one.

73. There are several points relative to the immersion of the body in the water which require attention. The water must be distilled for delicate experiments, but on ordinary occasions when that cannot be obtained the lightest rain-water may be substituted, or in common cases even well or spring water of ascertained purity. Several wells are known, amongst which are the deep ones of London, which supply water as pure or purer than rain-water. The temperature of the water and the substance to be examined should be the same, or otherwise currents will be produced, which to a slight degree affect the results: indeed, all delicate experiments must be made at one particular temperature, and 60° Fah. is very convenient for the purpose. A considerable difference of temperature at different times prevent the results from being comparable with each other.

74. The body, as well as the various contrivances for its suspension constructed by the instrument makers, such as pincers, forceps, &c. must of course be fully immersed in the water. It should have at least half an inch of water around it in every direction, that perfect freedom of motion in the balance may be obtained. All bubbles of air adhering to any part immersed should be removed by a hair pencil. Water taken from the bottom of any deep portion which has been exposed to contact with the air for a

length of time, will frequently evolve bubbles either spontaneously or upon the immersion of a rough substance, in consequence of its relief from the previously superincumbent pressure. Spring water drawn from the bottom of a well will illustrate this effect; which is very inconvenient when it happens with such water as is used for taking specific gravities, from the succession of bubbles produced. Exposure to the air for an hour or two is a remedy for the evil.

75. The oscillations of the balance, though much slower than those which occur when the body is weighed in air, should be quite free. Supposing the balance to be in good order, and the body suspended with perfect liberty in the water, neither touching any part of the vessel nor approaching the surface, still serious obstruction may arise, especially when the substance is small, the balance delicate, and the suspending link thick. Suppose a horse hair to be used for suspension, which from the manner in which it is wetted by the water, causes a small depression on the surface of the fluid around it as it descends, and a little elevation as it ascends. Such is a very common effect, and is produced not only on the first immersion and emersion of the hair, but is repeated, at every ascent and descent within certain limits. It is evident that this will very seriously retard the oscillations of a delicate balance, and prevent its motion either one way or the other by a force equal to the weight of the little elevation or depression of water. This may be partly corrected by tapping the vessel containing the water or the case of the balance, so as to occasion a slight tremor. Whenever it happens, the equilibrium should not be considered as obtained, unless the water have a plane surface at the part where it surrounds the hair.

76. The substance used as a support always becomes wetted by immersion in the water, and in consequence of the extent of oscillation, a portion of the wetted part is constantly out of the water when the balance is poised. This affects the result in two ways, first by the quantity of water which adheres to it, and which varies in proportion as it has been immersed to a greater or smaller depth, or as it is impervious to water like a hair, or more or less porous like

thread; secondly, by the little elevation of water which then exists round the line by capillary attraction, and which is the same whether more or less of the part above has been wetted. The weight of the water thus raised above the surface is counterbalanced by an equal weight in the opposite pan, thus an error to that extent is introduced, which though generally small, may from ignorance, inattention, or the minute size of the piece operated with, at times become very important.

77. Although the suspending line may have been very accurately compensated in the air before the body to be immersed in water was attached to it, yet when partly immersed during the progress of the experiment, the counterpoise is no longer its equivalent, the part immersed being buoyed up by a force equal to the weight of the water which it displaces; and this with a large horse hair, or a still coarser line of suspension, would be important. It may be estimated, as well also as the effect of the little elevation of water before spoken of, after the weighing has been finished, by removing the body, again immersing the hair to the same depth as before, allowing it to be wetted to the same degree and seeing how much it differs from its weight when freely suspended in a dry state in the air. Balances which are fitted up with apparatus for hydrostatical experiments, have counterpoises for the suspending parts, both when in and out of the water, and which might be made perfectly accurate were the surface of the water always brought to the same place upon the suspending line.

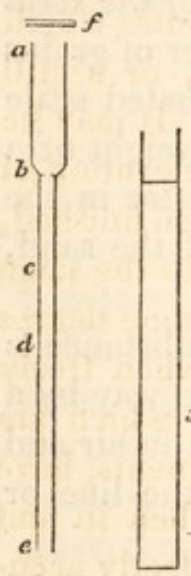
All these errors are lessened by diminution in the size of the suspension line; and when that is a silk filament, they almost disappear. Hence the great use of this substance in delicate experiments, as those made with small gems, minute globules of metal, or other rare substances.

78. When the substance of which the specific gravity is to be taken is soluble in water, some other fluid of known specific gravity must be used, and which does not dissolve it. There are very few cases which may not be met by alcohol, oil of turpentine, or olive oil.

79. Not unusually the body to be examined is porous

like coke, or divided, as in sand or powders, into numerous parts. In these cases the beautiful contrivance devised by Professor Leslie is so convenient and general in its use, that when it can be obtained, no other means need be thought of. Soluble as well as insoluble substances may be tried by it, provided they do not give off vapour, and the only precautions necessary are to prevent the existence of cavities unconnected with the air, and to destroy such minute cellular structures as, like that of charcoal, have the power of absorbing gases or vapours. It is proper therefore to reduce the substance to solid fragments by breaking it down coarsely, or pulverising it more or less in a mortar.

This instrument consists of a glass tube, *a e*, about three feet long, and open at both ends. The wide part, *a b*, is about 4-10ths of an inch in diameter; the part *b e*, 2-10ths. The two parts communicate at *b* by an extremely fine slit, which suffers air to pass but retains sand or powder. The mouth at *a* is ground smooth, and can be shut so as to be air-tight, by a small glass plate, *f*. The substance whose specific gravity we wish to find, suppose it to be sand, is put into the wide part of the tube, *a b*, which may either be filled to the top or not. The tube being then held in a vertical position, has the narrow part immersed in mercury, contained in an open vessel, till the metal rises within to the gorge *b*. The lid is then fitted on air-tight, at *a*. In this state it is evident there is no air in the tube except that mixed with the sand in the cavity *a b*. Suppose the barometer at the time to stand at 30 inches, and that the tube is lifted perpendicularly till the mercury stands in the inside of *b e*, at a point *c*, 15 inches (or one half 30) above its surface in the open vessel, it is evident then that the air in the inside of the tube is subjected to a pressure of exactly half an atmosphere, and of course it dilates, and fills precisely twice the space it originally occupied. It follows too that since the air is dilated to twice its bulk, the cavity *a b*, contains just half of what it did at first, and the cavity *b c*, now containing the other half, the quan-



tity of air in each of these parts of the tube are equal. In other words, the quantity of air in *b c*, is exactly equal to what is mixed with the sand in *a b*, and occupies precisely the same space which the *whole* occupied *before* its dilation. Let us now suppose the sand to be taken out, and the same experiment repeated, but with this difference, that the cavity *a b* is filled with air only. It is obvious that the quantity being greater, it will, when dilated to double the bulk under a pressure of 15 inches, occupy a larger space, and the mercury will rise, let us suppose only, to *d*. But the attenuated air in the narrow tube always occupies exactly the space which the whole occupied at ordinary atmospheric pressure, and this space therefore is in the one case *b c*, and in the other *b d*. Hence it follows, that the cavity *c d*, which is the difference between these, is equal to the *bulk of the solid matter in the sand*. Now by marking the number of grains of water held by the narrow tube *b e* on a graduated scale attached to it, we can find at once what is the weight of a quantity of water equal in bulk to the solid matter in the sand, and by comparing this with the weight of the sand, we have its true specific gravity.

When this apparatus is not at hand, and the substance is in small pieces, it must be supported in the usual way by a cup, which is of course to be counterpoised first in air and then in water, exactly as was described with the line or retaining forceps before mentioned.

80. The specific gravity of fluids is ascertained by weighing equal bulks of them at the balance, or by the immersion of hydrometers or bulbs; bodies which, by their floating or sinking, indicate the comparative weights of the substances into which they are introduced. Bottles are usually provided by the instrument maker as measures of the bulk of fluid to be weighed; these are arranged to hold a given quantity of distilled water expressible by weight, in round numbers, as 1000, 800, 500, 280 grains, &c. and are closed by a ground stopper. The ultimate adjustment is effected by removing portions from the lower surface of the stopper, so that when the bottle is filled with water, and the stopper put into its place, the quantity which remains in and

entirely fills the bottle, is of the bulk required. The stoppers instead of being solid, are sometimes made of a piece of thick thermometer tube of fine bore, the intention being to afford a free passage for the excess of fluid when the stopper is forced into its place. This answers the purpose very well with water and less volatile fluids, though it is not necessary, but with very volatile fluids, as ether, it occasions an evil. It does not merely afford a small surface for evaporation, but, in consequence of the impossibility of grinding a stopper so accurately, that when in its place it shall not let a little of these limpid fluids pass, actually accelerates the evaporation; for the ether, for instance, passing by capillary attraction between the stopper and the bottle, evaporates round the edge, whilst the air enters in a constant succession of bubbles by the centre passage, and thus a rapid diminution in the bulk of the fluid takes place; whereas if the bottle had been closed by a solid stopper, although the minute ring of fluid round the top would evaporate, no more would be able to rise, because air could not enter to supply its place, and the bulk would be comparatively unchanged.

81. Specific gravity bottles are constructed of various sizes, and are each accompanied by a weight which counterpoises the bottle full of distilled water, the quantity of water required for the purpose having been ascertained and marked upon it. All that is required in estimating the specific gravity of any other fluid is to fill the bottle with it, to ascertain its weight by observing how much heavier or lighter it is than the weight furnished with the instrument, and adding and subtracting accordingly; and the result, divided by the weight of water, will be the specific gravity. It is necessary in these experiments that the temperature be observed, or rather indeed when convenient that they be made at the same temperature, or it will not be possible to compare them unless previously corrected by calculation, which would in many cases be difficult. For the same reason it is requisite that the bottle should not be handled by uncovered hands, lest heat be communicated to it, and its bulk and the volume of the fluid within be affected; but upon intro-

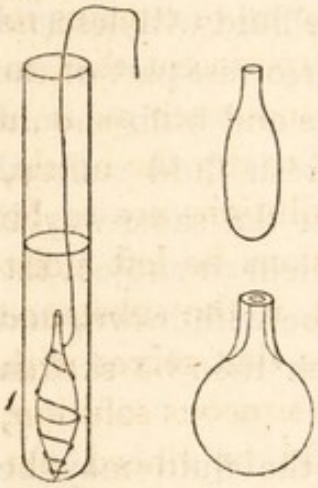
ducing the stopper, the overflow of liquid should be wiped off with a clean cloth, which may be used at the same time to prevent contact with the hands; and in transferring it to the balance, the fingers should be defended in a similar way: or if this be difficult from any particular circumstance, they must not on any occasion touch more than the thick rim of glass round the stopper.

82. It is further necessary that the bottle contain nothing but the particular substance to be weighed. To insure this point it is requisite that it be washed out after every experiment, the last two or three rincings being made with distilled water; if it be then dried, nothing more remains to be done upon the performance of a new experiment than to put in the liquid and to weigh. But inasmuch as it is inconvenient and unnecessary at all times to dry the bottle, as when the specific gravity of several solutions are to be taken in succession, it may on such occasions be left moist within; and then at the next experiment, if the substance to be operated with is abundant, and one that mixes with water, as a mineral water, alcohol, or an aqueous solution, it merely requires that the bottle should be rinced out with it two or three times before it be fllled for weighing. If it be a substance that is scarce, or oily, or that will not mix with water, the bottle must be washed and dried.

83. Instruments procured from the maker should be verified by the purchaser before they are used. For this purpose the bottle and stopper should be well cleaned and dried, and being brought to the temperature of 60° Fahrenheit, should be counterpoised. The bottle must next be carefully filled with pure water at 60°, and the increase of weight ascertained; this is the weight of the water, and should correspond with that marked on the weight or the stopper; finally, the counterpoise and water, weighed together, should exactly balance the weight sent with the bottle. If the maker graduates the bottles at any other temperature than 60°, it is useless to expect an exact accordance with estimates made at 60°, but he should always do it at a known and constant temperature with which the purchaser should be acquainted, and that

of 60° Fahrenheit, is for several reasons better than any other.

84. The directions given for the verification of a bottle made purposely for the estimation of specific gravities of liquids, will easily enable a person to supply its want. He has but to select a small well-stoppered phial of convenient capacity, clean, dry and weigh it, and then ascertain as before how much water it will hold; the weight of this water will be a divisor for the weight of any other fluid filling it, a dividend, and the quotient will be the specific gravity of the latter fluid.



85. Small bulbs blown out of glass tube, or even small thermometer bulbs like those figured in the margin, are often useful in estimating the specific gravity of rare fluid products. The little bulb (fig. 1.) is easily made, as is hereafter to be shewn, and having been counterpoised and furnished with a temporary handle by wrapping a piece of platina wire round it, may be warmed by a spirit lamp, and then dipped into the fluid in the tube; as it cools a portion will enter upon removing, rewarming, and re-immersing it, a second portion may be introduced by the same mode of proceeding; a small bubble of air will ultimately remain within, but this may be expelled by warming the fluid with the bulb in it in the state in which it is represented in the cut; the liquid will expand by the heat, and force out the air; and then by immersing the bottom of the tube in water to lower the temperature as the expanded air contracts, the fluid will enter the little bulb. A second or third performance of the heating and cooling process will effectually fill the bulb with liquid.

86. The filling of bulbs in this manner is very often required in certain trains of research, and amongst others in organic analysis. Hence it is necessary to point out one or two circumstances requiring attention in the operation. When the bulb is about four-fifths full, and the attempt is made to fill it by applying heat whilst it is immersed in the

liquid, it will perhaps be found that the bubble of air expands and contracts as its temperature changes, but does not go out of the vessel, the fluid which enters remaining in the narrower part of the top by capillary attraction, and consequently passing out again upon the re-elevation of temperature. But in such a case it is necessary, before the heat is applied, to make this portion of the fluid and the air change places, which is easily done: for this purpose the tube with its contents, should be held by the upper part, and suffered to hang as it were below the hand, a short swing of a foot or two should be given to it, so as to produce centrifugal force, all the fluid will descend except that which is contained in the narrowest part of the neck, and air will take its place; the tube and bulb should then be heated to expel the air, and fresh fluid suffered to enter, which is to be again treated in the same way if required. If any thing renders it inexpedient to subject the whole tube to this motion, the bulb can be withdrawn, and being held by the wire or in the hand, can then be shaken in the same way and with the same effect.



87. In the next place the fluid may be volatile and subject to waste by repeated elevations of temperature in an open tube, but in such circumstances it is easy to close the tube effectually by the fore finger of the left hand, whilst the thumb and second finger are occupied in holding it; the heating and cooling is then to be performed without allowing the end to be unclosed, and no waste is occasioned.

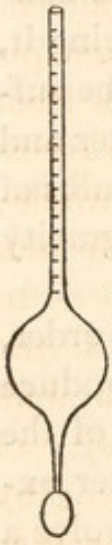
88. This point of manipulation will require a little practise to allow of all the advantage being derived from it which it is capable of affording in other operations, but when required, a volatile fluid, ether for example, may be heated until its vapour has a force of two or even three atmospheres, if the tube be strong enough, and be retained there for a quarter of an hour or more without any loss. The portion of common air in the tube is to be allowed to escape or not, according to circumstances (855.), and may be made

use of at times, as will be found by practice, to prevent the accession of heat to the fingers.

89. Returning to the fluid with which the bulb has been filled; upon removing the latter when cold, allow its exterior to drain as much as possible: the wire must then be taken off, the surface wiped, and the bulb put upon a cork stand (58,) and weighed. As the vessel will then be required full of water, it must be emptied of the fluid. Replace the wire handle, invert the bulb, holding its aperture within the mouth of the tube to which its contents are to be restored, and apply a little heat; a part of the liquid will be forced out, or indeed the whole if it be volatile, if not, on cooling, a bubble of air will enter, and a second and third application of heat will displace the whole of the contents. On introducing a portion of water and displacing it, and repeating this two or three times, the bulb will be sufficiently cleansed, may then be filled entirely with water and weighed when cold as before. The weights of equal bulks of the fluid and water are now known, and the specific gravity may be readily obtained.

90. Although the process has been described in this order, it is generally better, after weighing the bulb, to introduce the water and obtain its weight first, and then that of the peculiar fluid; for if an accident happens in the water experiment, and the bulb is destroyed, it does not involve a repetition of the process with the valuable liquid. Further, it is easy at all times to free the bulb from the water of the first part of the process, but not always so to dissipate the remains of peculiar substances which may be decomposable by heat or not soluble in water. The bulb may be emptied of water by first throwing out the larger part as already described, then heating it over the flame of a spirit lamp, or in hot air, to convert the rest of the moisture into vapour, and either retaining it there some time, or if that be inconvenient, allowing it to cool, that the vapour may condense and the air enter. A second application of heat, at the same time that it converts the remaining water into steam, throws out a portion with the expelled air; being cooled and again heated a few times, the bulb is soon effectually

dried. The process may be expedited by cooling a part near the mouth first, which is easily done by touching it with a cold substance (1242), and causing the principal condensation of moisture there, and then also heating the same part first; in this way the air carries out the water in fewer operations, but these facilities are only to be learned and appreciated by practice. In all exposures of the bulb to heat in experiments relating to specific gravity, especial care must be taken that the heat is not such as to soften the glass after one of the fluids has been weighed, for in that case the form and size of the vessel will be altered, the process must be recommenced, and the previous trouble will be utterly useless.



91. The specific gravity of fluids is frequently ascertained by the hydrometer, a well-known instrument, which is of great service where hasty estimates of only moderate accuracy are required; but it will not give correct or even constantly incorrect observations without attention. The stem, being the part which cuts the surface of the liquid, resembles in that respect the suspending link used in taking the specific gravity of solids (76, &c.); and is liable to be affected in a similar way, but in many cases to a much greater extent, because of its necessary thickness. If its surface does not moisten freely with the fluid in which it floats, it will be found easy upon trial, to make the hydrometer stand two or three degrees or more, higher or lower in the same liquid; and when the hydrometer does become wetted readily, and has even had the stem purposely moistened, the same effect may be produced, and that not in fluids particularly viscid, but in water and aqueous solutions. Hence a source of irregularity in the indications of the instrument, which must be avoided as much as possible. For this purpose, keep the hydrometer perfectly clean, and free from any unctuous or greasy matter which might be the consequence of handling it. When put into the fluid it should be allowed to sink gradually till at rest, and then be depressed about an inch lower, which will give it an ascending power, and moisten a certain portion of the stem; the jar containing

the fluid is to be tapped to cause vibration, and the instrument allowed again to take a state of rest, when its position should be observed. The instrument should then be raised about half an inch out of the fluid, and tapping the jar as before, suffered to sink slowly, and observed whether it takes the same position it occupied at first; if it does the observation is as correct in this respect as it can be.

92. If the fluid be viscid, the liability of inaccuracy in this instrument is increased, both by the difficulty with which it sinks or rises to the point to which its mere weight would carry it, and also by the greater quantity which adheres to the part of the stem that, having been immersed, is afterwards raised above the surface. If the fluid be turbid, it is not the gravity of the mere suspending fluid that is obtained, but of the liquid so laden with other matter. Some precipitates will be days and even weeks before they will settle from the fluid in which they are formed, and yet are so heavy as very materially to increase the specific gravity of the whole; and M. P. S. Girard has stated,* that a peculiar molecular attraction exists between such particles in the fluid as to buoy up the hydrometer by a force, not merely equal to the increased weight, but considerably surpassing it. Brewers and other persons frequently require the specific gravity of a mixture of solid and fluid matter, their object being by the buoyancy of the hydrometer, to estimate the former as well as the latter; but if the effect here noticed exists, a source of error is introduced of which they take no account, unless indeed their instruments be graduated by experiment with similar fluids, to those they wish to examine by it. It is probably however so small, as to be of no importance in their comparatively rough processes.

93. In all experiments made with the hydrometer an ascent of the fluid will take place round the stem, producing the elevation before mentioned (76). This occasions a curve in the surface, and some persons read off the graduation on the stem, where it coincides with the middle of this curve,

* On Liquid Atmospheres and their influence on the solid particles they envelope.—Memoires de l'Academie Royale, iv. 1819, 1820.

others at the top, and others again at the bottom. It is necessary for the sake of consistent observations, always to read off from the same part of the curve, and if the instrument has been graduated by experiment, the divisions being made with reference to the part of the curve from which they are afterwards to be read, it will so far be correct. As the force which causes the elevation tends to depress the instrument in the fluid, observations made at the bottom of the curve will be nearer to the truth than those made at the top. But the curve itself varies, not merely in size, because of differences in the weight or specific gravity of the fluid, but in weight also, because of differences in the cohesive attraction of different fluids.

94. Amongst other points relative to the state of the fluid, temperature should not be forgotten; constancy in this respect being as important as in experiments made with the bottle.

95. The hydrometer, when first procured, should be verified by trial in solutions of which the specific gravity has been ascertained by the bottle. It is not necessary to make many trials of this kind, its verification being more readily effected in the following manner. First ascertain with two fluids of different specific gravities, that one indication towards each end of the scale is correct. Then, suspending the hydrometer from the pan on one side of a balance, let it descend into a solution as light or lighter than any to be measured on the scale, but buoying it up by weights in the other pan, so that the surface of the fluid shall cut the scale at the lower part. Make equal additions of weight in succession to the pan from which the hydrometer is suspended, and observe the descent each time; if they are equal as read off on the scale, then the divisions are equal in bulk, and the graduation is correct; if unequal, the graduation is incorrect, and would not correspond with the results obtained by the specific gravity bottle. The more numerous the points thus observed, that is, the smaller the weight added each time, the more accurate and close is the trial.*

* See Moore on graduation of the hydrometer; Dublin Philosophical Journal.

96. A solid glass ball or bulbs of glass are frequently used for ascertaining the specific gravity of fluids. If a ball of glass suspended from the balance be wholly immersed in a liquid, it will be buoyed up by a force equal to the weight of the liquid it displaces, and seem to lose weight to that amount. By being immersed therefore in succession into different liquids, the weights of equal volumes are thus obtained, for the ball measures out the volume each time, and the specific gravities are then known. The precautions here required are the same as those belonging to the experiments on the specific gravity of solid bodies. (71—77).

97. Sometimes several hollow bulbs of different specific gravities are used, those which are too heavy sinking, and those which are too light floating. The proper strength of some solutions evaporated in the large way are thus estimated. Sea water for instance, in salt-works, is concentrated by exposure to air, until it has such a specific gravity, that of two previously arranged glass bulbs, one will sink and the other swim. Their use in chemical research is rare, but an excellent instance of the delicacy with which the principle may in some cases be applied, as also a specimen of useful manipulation, may be found in Mr. Crichton's paper on the maximum density of water.*

98. Another instance of the application of similar bulbs to the determination of specific gravity, when no other means were available, occurs with respect to the liquids produced by the condensation of gases.† The bulbs used were very small, and made as hereafter to be described, (Sect. xix.). Their specific gravities were ascertained by putting them into different solutions of known specific gravity, and the bulbs thus prepared, were introduced into the vessels in which the gases were to be liberated or condensed. When surrounded by the fluid its density was in some degree judged of by the sinking or swimming of the included bulb, and then by successive trials with heavier or lighter bulbs more accurately ascertained.

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* Annals of Philosophy, New Series, v. 401.

† Philosophical Transactions 1823, p. 191.

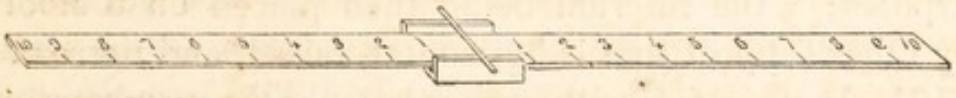
99. Substitutes for a balance, though not often required, are, in particular situations, very valuable, and there are few philosophic travellers who have not felt this want. Mr. Bevan recommends for this purpose a strung bow,* which if not at hand, may generally be made out of a piece of whale bone, a stick, or other substance, and which being suspended by the middle of the bow, is to have the body to be weighed attached to the middle of the string. The flexure occasioned by it is to be observed; which will best be done by marking the point to which that part of the string from which the body hangs, descends. Then removing the substance and replacing it by weights, sufficient are to be used to cause the same flexure, and thus the weight of the substance will be obtained. An elastic beam, stick, or other body, firmly fixed at one end, and loaded at the other with the substance and the weights in succession, will answer the same purpose; and the means of making a temporary scale pan, to receive the substance and the weights, and a graduation to measure its descent, are so simple and evident as not to require description.

100. The following account of a very delicate and easily constructed balance is from a letter written by Dr. Black to Mr. Smithson,† and is a valuable piece of information to those who having occasion for, are deprived of the use of a good balance. "The apparatus I use for weighing small globules of metal, or the like, is as follows: a thin piece of fir wood, not thicker than a shilling, and a foot long, 0.3 of an inch broad in the middle, and 0.15 of an inch at each end, is divided by transverse lines into 20 parts, that is, 10 parts on each side of the middle. These are the principal divisions, and each of them is subdivided into halves and quarters. Across the middle is fixed one of the smallest needles I could procure, to serve as an axis, and it is fitted in its place by means of a little sealing-wax. The numeration of the divisions is from the middle to each end of the beam. The fulcrum is a bit of brass plate, the middle of

* Technical Repository, vi. 196.

† Annals of Philosophy, N.S. x. 52.

which lies flat on my table when I use the balance, and the two ends are bent up to a right angle so as to stand upright. These two ends are ground at the same time on a flat hone, that the extreme surfaces of them may be in the same plane; and their distance is such that the needle when laid across them rests on them at a small distance from the sides of the beam. They rise above the surface of the table only $1\frac{1}{2}$ or 2-tenths of an inch, so that the beam is very limited in its



play. The weights I use are one globule of gold which weighs one grain, and two or three others which weigh one-tenth of a grain each; and also a number of small rings of fine brass wire, made in the manner first mentioned by Mr. Lewis, by appending a weight to the wire, and coiling it with the tension of that weight round a thicker brass wire in a close spiral, after which the extremity of the spiral being tied hard with waxed thread, I put the covered wire in a vice, and applying a sharp knife, which is struck with a hammer, I cut through a great number of the coils at one stroke, and find them as exactly equal to one another as can be desired. Those I use happen to be the one-thirtieth part of a grain each, or 300 of them weigh 10 grains, but I have others much lighter.

"You will perceive that by means of these weights placed on different parts of the beam, I can learn the weight of any little mass from one grain or a little more to the $\frac{1}{1200}$ of a grain. For if the thing to be weighed weighs one grain, it will, when placed on one extremity of the beam, counterpoise the large gold weight at the other extremity. If it weigh half a grain, it will counterpoise the heavy gold weight placed at five. If it weigh 0.6 of a grain, you must place the heavy gold weight at 5, and one of the lighter ones at the extremity to counterpoise it; and if it weighs only one, or two, or three, or four hundredths of a grain, it will be counterpoised by one of the small gold weights placed at the first, or second, or third, or fourth division. If, on the contrary, it weigh one grain and a fraction, it will be counter-

poised by the heavy gold weight at the extremity, and one or more of the lighter ones placed on some other part of the beam.

" This beam has served me hitherto for every purpose, but had I occasion for a more delicate one I could make it easily by taking a much thinner and lighter slip of wood, and grinding the needle to give it an edge. It would also be easy to make it carry small scales of paper for particular purposes;" the fulcrum being then placed on a stool or any other support that is horizontal, raised, and narrow.

101. In weighing with such a balance the weights should always be applied and ascertained on the same side with the substance, that irregularities of action may be avoided as much as possible. Thus, the substance to be weighed should be put into one pan and counterpoised by any convenient thing, as sand, in the other; after which, removing the substance, its place is to be supplied by weights until an exactly equal effect is produced, when of course the amount of the weights used will be the weight of the substance. Or if a given quantity be wanted, first counterpoise the weight, and afterwards replace it by the substance to be weighed. Inequality in the arms is thus compensated.

102. Substitutes for weights, should they ever be required, may be made by means of a balance in one or two ways. Pieces of metal or other convenient substances may be adjusted to have equal, double, triple, or any other proportion of weight, to a standard piece, and being used as weights at the time, will give proportionate results. Or if results comparable with other weights are required, their value may be estimated by actual comparison at a future convenient opportunity. Such regular weights of considerable accuracy are easily obtained by cutting off equal or given lengths of a copper wire, the wire being of such thickness that at least half an inch in length may be allowed for the smallest weight: its uniform thickness should be ascertained by trying the first and the last weight cut off against each other. Occasionally the products obtained from experiments may be balanced by pieces of lead which are to be weighed when an opportunity occurs, and the results to be numerically estimated.

103. A method of making small weights has been already described in Dr. Black's letter (100.), but Mr. Smithson finds it preferable first to ascertain the weight of a certain length of wire, and then to take that portion of it which may suffice for the weight wanted. If fine wire is employed, a set of small weights may be thus made with great accuracy and ease. Inconvenience from the length of the wire in the higher weights is obviated by rolling it round a cylindrical body into a ring, and twisting this to a cord.*

104. The following estimation of different weights will be frequently useful in the laboratory.

	Grains.
Pound avoirdupoise	7000
Ounce avoirdupoise	437.5
Pound troy	5760
Ounce troy	480
Gramme	15.4063
Decigramme	1.5406
Centigramme	0.1540
Milligramme	0.0154

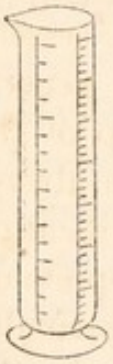
SECTION III.

Measures. Measuring.

105. ORDINARY laboratory service requires no other measures than such as are used to ascertain the bulk of liquids or gases. Hence two integers are abundantly sufficient, the pint and the cubic inch. The pint measures may be such as are furnished in commerce, either conical, cylindrical, or of any other form, and of glass, and graduated: but they should always be verified before they are permitted to pass into use. Where the same measure is used for large as well as small quantities, those which are conical have an advantage over such as are cylindrical in the smaller divi-

* Annals of Philosophy, N.S. x. p. 53.

sions, the surface of small quantities being less, and consequently the bulk more accurately determined; but it is better to have two or three measures of different sizes, varying in diameter, for different quantities. The pint measure is usually divided into sixteen parts, each being called a fluid-ounce, and liquids are frequently measured by it, which in such bulk weigh more or less than an ounce. The measure should be graduated in two places on opposite sides, that when the volume of a fluid is to be determined, its surface may, for greater accuracy, be observed by both graduations. A pint, a half pint, and a quarter pint measure, of the form and relative dimensions as to height and diameter of the one figured in the wood-cut, should be in the laboratory. It is also useful to have a graduation on the vessels in cubic inches, this being done on both sides at equal distances from the former graduations.



106. These measures should be graduated according to the late parliamentary standard, by which the pint is ascertained to consist of 8750 grains of water at 62° Fahrenheit, barometer at 30 inches, and the cubic inch of 252.458 grains of water at the same temperature and pressure. They are verified by being counterpoised (55) and having these quantities of water, or their multiples, or divisions, weighed into them, and the coincidence of the surface of the liquid and its corresponding mark noted. If they do not agree, a slight scratch should be made with a diamond or file at the place where the mark ought to be.

107. Preparatory to the use of these vessels, one particular place upon a table or shelf should be fixed on, which is flat, firm, and which should generally be kept clear of other things for this purpose alone. The measure when placed upon it should stand steady and perfectly upright. In the verification, it will be necessary to observe, that when the measure with the weighed quantity of water in it is placed in this situation, the surface of the fluid should coincide both with the graduation on the side towards the observer, and also on the farther side: this is best seen by bringing the eye to a level with the surface, and still further

security is gained as to the right position of the measure, if the water stand at equal heights on the lateral graduations of the denomination not immediately in use. In measuring at any future time, similar precautions should be observed, and these will require attention the more imperatively, if from any circumstance one particular spot is not selected as above advised, and if, on the contrary, any part of the table, without selection, be used.

108. With liquids which moisten the glass, an elevation of the fluid round its surface in contact with the vessel will take place. The measurement, except in minute vessels, will be most accurately made if taken from the general surface of the fluid and not from the middle or top of the elevation; but it is essentially necessary that it be always made in the same way as that adopted in the verification of the measures. With mercury there will be a depression round the glass instead of an elevation, except in particular circumstances. It is here again most correct to make the estimate from the general surface of the fluid.

109. When very accurate measurement is desirable, as in the analysis of a mineral water, it is better to perform it in a

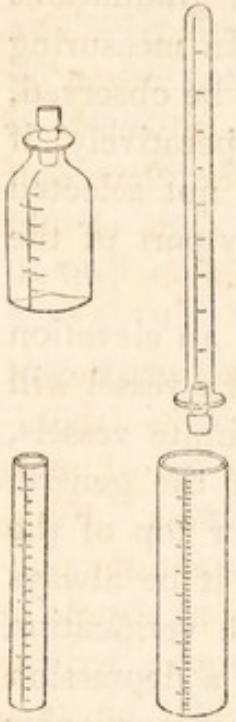


globular vessel having a glass neck, and of such capacity as to be filled partly up the neck by a weighed pint or half pint of water at 60°; the exact place being then marked with a diamond or file. So little surface is left at the place where the bulk is estimated, that scarcely any variation can occur in that respect; and if the measurements be made at one temperature, they are very accurate. Two such measures, a pint and a half-pint, will be quite sufficient. Small quantities are generally more accurately determined by weighing than by measuring.

110. Three jugs of half a pint, a pint, and a quart, will be found of great service for ordinary use.

111. The cubic inch, with its divisions and multiples, is used both for liquids and gases. For exclusive liquid use, the cubic inch graduation on the vessels already mentioned, will suffice; those to be described, will serve generally for both forms of matter.

112. Bottles are sold by the instrument makers which



contain an exact cubic inch when the stopper is put into its place. Tubes also of similar capacity, and supplied with a ground stopper, have a graduation on the side by which the subdivision is carried to tenths and twentieths, and even farther if necessary. Whether these are in the laboratory or not, there should be at all events a few jars and tubes accurately graduated into cubic inches, tenths, and hundredths; one jar may be about two inches in diameter and six inches high; another about an inch in diameter, and of the same height; a third, which will be almost a tube, half an inch in diameter and eight or nine inches long; and a fourth of the same length but still smaller. These should be moderately thick, so as to bear the weight of mercury in them when filled with that metal, and sustain laboratory use, without great risk of breaking: they should be ground at the ends, so as to be closed accurately by a flat piece of glass. It will be sufficient that the smaller vessels be graduated on one side only, but it is better that, when the diameter is an inch and a half or more, they should be graduated upon opposite sides, for the purpose of observing more accurately as before explained (107.)

113. All these measures should be verified by weighing into them successive portions of water or mercury. A cubic inch of water at 62°, weighs as before mentioned 252.458 grains, and a cubic inch of mercury at the same temperature 3425.35 grains. Water is very convenient for the estimation down to the cubic inch, and some divisions below it; but for the tenths, and especially the hundredths, mercury is far more exact and expeditious.

114. It is frequently necessary to graduate vessels, and especially tubes, in the laboratory. The general method of doing this will be easily understood from what has been said with regard to the verification of measures bought of the maker; but there are some facilities in the practice which will require description. Tubes are generally in use for

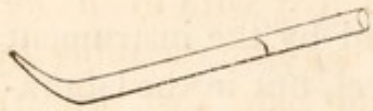
the measurement of gas at the mercurial trough, and should be several in number, and of different diameters, to afford opportunity for a graduation more or less minute. The laboratory is but poorly stocked that has not a dozen of them. They should not be less than the one-fifteenth of an inch in thickness when of a diameter smaller than half an inch, and thicker if wider. The closed ends should be of equal thickness with the sides, and should be round, not pointed.

115. The marks on vessels graduated by the instrument maker are cut by the glass-grinders wheel, but in the laboratory they are done by simpler instruments. A gun-flint is convenient for scratching on the surface of glass. Fragments of diamond are also set in handles for the same purpose; they are not intended to cut, but merely to abrade or roughen the surface, and are called scratching or writing diamonds. Small three-square files, about half an inch wide on each side, are so useful in the laboratory for marking on convex surfaces of glass or for cutting tubes, that they cannot be dispensed with.

116. Having selected the tube, first draw a line upon it from top to bottom. This is easily done by laying the tube against the edge of a flat slip of wood, or a ruler, upon the table, and drawing either the flint or scratching diamond down it where it rests against the ruler, bearing as it were into the angle formed by the ruler and the surface of the tube. The line should not be broad and rough, but regular, neat and straight. The tube is now to be balanced by a counterpoise (55), and is then ready to receive the successive portions of mercury, by which equal given volumes are to be measured out, and to have them marked off by small lines across the long one first drawn. Suppose the hundredths of a cubical inch are to be marked down, the tube being about 2-10ths of an inch internal diameter: 34.25 grains of mercury, which at 62° Fahr. are equal in bulk to the one-hundredth of a cubical inch, are to be weighed into it; the tube is to be marked at the level of the mercury, another 34.25 grains of metal is to be weighed in and its

place marked on the scale, and the operation so carried on until the graduation is finished.

117. But easy as this is in description, it is otherwise in practice, without the aid of certain facilities. If the mercury be added without care, either too much or too little will be introduced, and when the adjustment is nearly complete, scarcely little enough can be given or taken away, owing to the density and cohesion of the metal. Prepare therefore a tube like the one represented in the cut, about half an inch in diameter, four inches long, cut level at one end, so as to be closed by the finger if required, and drawn off laterally to a capillary opening at the other. If mercury be poured into such a tube, it will not flow out at the capillary opening whilst the position is such as in the figure, and this is easily given to it on the table by resting it on a list ring (59.). But when elevated sufficiently, the pressure of the column of metal will cause it to flow out, and either in a continuous stream or in minute successive drops, according to the degree of inclination: even a still greater command over the flow of metal is obtained by applying the finger to the upper extremity, and thus relieving the metal from the pressure of the atmosphere upon its upper surface to a greater or smaller degree as may be required. It is easy in this way to supply more or less of the metal at pleasure.



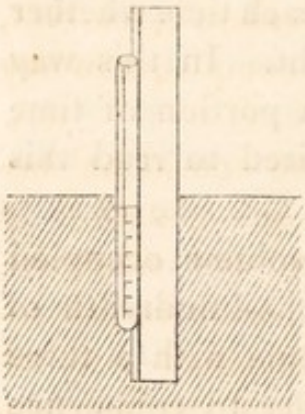
118. When therefore 34.25 grains of mercury are wanted in the tube, place the latter in one pan and weight amounting to 34.25 grains in the other; then, introducing the capillary extremity of the mercury feeding-tube into the mouth of the balanced tube, allow metal to flow in, moderating its addition as the balance approaches equilibrium, ultimately adding it only in minute drops. In this way the weight required is nearly attained in a very short time. Have it rather a little over than under weight, and relinquishing the feeding vessel, proceed to adjust the portion in the tube to be graduated. For this purpose, close its aperture with the fore finger of the right hand, invert the tube and its contents, which will of course cause the mercury to rest partly

on the finger, and then by slightly relaxing the finger, let a little drop squeeze out beneath the edge of the glass into the palm of the left hand, where it is to be preserved. Restore the tube to its right position, and place it in the balance; if too heavy, put the first drop of mercury out of the hand as useless, and take a second drop from the tube as before. In this way it will ultimately be obtained too light, but only by a part of the minute drop in the hand. Break this drop into several spherules by pressing upon it with the finger, and take one, two, three, or more of them into the tube, by pressing the edge of the glass on to the palm just beneath the drops, when they will roll in; observing each time whether the mercury in the tube balances the weight. In this way accurate adjustment may be obtained in a portion of time not exceeding a fourth part of that required to read this description.

119. The next object is to mark the volume occupied by the mercury, that being exactly the one-hundredth of a cubical inch. The mark will be best made with a three square file; and it will be found much easier to commence it from the cross line running up and down the tube, than from an unbroken surface. To make a fair mark requires a steady pressure on the file, and then motion to a slight extent. The feel will indicate whether a mark has been made, but the learner should practise first on a piece of waste glass tube, commencing both from an unabraded surface and from a cross line; and by making a mere spot, or marking a line of half an inch in length. He will in this way learn in half an hour to appreciate by the feel, the kind and the extent of the mark he makes. He should also practice marking upon any desired spot. For this purpose the tube should be held in the left hand with the thumb close upon the spot to be marked, then placing the edge of the file upon the particular place, and supporting the pressure at the same time by the thumb at its side, the slightest possible motion, sufficient to break the surface, should be given. If the commencement be exactly in the right place, there is no difficulty in continuing it, the file, when its motion is renewed, catching the previously roughened part; if the commencement be

in the wrong place, another trial must be made; the practice of making the mark where desired will soon be acquired.

120. This point attained, the next thing to be done is to mark the tube so as to record permanently the volume occupied by the mercury. For this purpose it must be placed in a steady upright position; and though this may be effected sufficiently well with very small tubes by holding them firmly in the hand, yet it is an incorrect method with larger ones. Choose therefore a flat place on the wall, in a convenient situation, and at the height of the eye. From a line level with the eye and about two or three inches downward, and for a width of five or six inches, blacken the wall, either by pigment or attaching a piece of black paper to it. Then firmly fix a piece of wood planed smooth and true, about the third of an inch thick, an inch wide, and six inches in length, to the wall in an upright position, across the middle of the blackened part, and so that half its length shall be on the white part above. Two upright re-entering angles are in this way produced, against which the tubes may be firmly held, and the necessary position thus effectually obtained. The black and white surfaces behind will each be found advantageous in turn, for shewing the coincidence of the surface of the mercury with any particular part of the glass, according to the light and other circumstances; and by shifting the tube a little up or down, the part where the mercury stands may be placed on one or the other at pleasure, and yet the eye be brought to the same horizontal line with it without any difficulty. By this means the position of the tube, of whatever size it may be less than an inch, is securely obtained, use being made of the angle on either side of the lath. An advantage sometimes results from using a piece of lath planed obliquely, so as to be thicker at one edge than the other, large tubes being applied to the deep angle on one side, and small tubes to the shallower angle on the other. Sometimes an angle previously existing on the walls



of the laboratory, as that formed by a bead, may be used for these purposes.

121. The tube when held in the angle may easily be marked as before mentioned by laying the three-square file horizontally across it upon the perpendicular line previously drawn, and abrading the surface by a little motion and pressure. The first mark is merely to be a slight extension of the rough surface on the side of the line; a mere spot, which if wrong may be neglected and another made, if right, may afterwards be lengthened into a line. There is no necessity for retaining the tube against the wall whilst the division is being fully marked; if the commencement be correct, the tube may be taken down, and the line completed in any other position that may be convenient.

122. But there is yet another point to be considered before we can proceed thus far. Mercury when contained in glass vessels is, in consequence of its cohesive attraction, depressed in that part of its surface where it verges towards the sides of the vessel; the place of contact with the glass is thus rendered lower than the general surface, and consequently a small space beneath that level remains unfilled by the metal. Hence a mark made to correspond with that surface, would include a space in the vessel rather larger than that occupied by the metal; and though in wide vessels or tubes the error thus introduced is minute, it is not so in tubes of small diameter, and frequently amounts to one of the divisions marked upon them. When to this is added the consideration that the convexity of the mercury in graduating a tube, is the reverse of that which occurs when using the same tube over mercury to measure gas, it is evident that always reading off from the top or bottom of the curve, would but increase the errors in this case; and that with small quantities of gas, and in delicate experiments, they would become very serious. To these may be added another circumstance which complicates the errors still further, namely, that when the tubes are used with or over water, the convexity is the reverse of that with mercury, and the correction required consequently of a contrary kind.

123. With reference to the process of graduation, the difficulty thus introduced may be avoided by using mercury which is not quite clean, but which, from containing a little of some other metal, as tin, lead, &c. has a film formed upon its surface. The mercury of the pneumatic trough, if in much use, is generally of this kind, or a small quantity can be readily made so for the purpose, by adding one grain of lead to four or five thousand grains of the fluid metal, that quantity being quite sufficient. When such mercury is put into a tube, a slight tremor given to it extends the film and allows the metal to flow beneath, so as to acquire a flat surface instead of a round one, and then the volume may be accurately marked off by a line upon the glass coinciding with that surface. Care is to be taken that the mercury used be not excessively foul, or so dusty as to throw up a thick coat of film to its surface, since no indication of volume belonging to a given weight of mercury would then be obtained.

124. No further difficulty will now arise in the way of graduating a tube. The 34.25 grains of mercury are to be weighed in, the tube is to be placed against the wall, slightly shaken to produce a level surface, and then a division is to be marked by the file. Another 34.25 grains of mercury are to be weighed into the tube to the metal already contained in it, and the volume is to be marked as before; third, fourth, and fifth divisions are to be obtained in the same way, and thus a scale will be gradually produced.

125. By degrees the tube, if large, will contain so much mercury as to be too heavy for the balance. But it is then easy to use a smaller vessel to weigh the metal in, transfering the mercury from that into the tube each time, and graduating as before. One advantage of thus weighing the measuring portions of metal in a separate vessel is, that water may be introduced into the tube under graduation. This facilitates the production of the level surface required on the mercury, and sometimes assists in marking down the graduations by the particular appearance of the tube: but as dirty mercury froths more readily in water than in air, the operator should be aware of any error in bulk that might arise from

this cause; and a little time should also be allowed before a mark is made, that the water may pass to the surface from between the glass and the metal, and the mercury attain its level. No quantity of water that is worth consideration will remain adhering to the glass after it has stood a few seconds.

126. There is another mode of obtaining the successive portions of mercury; it is by measuring instead of weighing, yet with such accuracy as to be unobjectionable, and is as follows. Procure a piece of glass tube of such diameter that the division required shall occupy in it from half an inch to an inch in length; for hundredths it may be one-sixth of an inch internal diameter, and for tenths about one-third of an inch; draw out one extremity at the lamp table, so as to give it the form in the figure, the lower end being a capillary continuation, from which mercury will flow out in a small stream, by the pressure of half an inch of metal above. Close the lower extremity by introducing the tip into the flame of a spirit lamp, so that the sealed part may afterwards be cut off without removing more than the one-sixteenth or one-eighth of an inch. Counterpoise the tube. Now weigh into it (if for hundredths,) 34.25 grains of mercury (or if for tenths, 342.53 grains,) and when the weight is accurately adjusted, observe whether the metal be continuous throughout; if not, make it so. The only thing which will interfere with this continuity is the occurrence of a bubble or two of air about *b* (see the figure). These are easily removed by introducing a horse hair or thin platina wire down between the glass and the mercury, until it reaches the bubble, the air of which will immediately pass up by the hair or wire. The air which is sure to remain in the capillary part may be removed in the same manner as low as *a*, but it is better that a small but constant portion should remain between the bottom of the mercury and the sealed part. The next thing to be done is to mark the tube at the surface of the mercury, and by weighing in two, three, four or more portions, each of 34.25 grains, and marking off their heights, an accurate graduation will be produced. Now by the scratching of a file, and then a little



lateral force as directed in glass blowing, Sect. xix. (1060) cut off the sealed capillary end about half way below *a*, and thus open that extremity.

127. The measure is now complete, and all that is further requisite is the mode of using it. Suppose mercury equal to one or more divisions, were required; pour some of the metal into the measure above its highest division, at the same time closing its capillary opening by bearing a finger slightly against it; then shutting the top by the fore finger, allow the mercury to run out at the capillary termination (117.), until its upper surface coincides with the uppermost line. Now stop the stream by inclining the measure, until having directed the jet into the tube to be graduated, any mercury that afterward passes out may be received by it. Again relieve the finger above, so that the metal may fall as before, passing through the extremity into the lower tube, and when the level in the *measure* again coincides with a division, it will be known that the hundredth of a cubic inch has gone from it into the tube to be graduated. Prevent the passage of more mercury by inclining the measure; mark off the portion already transferred; then add a second hundredth in the same way, and proceed in this manner to any extent required. When once a measure of this kind is made, it is exceedingly convenient and ready in its use, and being of sufficient length, will readily serve to estimate tenths as well as hundredths.

128. One other mode of measuring the mercury in these cases of graduation it will be necessary to mention, because it is common, and at times has peculiar advantages. It consists in forming a tube which, when closed with the finger, shall hold exactly the quantity of mercury required. The use of such a tube requires a little practice, for when the diameter is more than the third of an inch, variations in the pressure of the finger upon its open end, or the use of the finger or thumb indifferently, causes variations in the quantity contained. By practice such uniformity is obtained however, as not to involve any important error.

129. These measures are best made in the following manner; select a piece of tube sealed at one end, with a rounded

termination, and which shall be competent to hold about twice the bulk desired: counterpoise it, and then weigh in the mercury corresponding to the volume required. Mark this volume, and, pouring the mercury into another tube or dish, cut off the measure (1060) as near as may be to the mark, leaving it, if not exact, rather larger than is required. Draw out a few thick threads of cement, or make a thin roll of wax, and having poured the mercury back into the intended measure, put upon it a piece or two of the cement or wax, and covering it with the finger, depress it into the fluid metal, and observe whether there be sufficient to fill the tube or not; the wax or cement is to be increased or diminished in bulk, until with the mercury, it exactly fills the tube when closed by the finger; and this adjustment is to be made over a Wedgewood's basin, that any particles of mercury thrown out during the trial may be readily returned to the tube, and prevent alteration of the original quantity. When this adjustment of the wax has been obtained pour out the mercury, drop the wax to the bottom of the tube, warm the latter, so as to melt the wax, and then allowing it to cool, the measure is completed.

130. It is not necessary in every case to weigh out mercury for each division on the graduation; for when the divisions are small, as on a comparatively large tube, it can frequently be effected as accurately, or more so, by the unassisted eye, as by measurement with mercury. Thus for instance, if a tube of one-fourth of an inch in diameter were to be graduated into tenths and hundredths of a cubical inch, and by measuring every four hundredths by some of the preceding methods, the resulting divisions were found to be as nearly as possible equal in length, and consequently the tube uniform; then the single hundredths may, by very little practice, be marked off by the eye alone more accurately than by any other method usually adopted in the laboratory, and sufficiently so for the most refined experiments. The object is of course to divide the space of four hundredths, first into two of two hundredths, and each of these into two of one hundredth. This is best done, not by holding the

tube vertically against the wall, but laying it horizontally upon the table on a surface of uniform colour; and the division should first be made by dots as before mentioned, and their uniform and accurate distance acknowledged by the eye before the lines which are to form the scale are marked. Very little experience will shew the value and rapidity of this method, which, in the hands of a careful person, may be extended to the division of a space into 5, 6, 8, 10, or even more parts.

131. Where the mercury is *measured* into the tube to be graduated, every five or ten portions put in should be transferred to the balance and weighed, to ascertain their correct accordance with the quantity marked on the scale. Thus supposing the measuring tube before described (126) to be in use, when twenty divisions have been transferred from it, the operator should acertain that the mercury in the tube to be graduated actually amounts to twenty times 34.25 grains, and when forty divisions have been put in, that 1370 grains of mercury are there.

All these experiments relative to the weighing and measuring of mercury should be made on a tray, or over the mercury table (9.).

In marking the divisions every fifth and tenth should be distinguished from the others, for the purpose of ready observation, the fifths by a little extra length, and the tenths by being marked on both sides the upright line, as indicating larger divisions.

132. In eudiometrical and other experiments with small quantities of gas, very small divisions are required, and sometimes other parts than those of the tenths or hundredths of a cubical inch, are from their size useful. In these cases it is far better to take other subdivisions of the cubical inch than to have an independent standard, and through it introduce complexity into the laboratory measures. If hundredths are not small enough, divide them into two hundreths, or five hundredths, or thousandths; or if hundredths are too small, count two of them as one part, which may easily be done upon the tubes graduated as already described; and indeed every other division may be distinguished

by a little additional mark opposite to it on the other side of the perpendicular line.

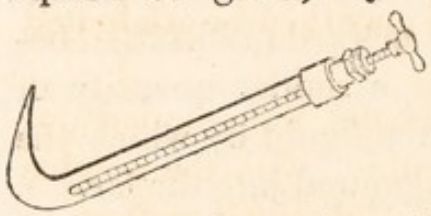
133. The graduation of jars is to be effected in a manner very similar to that which has been recommended for tubes, but if performed by weighing, water is a better substance than mercury for all quantities above half a cubic inch, because of the weight of the latter, and the consequent burden it occasions to the balance. A cubic inch of water at 62°. it will be remembered, weighs 252.458 grains. If measures are to be used, the vessels for them should be perfectly clean, so as to become wetted over the interior: they should be well rinced out with water, and after being left to drain for a few seconds, should, without further drying, be counterbalanced before the given weight of water, which is to form the standard, is introduced, and its volume marked (126.128); because on every occasion for their use a similar quantity of moisture will be left in them, after the liquid by which the graduations are to be made, has been poured into the jar.

134. In marking the jars it will not be advisable to place them against the wall, as has been directed for tubes, their larger diameter interfering with such an arrangement. They should be put upon a steady firm place: as the one appointed for measuring (107), and the liquid having acquired a state of rest, three points should be marked, upon upright and equidistant lines, corresponding accurately with the general surface of the water in the jar. These points are best obtained in the first place by the scratching diamond, and they may afterwards be extended into short lines by the file (119).

135. When the jars to be graduated are such as cannot stand steadily upon their own bases, the graduation at three different places becomes still more important. Thus with such as are capped, and being closed with a stop-cock, require, when graduated, to be supported on other jars, or list rings (59), or over holes, the triple graduation is a security independent of a correct perpendicular position. For though the jar might perchance shift a little in its situation from the perpendicular, still if any quantity of water, for instance 20 cubic inches, were then marked off by three lines

on different sides of the glass, any quantity which at a future time should coincide with those marks, would be known to be accurately 20 cubic inches. This might be effected indeed by two graduations on opposite sides, but it would not be so certain in practice as three. In using three also, the two first, if minutely incorrect, may be adjusted to perfect accuracy, by very slight motion of the jar before the third mark is made. The necessity of making these graduations at one temperature, that of 60°. has been before insisted upon.

136. Several instruments have been constructed by Dr. Hare,* in which he has introduced a mode of measuring, dependent upon the displacement of certain volumes of liquids or gases, by the different parts of a graduated rod. The figure represents one of these instruments. It consists of a glass tube fixed by one extremity into a cap and collar of leather, and terminated at the other in a capillary opening. A rod graduated into equal parts passes air-tight through the collar of leather, and is moved by a handle at the exterior. If the aperture be immersed in water, and the rod drawn out and thrust in again several times, the air is ejected, water enters, and by inclining the instrument it may be entirely filled with the latter fluid, and left with the greater part of the rod in the air. If it be then removed from the water and dried, it is evident that by inserting the rod, an equal volume of the water will be expelled from the tube by the capillary aperture, and may be transferred into the vessels to be graduated ; it is also evident that this water may be thrown out in successive minute portions, each equal to the other, and to one of the graduations on the rod. When the rod is thrust in, it is easy by drawing it out to replace it by water, as in the filling of the instrument, and then more equal bulks of water may be measured out.



137. By terminating the tube as before described (117),

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* Phil. Mag. lxvii. 21.

and using mercury instead of water, the instrument becomes an excellent measurer of equal portions of mercury, and may then be used in graduating tubes (124). The rod itself is easily graduated to any required dimensions, by observing how much of its length must be inserted to displace a given weight of mercury, as 34.25 grains (124), and then by proceeding to mark off other degrees of equal value.

138. An instrument of this kind may be made without difficulty, from a tube like that figured at page 72; the rod may be of solid glass, or a glass tube closed at the inner termination; it should be made to slide through some tow well impregnated with tallow, which being wrapped round it, is to form a plug sufficient to close the end of the tube. By tying this over with a piece of cloth it may be made quite firm and air tight; and the rod may then be graduated experimentally.

139. The following are useful estimates and comparisons of certain measures both linear and cubic, with the weights of the cubic measures added in grains of distilled water:

	Inches.
Yard	36
Metre	39.37039
Decimetre	3.93704
Centimetre	0.39370
Millimetre	0.03937

The seconds pendulum vibrating at London. 39.12929.

	Cubic Inches.	Grains of distilled Water.
Gallon	277.274	70000
Pint	34.65925	8750
Cubic Inch	1.	252.458
Litre	61.02525	15406.312
Decilitre	6.10252	1540.631
Centilitre	0.61025	154.063
Millilitre	0.06102	15.406

SECTION IV.

Sources and Management of Heat.

140. Heat is so important, as modifying chemical action, and the chemical and physical properties of bodies, that it must always be of the utmost consequence to the Chemist. So great is its influence over his researches, that he has been called the philosopher by fire; and though the consideration of its peculiar action on matter forms no part of the direct subject of the present volume, yet, as the modes of augmenting and applying it are proportionate in number and extent to the powers of the agent itself, so the sources and management of heat will claim much present attention. It is, however, by no means intended here to dwell upon this subject in its full extent, but rather to limit and compress it as much as possible; supplying to the student that portion of instruction which relates to the simplest and most effectual means of obtaining the temperatures he may require in his experiments, but not extending it to every furnace, lamp, or blow-pipe, or even to every one beneficially used in chemical arts and processes.

Furnaces.

141. There is scarcely any limit to the number of furnaces that have been contrived at different times as particularly adapted, either for special or general uses; all, no doubt, were good at the time they were devised, and superior for some reason or other to those which had preceded them. But the character of chemical operations has changed so much as to render many of these contrivances useless, or of little importance, and each person is now left to select those which are most agreeable to himself, as accordant with either his notions or modes of experimenting. For these reasons the author will here describe those which he has been induced to adopt as economical and effectual; convinced that he ought not to omit them, and that to describe

a greater number would be assigning to this subject a larger proportion of the volume than it can fairly claim.

142. An exceedingly useful furnace, either in a large or small laboratory, may be made out of a black lead or earthen crucible. The proper crucibles for this purpose are known by the name of *blue pots*, and may be had of almost every size, less than the height of 22 inches, and of 12 or 14 inches diameter at the top; they are made of clay and plumbago mixed, and are easily cut by a saw, rasp, or file. The price of one, which will make a very good furnace for small operations, is about six shillings. Anstey's coke crucibles are also serviceable for these uses; they may be cut and worked as readily as the blue pots, retain the heat very well, and are much cheaper: but they crack and fall to pieces by frequent change of temperature. They may be bought at Mr. Foster's, 2, St. John's-square, Clerkenwell; one 12 inches high and 7 inches diameter at the top, costing 16 pence.

143. One of these vessels, of the height of 12 inches, and 7 inches in width at the top within, will make a very useful furnace for the igniting of a small crucible, heating a tube, or distilling with large glass retorts at moderate temperatures, or with smaller glass or earthen retorts at higher temperatures. It is first in the course of preparation necessary to have certain round holes pierced in it. These are easily made; a gimblet, brad-awl, or other small instrument, is to be used, to penetrate the sides, and the small apertures thus produced are to be enlarged with a rat's-tail and round rasp, and ultimately finished with a half-round rasp, which will make them of the size required. Four of these holes are to be placed at equal distances from each other, and about two inches from the bottom of the pot; they may be $1\frac{1}{4}$ or $1\frac{1}{2}$ inches in diameter; a second ring of holes, five or six in number, is to be made half way between the top and bottom of the pot, and a third row of five or six within two inches of the top; these holes should be rather smaller than the four lower ones.



144. The pot should now be bound round with iron or copper wire, $\frac{1}{12}$ of an inch thick, to strengthen and hold

it together when it cracks, an effect which is sure to take place after it has been a few times heated. The wire should be carried round in three different places, just above the upper holes, between the top and second row, and between the second and lowermost row. A single wire, especially if of iron, is sufficient, and two or three long notches should be made with the edge of the rasp in the line of each ring of wire, just deep enough to receive it and prevent it from slipping down when drawn tight; the ends should then be twisted together. It is very convenient to have a handle to these furnaces, by which they may be lifted when hot, with a pair of tongs or a hook. It should be of iron wire one-eighth or more of an inch in thickness; one piece should be carried under the pot, and lodged in a groove deep enough to receive it, and prevent unsteadiness; it should rise up on opposite sides of the furnace, until near the top, and there be turned so as to form a hook or ring on each side to receive the handle. This wire should be put on at the same time with that which binds the whole together, and the latter wires should take a turn round the former wherever they cross it, which will add considerably to the strength of the whole. The handle above is easily made of a piece of the same thick wire curved over the top of the furnace, and bent into hooks at the extremities by which it is to be attached to the former piece. The handle should have such a curve that when not in use it may pass over the edge and lie out of the way against the side of the furnace.



145. A small round moveable grate of cast-iron, like that figured in the wood cut, makes this furnace complete for many operations. If it be required to heat a crucible, the grate should be of such a size as to drop into the furnace, and rest between the bottom and the second row of holes. The part below then forms the ash-pit, to be supplied with air for the fire by the four holes; and the part above forms the body of the furnace to receive the fire and crucible. If a shallow fire only is wanted, as in processes of distillation or the heating of tubes, the grate should be of such a size as, when dropped into the furnace, to descend only a little below the first tier of holes,

the ash-pit then having two tier of holes entering it. Half a dozen of these small grates will be required in the laboratory, for the purpose of fitting at different times into different parts of the same furnace, and also for use in different sized furnaces of the kind now described. They are of small price, and may be bought of the instrument maker.

146. When larger or smaller furnaces of this sort are constructed, variations in the number and arrangement of the air holes will of course suggest themselves. A smaller furnace will require only two tiers of holes; one of three or four for the ash-pit, and another for the body of the furnace. A larger furnace may require more holes, and may at times have those which communicate with the ash-pit enlarged into other forms, and furnished with stoppers of soft red brick (1240) or pieces of old pots.

The fuel used with these furnaces is charcoal, or in the larger ones charcoal mixed with coke.

147. The fire is considerably under command, both as to the diminution and increase of its intensity. A box of round stoppers, made of soft brick (1240) or old blue pots, and something like corks in form, should be provided. These serve to close the air holes which lead either to the ash-pit or directly to the fire, and by moderating the quantity of air which enters, reduce the combustion in any required degree. When the grate is placed high up in the furnace, as for distillations, these stoppers are frequently required for the lower holes.

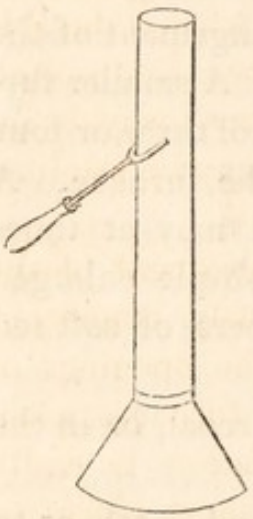
On the contrary, to increase temperature, and sometimes to increase the body of fuel, additions are made at the top of the furnace. A very useful one consists of the upper part



of an old pot, cut off so as to form a ring, which should be bound with wire, as was directed in regard to the furnace (144). Rings of this kind may be from an inch to three inches or more in depth, and when placed upon the top of the furnace, so as to form as it were a continuation of it in height, they considerably increase both the capacity and the draught. They may be made with holes or not, according to their depth. Such holes of course weaken the ring, but when the quantity

of fuel in the fire is increased, it is frequently necessary to increase the supply of air also; and when a crucible stands in the middle of the mass of fuel, these lateral supplies of air, especially in the smaller furnaces, are essential to the vividness of combustion, and the high temperature required.

148. A most useful accompaniment to these small portable



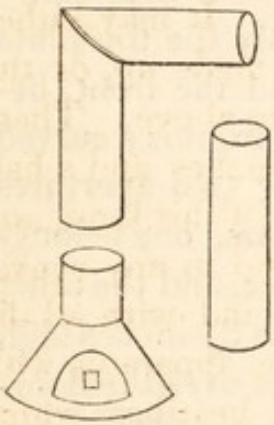
furnaces, is a piece of straight funnel-pipe, about two feet long, four inches in width, and opening out below funnel-fashion, until it is about eight inches in diameter. This will easily rest upon any furnace not more than eight inches, nor less than four or five inches wide; is quickly put on or off; stands steadily of itself, and increases the draught powerfully. A wooden handle may be attached to it for convenience, or without it the tongs will serve to remove it. It may either be taken off when the fire requires to be made up, or the pieces of charcoal may be dropped in from above. There is no difficulty in raising a crucible two inches and a half in diameter to a white heat, by a furnace of this kind, and of the dimensions before stated (143), and in any convenient station upon the tables or the floor, and with all the advantage of arranging or dismounting the apparatus with extreme facility. All the ignitings and heatings which belong to the analysis of siliceous and other minerals, have long been made in furnaces of this kind at the Royal Institution.

149. To fit this furnace for the igniting of tubes, it is useful to cut a couple of notches in its upper edge, about an inch deep, in which the tube may be laid when the grate is high in the furnace; at other times when a smaller heated length only is wanted, it may be passed through two opposite holes lower down in the furnace. When heating a tube in this manner, it is not necessary to have a greater space than an inch or an inch and a half between it and the grate.

150. When these furnaces are made out of large pots, the grates being upwards of six inches in diameter, and the fuel

chamber six or eight inches high, they become very powerful, and may be used to heat crucibles of considerable size. From the larger dimensions of the grate, it is generally unnecessary to form lateral air holes through the body of the furnace, but it is then requisite that an abundant supply of air be admitted to the ash-pit, and through the grate to the fire. The fuel used in these larger furnaces should be a mixture of coke and charcoal, or sometimes, when a durable fire is required for long operations, coke alone; for in such cases the rapidity with which charcoal burns away is inconvenient, and the heat which it produces may be attained with coke by improving the draught.

151. These furnaces may, when the employment of the highest heat is desirable, be advantageously connected with the spare laboratory flue, (3), and the openings of that flue should be above the level of the furnaces when they stand on the floor. The communication is easily effected by two or three short pieces of funnel-pipe like those in the margin, made to fit into each other, one having a funnel termination at the bottom, lined with fire-clay, to adapt it to the furnace, and another a bend or joint at right angles. The pipe should be at least four inches in diameter. These furnaces thus arranged, are very powerful, and being sometimes wanted for long operations, require to be fed without disturbance of the arrangement; for which reason it is proper to have an aperture in the funnel-pipe, by which fuel can be introduced, and which may be closed by a stopper, when the fire is in order. Another, and at times a more convenient mode of arrangement, is to continue the furnace upwards by a deep ring (being the upper part of another pot) in which is an aperture by which the fire can be fed when required, but which can be closed by a stopper when

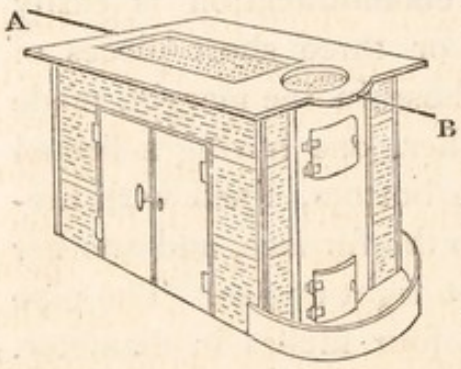




not in use. The funnel-pipe is then to extend from the top of this ring to the hole of the flue in the wall. These large furnaces should be bound with iron hoop.

For further information relative to these kinds of furnaces, see Lewis's Philosophical Commerce of the Arts, pp. 1—37.

152. The furnace next requiring description, is that intended for general laboratory use, and already referred to, (6). Being in constant requisition as a table, it should be about 34 or 35 inches in height; its other dimensions, and even its form, must depend upon the space that can be allotted for it. The one in the laboratory of the Royal Institution, constructed several years since, under the direction of Mr. Brande, has the brick-work 52 inches in length and 30 inches in width; the iron plate, including sand-baths, being 57 inches by 42; others have been constructed, the plates of which are only 40 inches by 27. The principal part of this furnace is necessarily of brick-work, only the top plate with the baths and the front, being of iron. The front is a curved iron plate, having two apertures closed by iron doors, one belonging to the fire-place, and the other to the ash-pit. It is 34 inches high and 14 inches wide. The ash-hole door moves over the flooring beneath; the bottom of the fire-place door is 22 inches from the ground, and the door itself is $8\frac{1}{2}$ inches by 7. This front is guarded within at the part which incloses the fire by a strong cast-iron plate, having an opening through it corresponding to the door of the fire-place. It has clamps attached to it, which, when the furnace is built up, are inclosed in the brick-work.

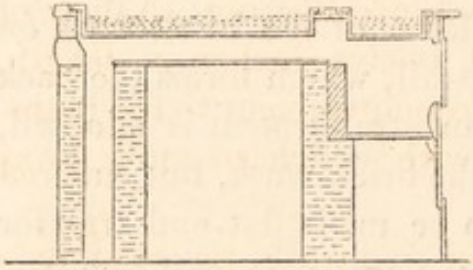


In the setting or building of the furnace, two lateral brick walls are raised on each side the front plate, and a back wall at such a distance from it as to leave space for the ash-hole and fire-place; these walls are lined with Welch lumps, where they form the fire-chamber: two iron bars are inserted in the course of the work to support the

loose grate bars in the usual manner, the grate being raised 19 inches from the ground. The side walls are continued until of the height of the front, and are carried backward from the front in two parallel lines, so as to afford support for the iron plate which is to cover the whole. The back wall of the fire-place is not raised so high as the side walls by six inches and a half, the interval which is left between it and the bottom of the sand-bath, being the commencement of the flue or throat of the furnace. In this way the fire-place, which is fourteen inches from back to front, and nine inches wide, is formed, and also the two sides of the portion of horizontal flue which belongs to the furnace, and is intended to heat the larger sand-bath. The bottom of this part of the flue may be made of brick-work resting upon bearers laid on the two side walls, or it may be a plate of cast-iron resting upon a ledge of the brick-work on each side, and on the top of the wall, which forms the back of the fire-place. When such an arrangement is adopted, the plate must not be built into the brick-work, but suffered to lie on the ledges, which are to be made flat and true for the purpose: for if attached to the walls, it will by alternate expansion and contraction disturb and throw them down. The ends of the side walls, forming as it were the back of the furnace, may be finished either by being carried to the wall against which the furnace is built, or inclosed by a piece of connecting brick-work, to make the whole square and complete, or a warm air cupboard may be built in the cavity beneath the flue, and the door made to occupy the opening between the walls. Occasionally the flue may be required to descend there, and pass some distance under ground. These points should be arranged and prepared before the plate constituting the top of the furnace is put on to the brick-work, so that when the plate with its sand baths are in their places, they may complete the portion of horizontal flue by forming its upper side.

153. The size of this plate is the first thing to be considered, and having been determined upon, from a consideration of the situation to be occupied by the furnace,

and the places of the sand-baths also having been arranged; the brick-work must then be carried up, so as to correspond with these determinations, and with the plate itself, which in the mean time is to be cast. The sand-baths and the plate are to be formed in separate pieces. The bath over the fire is best of a circular form, and of such diameter that, when lifted out of its place, it may leave an aperture in the plate equal in width to the upper part of the fire-place beneath; so that a still, or cast-iron pot, or a set of rings may be put into its place over the fire. The other sand-bath must be of such a form, as to correspond with the shape and size of the flue beneath. These vessels are to be of cast-iron, about three-tenths of an inch thick; their depth is to be two inches and a half or three inches, and they are to be cast with flanches, so as to rest in the corresponding depressions of the plate that the level of the junctions may be uniform. This will be understood from the accompanying section of the furnace, given through the line A B of the view.



It is essential that these sand-baths be of such dimensions as to fit very loosely into the apertures in the plate, when cold, a space of the eighth of an inch or more being left all round them, as shewn in the section, otherwise, when heated, they will expand so much as entirely to fill the apertures, and even break the plate. The plate itself should be half an inch thick.

154. When the plate and its sand-baths are prepared, and the brick-work is ready, the furnace is finished by laying the plate on the brick-work, with a bed of mortar intervening. If the walls are thin, or any peculiarity in their arrangement occasions weakness, they should be bound together, within by cranks built into the work, and without by iron bands. The alternate changes of temperature from high to low, and low to high, to which the furnace is constantly subject, renders it liable to mechanical injury, in a degree much surpassing that which would occur to a similar piece of brick-work, always retained nearly at one temperature.

155. The sand-baths which have been described are liable to an accident, that has induced some chemists to substitute others made of wrought iron. When first heated they frequently, indeed generally, crack from the unequal expansion in different parts; and the plate itself is subject to the same accident. If constructed of wrought iron this effect is not produced; but then after being used for some time they warp into very irregular and inconvenient forms, especially if made of thin metal; whilst on the contrary, these of cast-iron, when cracked, are rarely injured for the uses to which they are to be applied, and seldom suffer further change.

These baths should have washed sea sand put into them; it is heavy and occasions no dust when moved, whilst on the contrary, unwashed and bad sand contains much dirt, and occasions great injury in experimenting. A piece of straightened iron hoop, about twelve inches in length, should lie on the furnace, as an accompaniment to the baths, being a sort of coarse spatula with which to move away the sand.

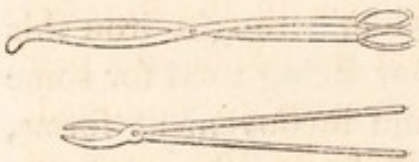
156. The circular sand-bath is frequently replaced by a set of concentric iron rings, or a cast-iron pot. The rings



are convenient for leaving an aperture over the fire of larger or smaller dimension, according as a smaller or larger number are used at once; and being bevelled at the edges, fit accurately into each other, without any risk of becoming fixed by expansion. The external one like the sand-baths (153) should be made smaller than the depression in the furnace plate in which it rests. The iron pots are of various sizes, and are adapted to the furnace by means of the rings; a red heat is easily obtained in them for sublimation.

157. Occasionally the sand-bath is replaced by a still, for the production of distilled water. The form of the aperture and furnace is such as to enable the still to be placed very advantageously as relates to the fire beneath.

158. Tongs are essential accompaniments to furnaces. There are many forms of these necessary implements; those which have the rivet in the middle of their length, so as to allow of considerable opening at their extremity, and also have the ends bent downward are best for common use.



They should be of different lengths from a foot to two feet; and there should be one or two pair having the rivet near the extremity, by which a powerful hold is obtained, so as to prevent the slipping of a heavy weight from between them.

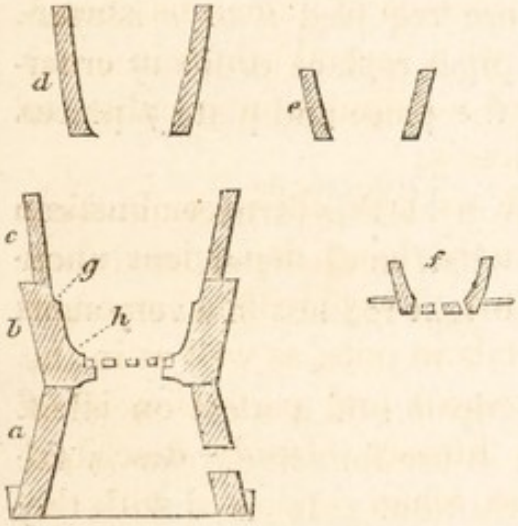
159. Mr. Knight of Foster Lane, has contrived a small furnace, competent for the performance of numerous chemical operations. It is described with several others in many chemical works. The points of manipulation peculiar to each become evident upon inspection.

160. *Wind furnaces* are such as have their combustion urged by a draught of air through them, dependent upon the flue to which they are attached. They are usual amongst refiners, and those who melt metals in pots, as well as in the laboratory; hence their improvement and perfection is of great importance. The table furnace already described (6.152), and the crucible furnaces, when connected with the laboratory flues, are wind furnaces; but by proportioning the size of the chimney to that of the furnace, others may be constructed, much surpassing these in the intensity of heat produced. It has been found that the combustion is most vivid, when carried on in a furnace of equal diameter with the flue placed immediately over it, the latter being of a height equal to about thirty times its diameter, and free access of air to the grate being permitted. But in practice, many variations are introduced, which, though they diminish the intensity of heat, still enable the worker of metals to heat a larger mass of matter up to the point he requires, with a diminished consumption of fuel, and consequently at a smaller expense.

161. In the laboratory of research, the wind-furnace may generally be replaced with advantage by the *blast-furnace*;

the operations being more manageable and expeditious, the heater greater, and the consumption of fuel smaller. By a little contrivance, one of the crucible furnaces before described (143), is easily converted into a blast furnace, and a very high temperature for small vessels obtained. This is done by closing the holes of the ash-pit with the stoppers (146), except one, and applying to that the nozzle of a pair of double-hand bellows, from which a blast is to be urged, and the furnace aided at the same time by the piece of upright funnel-pipe (148); the fuel is to be charcoal.

162. Mr. Charles Aikin has devised an arrangement for a blast furnace on a small scale, which is exceedingly good and powerful. The furnace is made out of fragments of broken blue pots, and consists of several parts, sections of which are here given, drawn upon a scale of one inch to ten. The lower piece *a* is fitted into a tin bottom, consisting of a circular plate with a rising rim; the junction being made tight by plaister of Paris. The piece *b*, resting upon *a*, is so formed as to have three circular shoulders, running round the inside, one at *g*, a second at *h*, and a third a little lower, namely where the grate in section is observed to rest. The grate is circular, and can be removed at pleasure. The piece *c* is merely a broad rim, which resting upon the edge of the piece *b*, increases the capacity of the furnace. The piece *d* is to be used when, in place of enlarging the fire, it is required to be diminished. It it to be placed within *b*, resting at its lower edge on the rim or shoulder *h*: *e* is a similar piece, but smaller, it rests also on the shoulder *h*: it has a notch half way between the upper and the lower edge, to admit the stem of a tobacco pipe, or other similarly formed article. Another part of the furnace is a circular plate of sheet iron, of such a diameter as to fit into the rim *g*; this plate is perforated with an aperture three inches and



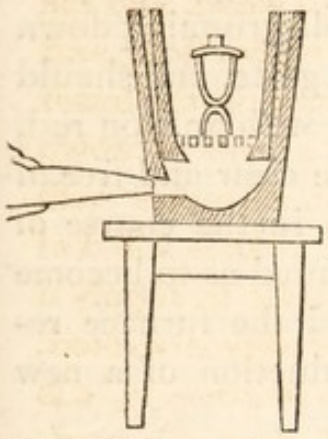
a half in width, into which a very small furnace-body fits, having its lower part pierced with holes instead of a grate; both these are represented at *f*.

When the furnace is in use it is raised on a stand, and the nozzle of a pair of double bellows, twelve inches long and ten inches wide, brought towards the aperture in the lower piece but not inserted. The fire is lighted by a piece of brown paper and a little small coal, and is sustained, either with coke and small coal, or coke alone. The coke is sifted of two sizes, and preserved in boxes, with a ladle to supply it to the fire. When a fire of a moderate size only is wanted, the piece *b* is used; if there be occasion to increase it, *c* is put on. When smaller fires are required *d* or *e* is used. For operations where tobacco pipes replace ordinary crucibles the grate is removed, and the piece and plate *f* placed within *b* at the shoulder *g*.

Mr. Aikin easily melts cast iron at this furnace, and can heat a crucible two inches and a half in diameter, and three inches and a half in height, to bright redness in a very short time.

163. The following is a description of a most excellent blast-furnace, which has been in use for some years in the laboratory of the Royal Institution. It is sufficiently powerful to melt pure iron in a crucible, in twelve or fifteen minutes, the fire having been previously lighted. It will effect the fusion of rhodium, and even pieces of pure platinum have sunk together into one button in a crucible subjected to its heat. All kinds of crucibles, including the Cornish and the Hessian, soften, fuse, and become frothy in it; and it is the want of vessels which has hitherto put a limit to its applications. The exterior consists of a blue pot eighteen inches in height, and thirteen inches in external diameter at the top. A small blue pot of seven inches and a half internal diameter at the top, had the lower part cut off, so as to leave an aperture of five inches. This when put into the larger pot rested upon its lower external edge, the tops of the two being level. The interval between them, which gradually increased from the lower to the upper part, was filled with pulverized glass-blower's pots, to which

enough water had been added to moisten the powder, which was pressed down by sticks, so as to make the whole a compact mass. A round grate was then dropped into the



furnace, of such a size that it rested about an inch above the lower edge of the inner pot: the space beneath it therefore constituted the air chamber, and the part above the body of the furnace. The former was $7\frac{1}{2}$ inches from the grate to the bottom, and the latter $7\frac{1}{2}$ inches from the grate to the top. Finally, a horizontal hole, conical in form, and $1\frac{1}{2}$ inches in diameter on the exterior, was cut through the outer pot, forming an opening into the air chamber at the lower part, its use being to receive the nozzle of the bellows by which the blast was to be thrown in. The furnace being thus completed, the next object was to dry it gradually, that when used it might not be blown to pieces by confined aqueous vapour; a charcoal fire was therefore made in it, and left to burn for some hours, being supplied with air only by the draught through the hole into the chamber beneath. When vapours ceased to be formed, the furnace was considered to be ready for use.

164. This furnace has always been used with a pair of large double bellows mounted in an iron frame, the furnace being raised upon a stool so as to bring the aperture of the air chamber to a level with the nozzle of the bellows. The latter has generally been inserted in the aperture; for this and similar furnaces are of such depth compared to their width, that when charged with a crucible and fuel, there is so much resistance to the passage of the air when urged by a blast competent to create and sustain a vivid combustion, that a part returns by the side of the nozzle, if the aperture be left open. The bellows spoken of is far larger than necessary for the furnace described, and is rarely worked to one-third of its power; for otherwise the heat rises so high as to destroy the crucible, and the results are lost: it is however at all times advisable to have an abundant command of air.

165. The heat produced in this furnace is such, as at every violent operation, to cause the production of some slag from the melting of the inner surface of the furnace itself, where the combustion has been most vivid. The slag running down the interior, collects round the edge of the grate, and should be removed with a chissel and hammer, or with an iron rod, after each operation, that the grate may be clear and free of obstruction for the next process. When in the course of time the interior of the furnace is so far injured as to become thin and weak, it must be displaced, and the furnace restored to its original state by the introduction of a new inside as before (163).

166. The fuel to be used in this furnace is coke. Its consumption is very small, considering the heat that is obtained, in consequence of the short period of each operation. The superiority of the blast-furnace over the wind-furnace in many operations for which high temperatures are required, depends upon the rapidity of its action. It is requisite to employ this furnace in the open air, or under a well arranged vent, for an immense number of sparks, much flame, and a current of hot air are projected during its operation, which might occasion serious mischief in a room, unless the ceiling were at a considerable height or guarded by a metal screen.

167. Lavoisier proposed the application of oxygen to furnaces, to increase the rapidity of combustion, and consequently the intensity of heat: but it will evidently be unnecessary to employ it whilst furnaces in which common air is used continue to be more than equal to our means, in consequence of the limit put to their application by the inadequacy of the vessels we possess to resist higher temperatures.

168. The *fuel* to be used in furnaces is of three kinds, coal, coke, and charcoal. *Coal* is the ordinary fuel for the laboratory table-furnace (6.152), or that intended to be in use every day, and to serve for fusions, roastings, and other operations, for which its temperature may be sufficient. It is very desirable that this coal should be good, and not of the kind which contains much sulphur, or an abundance

of earthy matter; for the first interferes with various fusions and ignitions, and the latter renders the fire dirty and dusty, and when the temperature is raised to a high point, causes an abundance of clinkers. On certain occasions, to be hereafter distinguished, especially if the coal be sulphureous and bad, it may be necessary at times to use both coke and charcoal in the table-furnace. Coal should never be used in the blast-furnace: for in consequence of its softening and swelling by heat, it aggregates, closes the small channels by which the air finds a passage through the fuel, and impedes the combustion.

169. *Coke* is in constant requisition; it varies in quality with the coal from which it is obtained. Such as is intended for the service of the blast-furnace should be free from sulphureous, earthy and metallic matter. Of this kind is the Staffordshire coke, which may be obtained at various wharfs on the canals near London. It is frequently so little altered in appearance as to resemble the original coal. It burns completely away in a blast-furnace, leaving scarcely a trace of slag: so that after several successive portions have been introduced, no material quantity of refuse is produced upon the grate, nor any thing that will act seriously on the crucible as a flux.

170. On the contrary, if common gas-coke be used in this furnace, the oxide of iron and earthy matter which it contains is so abundant that slag is soon produced, which, flowing over the crucible, corrodes and destroys it; by mixing with the fuel, it tends to prevent the access of air to the surface, and by accumulating upon the grate, at last so far obstructs the entrance of air from beneath, as entirely to prevent the attainment of a high temperature. This coke is not more than half the price of that from Staffordshire, and is very convenient and serviceable in the laboratory table-furnace, where, when an iron bottle is to be ignited, or a crucible heated only to bright redness, it answers far better as fuel than coal; and as it does not swell nor aggregate, the passage for air through the fuel remains open, and a much more general and regular heat is obtained.

171. The Staffordshire coke when used in the blast-fur-

nace before described (163), should be broken into pieces somewhat larger than a walnut, that it may sink down in the fire between the crucible and the furnace, presenting a constantly compact body of fuel; and it should also be sifted or screened before it is used, to remove the dust and small particles; which otherwise being mixed with it, would interfere with the passage of the air, by stopping up the small vacuities between the different pieces of fuel as they lie in the furnace.

172. The *charcoal* intended for laboratory use may be of the ordinary kind, and must not be either too large or too small. If large the pieces should be broken down, or they will be unfit for use in the crucible furnaces, for which it is principally intended. Charcoal is a quick fuel; but burning with facility, a small quantity of it can be easily retained in a state of regular combustion; and hence in cases where but little space intervenes between the substance to be heated and the side of the furnace, or when a small temporary fire is required in the air, it is very convenient. Where Staffordshire coke will burn, and by means of a blast or a draught of air will give sufficient intensity of heat, it is very superior to charcoal in duration. Occasionally a mixture of coke and charcoal is convenient, since it affords a combination possessing the qualities of permanency and freedom of combustion.

A charcoal box is almost as essential to a laboratory as one for coal, and should have its appointed place.

173. It must be remembered that all operations with furnaces should be carried on in safe situations, care being taken that no danger be incurred by the ascent of sparks, flame, or hot air; by lateral vicinity to combustible bodies; or by standing upon an unprotected wooden surface. When from peculiar circumstances a small furnace is necessarily placed in such a situation that danger may be anticipated from the ascending current of air, the latter may frequently be rendered harmless by fixing a plate of tin over the furnace, so as to break the current, and mix the hot air of which it consists with the neighbouring atmosphere. Injury from the vicinity of a heated furnace on its side to a wainscoat,

trough, or any thing destructible by heat, may almost always be prevented by interposing a bright sheet of tin-plate; the heat being then reflected, and the neighbouring body kept perfectly cool.

174. When small furnaces are placed upon tables, stools, or trays, a brick, or a piece of sheet-iron or tin-plate should be interposed, according to the mode by which the heat is likely to be communicated: a brick or tile should be used in cases of conduction, metal in sheets to catch ashes, and bright tin-plate to prevent the ill effects resulting from radiation. When a permanent furnace is erected in a room which, being floored with wood, is to be converted into a laboratory, great care should be taken that the ash-pit and parts adjacent be guarded by a stone flooring laid down for the purpose. The stones should be bedded in a proper manner beneath, that no injury may arise should cracks occur in them, or in case they should not be of sufficient thickness to prevent the transmission of heat.

Lamps.

175. Lamps may be considered as small furnaces, and are very economical and ready sources of heat. Nor are they deficient in temperature; for as Sir Humphrey Davy has shewn, the intensity of heat in flame is very high. Since the method of operating on small quantities of matter has been practised and improved, not only has the heat of a simple unassisted lamp-flame been taken advantage of, but many contrivances have been effected by which it has been powerfully increased and more beneficially applied.

176. Of the varieties of lamps used in the laboratory, the most useful is that in which spirit is burned. Spirit lamps may be bought at the instrument makers, and are to be trimmed with a cotton wick and supplied with alcohol. When in combustion, the flame though pale produces intense heat, as may be proved by introducing a small platina wire or other piece of filamentous matter into it. The student should in his first practice accustom himself to the introduction of small fragments of minerals, metals, and other substances, into the flame, at the extremity of a thin

wire, or a filament of asbestus or cyanite, or upon a narrow slip of platina foil. He will thus habituate himself to various appearances, obtain a knowledge of the heating power, and learn from experience at what part in the flame the highest temperature exists, and where he should intersect it when he wishes to obtain a more moderate but more general heat.

177. The flame of alcohol produces no smoke or fuliginous matter, and hence a great and constant advantage possessed by it. If a platina capsule, or a small platina crucible, be held in the flame of a candle, for the purpose of applying heat to its contents, a black sooty film is soon deposited, which from its great radiating power tends to diminish the heat of the vessel, and prevents that elevation of temperature which the flame otherwise is competent to occasion. But held in the flame of a spirit lamp, the blackening does not take place, and this forms one great cause for the rising of the temperature to a much higher degree in this than in the former instance. If a candle were used to apply heat to the exterior of a glass flask or retort, the carbonaceous matter would soon accumulate, so as to obscure the vessel and hide the contents; but a spirit lamp occasions no such obscuration, and at the same time that heat is applied, the utmost facility of observing the substances within is afforded.

178. Where the flame comes in direct contact with the substance under experiment, the advantages are equally on the side of the spirit lamp. For the carbonaceous matter, besides interfering as above described, would frequently have an injurious chemical effect; whereas it seldom happens that the water and carbonic acid which result from the combustion of alcohol, produce any change by their contact.

179. The place of greatest heat in the steady flame of the spirit lamp, is just within its summit. The substance to be heated, when it will bear the direct contact of the flame, should be as small as possible, consistently with the due notice of its changes. It may be supported by a pair of delicate platina forceps, or at the end of a piece of fine platina wire or foil, or when the substance will admit of splintering, may itself be the extreme end of a sharp splinter, and will then require no other support. In all cases the support

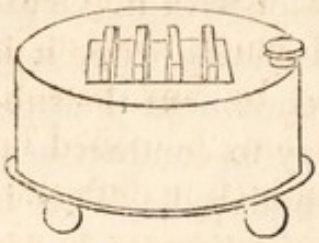
should be as thin and delicate as possible, that the heat may not be conducted by it from the substance to be examined, or the flame itself cooled by contact with it. Occasionally, especially when the support is a platina wire, it is advantageous to make that part of it which is next the substance as hot as possible, that its tendency to conduct heat from the body to be ignited may be diminished. This is easily done by holding it so that the wire shall ascend as it were up the side and just within the verge of the flame, still supporting the body to be heated in the hottest part: or at times it is sufficient to let the support descend from above, the hot air from the flame heating the part next to the substance to a sufficiently high temperature.

180. When a larger substance is to be heated, it is generally best done by putting it lower down in the flame than the hottest point, the flame being made to divide under it and ascend a little distance on all sides. In this way a small platina crucible or a capsule may be heated red-hot throughout; whereas, if put at the summit of the flame, such effect would not be produced because of the partial exposure of the vessel to the surrounding air.

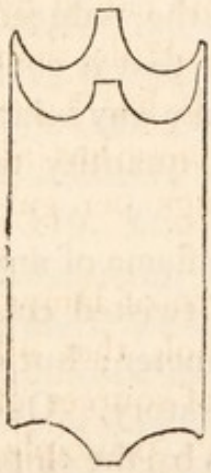
181. Platina foil is a useful accompaniment to the spirit lamp. A square inch of its surface may be made at once red-hot. It may be readily bent into any convenient form, so as to supply the place of crucibles and capsules for small quantities of matter. It suffers scarcely any change by heat, is affected by few bodies except sulphur and the reduced metals, and withal is so bad a conductor of heat that it conveys less away from substances lying upon it than any other metal, and does not conduct any inconvenient quantity to the fingers.

182. Spirit lamps of the usual size will give a flame of any height less than two inches, the wicks being of twisted cotton, usually about a quarter of an inch in diameter; but a lamp with a larger wick is desirable in the laboratory. One made of copper, with a burner one inch long by the third of an inch wide, will produce a flame in which a platina crucible nearly two inches in diameter, and small glass retorts, may be raised to redness.

183. A very powerful and useful spirit lamp, frequently supplying the place of a furnace, is formed by making an aperture of 0.8 or 0.9 of an inch by $1\frac{1}{4}$ inch, through the body of the lamp, and fixing in it four burners, upon Count Rumford's principle, each of a length equal to the width of the aperture, and the $\frac{1}{8}$ or $\frac{1}{10}$ of an inch wide. These are to be parallel to each other, and at such distances as to have five spaces or air-ways, the two outer being half the width of the inner. These burners rise about a quarter of an inch above the lamp, and descend as low as the bottom of the body, being fastened in the aperture by their edges. Each burner is closed beneath, but has a small hole into the lamp as a passage for the alcohol, thus forming as it were a part of the lamp. The lamp is supported upon four balls about half an inch in diameter, to allow of the access of air beneath and up the apertures to the flame. The alcohol is introduced by a hole in the upper surface of the lamp, which is usually closed by a screw; and the burners are trimmed by putting down each a doubled cotton of an Argand lamp until it touches the bottom, and then cutting it off about the eighth of an inch above the top.



184. Such a lamp is very powerful when applied merely as other spirit lamps are to the vessels to be heated, but it becomes still more effectual in heating a crucible when assisted by a chimney. This may be as usual, a copper cylinder, resting below upon the flat surface of the lamp, and either level at the top or cut out into three or four large scollops. Two chimnies are useful, of an inch and three quarters in diameter each, one about $3\frac{1}{2}$ and the other 5 inches in length. Such a lamp, besides having the power of heating crucibles and retorts, is easily adjusted in any convenient place, soon set to work, and as soon extinguished; and if convenient, only one or two wicks may be lighted at once, those which are not employed being covered up by the caps which are used to slip over the



burners to prevent evaporation when the lamp is not at work.

185. It would be improper to omit mentioning Mr. Phillips's spirit lamp,* the advantage of which consists in its ready construction in any place and by any person. "Let a piece of tin plate about an inch long be coiled up into a cylinder of about three-eighths of an inch in diameter, and if the edges be well hammered it is not necessary to use solder. Perforate a cork previously fitted to a phial, and put a cotton wick through the short tin tube, and the tube through the cork; the lamp is now complete, and will afford a strong flame, taking care of course not to prevent the rise of the spirit by fitting the cork too closely."

186. All these lamps should have caps for the burners, to prevent the evaporation of the alcohol when they are not in use. Those which are sold in the shops are always furnished with them. The large spirit lamp above described should have one for each burner, the material being tin plate. Mr. Phillips's lamp may easily have a cover made for it by a little piece of glass tube closed at one extremity.

187. Alcohol is the fuel burned in these lamps, and though it need not be highly rectified, yet disadvantages arise if it be too weak. The spirits of wine of the distillers or doubly rectified spirit, is sufficiently good for the purpose, the specific gravity of which is about 0.84 or 0.85.

188. There is a substance produced during the destructive distillation of wood in considerable quantity, and called by Mr. Taylor, Pyroligneous ether. It is more volatile than alcohol, but burns very well in a spirit-lamp. It has a peculiar odour, but in consequence of its cheapness has an advantage, its price being only sixteen shillings per gallon.

189. *Oil* is a fuel so applicable in the service of lamps, and also so economical as compared to alcohol, that oil lamps must not be omitted in the enumeration of sources of heat. Such as are constructed upon Argand's principle, having circular wicks with a current of air both inside and

* Annals of Philosophy, New Series, VII. 36.

outside, are most valuable. They are now constantly constructed for laboratory service, the material being copper, and the chimney, in place of glass, being also made of that metal. Their principal use is in distillations or evaporations, as they possess the advantages of yielding a nearly uniform heat for several hours together, and allowing its increase or diminution within certain limits at a moment's notice. It sometimes happens that the highest temperature or greatest quantity of heat of which these lamps are capable cannot be attained, because, notwithstanding the careful and regular manner in which they have been trimmed, one part of the flame will smoke, if the wick be turned as high as the rest of the flame will bear, without smoking. Upon examination it will generally be found that the part which smokes is that coinciding with the notch by which the arm, connecting the cotton ring with the rack, descends; in which part the cotton is necessarily more exposed than elsewhere. Should it be so, the fault is easily corrected for the time, by placing a little slip of copper or tin plate against the cotton in that place; and then the other parts may be raised so high as to give their full combustion without smoke.

190. Double concentric-wick oil lamps have been constructed for the purpose of permitting greater combustion and supplying more heat. These frequently fail in their applications, and generally because both cottons being attached to one rack, which is necessarily placed considerably on one side, there is great irregularity of action, and too much friction, whence the lamp soon becomes deranged, and is rendered useless. This evil is readily corrected by having two racks, the second being attached to the double cotton ring exactly as the first is, but on the opposite side: and then with care the lamp may be arranged with accuracy, producing as much heat as may be required for crucible operations. The racks should be raised or lowered regularly and equally, so that both may assist in moving the cotton; and care should be taken that one be not raised without the other, or the one made to pull against the other. In reference to the wicks also, more care is required with

the double than the single lamps, in consequence of the difficulty of trimming the two cottons so that the flame of one shall not have a greater tendency to smoke than the other. The best method is to cut them as seldom as possible, but instead, to allow them to burn regularly, and when extinguished and cold, to remove the hard crust and leave the singed edge of the cotton that will then be exposed, as undisturbed as possible. A careful attentive experimenter will in this way find no difficulty in keeping a double-wicked lamp in order, and will obtain all the benefit which it is capable of affording; whilst a hasty careless operator will never be able to make the cottons move easily, or burn without smoke, or obtain any advantage from the lamp over an ordinary one.

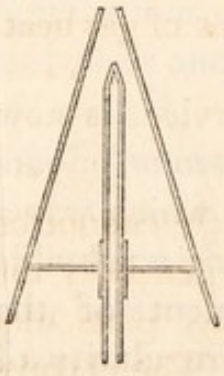
191. It is essential in these oil lamps that an abundant supply of air be obtained to the wick. As generally constructed there is seldom sufficient air way, especially in those with double wicks; and though they may burn very well at first, yet the accumulation of oil and dust soon interferes by stopping up the narrow apertures, and thus manifests the deficiency. It is advisable to use the best lamp oil; for the constancy and steadiness of its flame, and brilliancy of the combustion, more than compensate for the higher price of the fuel.

Gas Lamps.

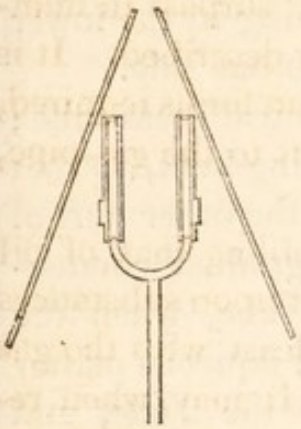
192. The erection of gas works for public service, is now so general in most large towns and in numerous private establishments, that the chemical gas lamp, which was a few years ago a mere curiosity, is now becoming a valuable and economical auxiliary to the establishment of the chemist. The facility of management and the regularity of flame, are even greater than with the Argand oil lamp, for by means of jointed or flexible tubes, in conjunction with the smallness of the burner from which the flame proceeds, as compared with the body of an oil lamp, it can be adjusted with the utmost nicety in any required position. The kind of flame depends upon the form of the burner.

A single jet, or a series of jets in a line, or a circular flame, or several concentric flames, may be obtained at pleasure, and thus the applications of the gas lamp to distillation, the igniting of crucibles, &c. may be made to surpass in number and effect those of the lamps already described. It is only requisite to have burners of the different forms required, capable of being attached by a ground joint to the gas-pipe, which has been laid on from the works.

193. The gas burns with a flame resembling that of oil in its tendency to deposit fuliginous matter upon substances placed in it (177), this tendency being least with the gas from coal, greatest with that from oil. It may when required be prevented in several ways, by the admixture of air with the gas in certain proportions previous to its combustion; the flame being brought to resemble that of alcohol, (177). This is best effected, not by adding air to a quantity of gas in a gasometer, which would always be partial, and sometimes dangerous in its application, but by some simple additions to the burners. That necessary to produce a smokeless jet of flame from gas, will be understood from the wood-cut, in which is represented the section of a cylindrical single jet burner, and that of a conical cap made of thick sheet copper or brass, fastened by three or four cross wires to a ring, which, slipping up and down upon the burner, admits of being supported at any required height. It should have an extent of motion up and down of about one inch and a half; the aperture at the top should be one-fifth of an inch in diameter; the other dimensions may be obtained from the figure, which is on the scale of one inch to three. When the gas is turned on, it passes through the jet, and issuing into the upper part of the cone, it there mixes with the air present, and passing out above by its levity and the draught occasioned by the heat of the cone, is then burnt. More or less air may be allowed to mix with the gas, by raising or lowering the cone. By depressing it sufficiently the air may be entirely cut off. The upper aper-



ture is large, that the gas and air may easily pass out, for as no pressure is exerted on the mixture, nor any force to make it ascend, except that due to the lightness of the gas and the expansion of the whole by the heat of the cone, it might pass otherwise downwards, and sometimes cause combustion beneath, or an unpleasant smell.



194. A cone with an aperture at the top merely dropped over an Argand burner, as in the annexed section, with the gas turned very little on, is sufficient to give a single jet of smokeless flame.

195. A similar arrangement for a circular flame is easily constructed by making the cone much larger, and attaching it to an internal cylinder with connecting arms. The cylinder, if slit below and opened slightly outwards, will, when introduced into the gas burner, act as a spring against the inside, and support the air feeder at any required height. Chimneys may easily be attached to these burners when found desirable.

Much stress or value is not placed at present on these arrangements, but they are briefly described, because from the first trials of them, their effect was such as to leave little doubt that when improved they would be found advantageous in the continually increasing applications of gas heat.

Blow-pipes.

196. The blow-pipe is an instrument which cannot be dispensed with in the laboratory; and, as is generally the case in contrivances for the attainment of any particular object, the most common is the most valuable. The chemist does not possess a more ready, powerful, and generally useful instrument, than the mouth blow-pipe, and every student should early accustom himself to its effectual use and application.

197. The forms which have been given to this instrument and the materials of which it is constructed, are very various.

All that is essential is a tube to conduct the air from the mouth, terminated by a small regular round aperture, by which the air can be thrown out in an undisturbed stream: and, that facility may be obtained in directing it, the lower end of the instrument is generally turned on one side.

198. The common blow-pipe is a long conical brass tube; two or three inches of the narrow end being bent, so that the termination is nearly at right angles to the other part of the instrument. In consequence of the gradual condensation of moisture from the breath in the tube, when the instrument is much in use, a small portion of aqueous matter is sometimes ejected through the beak into the flame, and upon the substance to be heated. The blow-pipe has in this respect been improved, by having a chamber introduced into one part of it for the reception of such moisture; the accumulated water being removed after the experiments are over. Dr. Black's blow-pipe is a conical vessel, close, except at the summit, to which the mouth is applied, and at a lateral aperture below, from which a small pipe proceeds, terminating in the nozzle or jet. This cone serves not merely to condense the moisture, but in a slight degree to regulate the pressure of the air forced through it by the lungs and mouth. Dr. Wollaston's instrument, on the contrary, has no chamber, but consists of two or three pieces of tube, which, when arranged together, form an excellent blow-pipe, and when dismounted, pack into the size of a small pencil-case.

199. The essential part of the blow-pipe is the jet or termination by which the air is thrown out. The aperture should be a smooth round hole, not leading suddenly inwards, to an irregular cavity, but enlarging in an uniform manner, so as to form a small regular conical channel, at least the third of an inch in length, gradually passing into the general air way of the instrument. The exterior should also be regular in its form, and diminish by degrees to the aperture; that when a stream of air is forced through the blow-pipe, the external air surrounding the jet may coalesce gradually with the current, and not have the motion com-



municated to it disturbed by any external irregularities of form. Perhaps the best model for a jet is that obtained by drawing out a piece of cylindrical glass tube, and cutting it off so as to leave an aperture of a proper size; the nearer those which are made of metal approach to this in form, the better they will act. The size of the aperture of a blow-pipe must depend upon the flame to be urged, and the substance to be heated; for ordinary use it may be one-fortieth or one-fiftieth of an inch in diameter.

200. The jets of blow-pipes are constructed of different substances, those being in this point the best which are made of materials least liable to change. For this reason, and also because facility is thus afforded of having differently sized apertures, they are frequently made in separate pieces from the instrument, and arranged to slip on or off the extremity at pleasure. From the small quantity of metal required in their construction, they may then be made of platina; and a conical form given to them closely approaching to the model before mentioned. The single objection to jets with these delicate terminations, is the facility with which they are altered in form and injured: but it is only the careless who suffer in this way, for no one acquainted with the value of the instrument will voluntarily subject it to mechanical injury.

201. When a blow-pipe is not at hand, a very excellent temporary one may be made from glass tube. A piece, nine or ten inches in length, and about one-third of an inch in diameter, is to be drawn out in the spirit lamp, so as gradually to diminish in size, and then to be cut with a file, that its extremity may imitate the jet before figured. It is afterwards to be softened and bent on one side, about two inches above the jet, and thus a perfect instrument for the time will be obtained. It is unfortunately brittle, and the jet is liable to fuze and become closed in the flame when the current of air is suspended; otherwise it would supersede most of the common blow-pipes.

202. The first point to be acquired in the use of the blow-pipe, is the practice of the mouth. It is easy by blowing

through the tube in the usual manner, to produce a current of air, which if tried upon a lighted candle, will occasionally produce a clear and regular jet of flame. But this operation will soon be found uncertain and fatiguing, and recourse must be had to the action of the mouth and its muscles, not only to regulate, but at intervals to perform the whole office of supplying air to the instrument.

203. The practice necessary in the first place, is that of making the mouth replace the lungs for a short time, by using no other air for the blow-pipe than that contained in it. This practice is simple in itself and soon becomes easy, but is difficult to describe. Let the student first observe that it is easy after having closed the lips to fill the mouth with air, and to retain it so, at the same time that respiration may be freely carried on, the air passing to and from the lungs by the nostrils. The mouth then resembles a closed but distended bag, and the means being well observed by which it is thus for a time rendered independent of the lungs and nostrils as to air, let a blow-pipe with a small aperture be placed between the lips, and then again filling the mouth with air, let it be separated as before from the lungs: let the respiration be carried on as in the former case, but at the same time let the capacity of the mouth be contracted by the action of the muscles of the cheeks and jaws, and the air which it contained propelled through the blow-pipe. If the aperture be small, this operation will require ten or fifteen seconds, and being repeated a few times, a ready facility of using the blow-pipe independent of the lungs, will thus soon be acquired.

204. This step being taken, the next is to combine this process with the ordinary one of propelling air directly from the lungs through the mouth in such a way that, when the action of the lungs is suspended during inspiration, the blast may be continued by the action of the mouth itself from the air contained within it. The mouth at this time represents the going fuzee of a chronometer, which causes the works to advance during the interval that the direct action of the spring is taken off, by the hand which holds the key when the machine is wound up for the renewal

of motive power. The time of fourteen or fifteen seconds, during which the mouth can supply air independently of the lungs, is far more than that requisite for one or even many inspirations; and all that is required to complete the necessary habit is, the power of opening and closing the communication between the mouth and the lungs, and between the lungs and the air, at pleasure.

205. The capability of closing the passages to the nostrils is very readily proved; every one possesses and uses it when he blows from the mouth; and that of closing or opening the mouth to the lungs may be acquired with equal readiness. Applying the same blow-pipe to the lips as before, use the air in the mouth to produce a current, and when it is about half expended, open the lungs to the mouth so as to replace the air which has passed through the blow-pipe; again cut off the supply as at first, but continue to send a current through the instrument, and when the second mouthful of air is nearly gone, renew it as before from the lungs. In this way acquire the power of using the air of one inspiration by mouthfuls, as it may be termed, not at any time letting the air from the lungs press upon that passing through the blow-pipe, except for the short intervals during which it is being renewed in the mouth; but measureing it out as it were in successive portions, and giving the muscles of the cheeks and jaws the work of propelling it forward. This advance made, then, as the last step necessary, learn to fill the lungs whilst the mouth is independent of them, and occupied in propelling the air; and this cannot be difficult for many minutes to those who have already done the same thing for ten or fifteen seconds together, as just described. Once effected, let this second inspiration of air be used as the first was, and in the course of three or four inspirations, the student will find no further difficulty in understanding the succession of actions which are necessary to the production of a continued stream of air, and in performing them either separately or in order, as may be required.

206. The description of these processes is necessarily

tedious, and the performance of them for the first time laborious and tiresome. The pupil should not endeavour in these trials to produce a strong current of air, as that occasions unnecessary fatigue. The smallest stream is as efficient as a larger one. The art once obtained, it will be quite unnecessary to repeat the effects in actual practice in the order they have been described. The peculiar action of the mouth is not necessary to a continued stream of air, except as connecting the air of one inspiration with that of the next, and continuing the current whilst the experimenter is inhaling: that effected, the mouth need not be resorted to, except for peculiar purposes, until fresh air is wanted, and inhalation again necessary.

207. In fact, however, the mouth, besides continuing, regulates and modifies the blast; and the muscles belonging to it, being more powerful than those which command the lungs, are competent to the production of a much stronger stream of air. This upon occasion is very useful and important. The action of the mouth frequently helps to sustain and regulate the propelling force of the lungs, and frequently also, when a stream of air for a long period of time is required, the mouth is advantageously used to propel and continue it whilst four or five inspirations are made: the lungs are thus relieved and refreshed, and this being repeated from time to time, takes from the operation a great portion of its labour.

208. The powers of the blow-pipe will, in the laboratory, frequently be added to those of the spirit lamp, especially in the heating of capsules, small platina crucibles, platina foil, glass tubes, &c. But when a very intense heat, and that only over a small extent is required, it would appear that other fuel than alcohol is better for the purpose. A tallow or a wax candle, or an oil lamp with a wick about three-tenths of an inch in diameter, affords a very convenient flame. Sometimes the wicks of lamps are made broad and flat, for the purpose of supplying a greater extent of heat when required.

209. The lamps, if such be used, being trimmed so as to

occasion their full ordinary combustion, the jet of the blow-pipe is to be placed in a horizontal position opposite the flame, about the eighth or tenth of an inch above the wick; and a steady blast of air being thrown from it, it will be found that the flame loses its ordinary form and appearance, and is projected as a luminous pencil along the course of the stream of air. It should be steady, constant, and noiseless, not quivering, uncertain, or roaring. A small proportion at its commencement should be brightly luminous, but soon pass into a clear blue conical flame, towards the end of which on the exterior, another should begin to appear of a pale lambent yellow colour, and continue to an inch or more beyond the termination of the blue flame prolonging the cone. The end of the blue flame should be round, well defined, and even sharp in its outline.

210. If a candle be used, it should be snuffed but not short, the wick inclined a little on one side, and the current of air from the jet sent obliquely upwards. If sent horizontally, the heat soon melts the tallow or wax on the side beneath the flame, and causes it to run down. The candle will frequently want snuffing, and should never be allowed to have any useless wick. The disadvantage of oil lamps is, that they also require frequent trimming, and in that respect are not so convenient as candles.

211. The lamp or candle should be low, that whilst using the blow-pipe the arms may rest steadily upon the table. The hand should lay hold of the instrument as far from the mouth as convenient, greater freedom of motion being thus obtained, and the left or the right hand should be used indifferently. Steadiness is requisite, and it should be the constant endeavour of the student when he is using the instrument to obtain the power of so apportioning his breath, and of retaining the instrument and the flame, that the latter shall appear like a fixture, and neither change in appearance nor direction for several minutes together; yet this with such lightness of touch and easy hold, that he may at pleasure send the flame in any direction and upon any place he pleases.

212. The point of highest temperature in the flame is just

at the extremity on the exterior of the blue cone. Here the combustion is complete, and has suffered least from cooling agencies: but there are some parts of the flame which, because of their peculiar qualities, demand a few observations. Without the blue flame combustion is complete; all the fuel is burnt, and the oxygen of the atmosphere in which the flame is formed begins to appear in excess, and from thence increases outwards. Hence the power of oxygenation to a great degree, in consequence of the elevation of temperature and the free oxygen existing there. On the contrary, within the blue flame combustion is still going on, consequently combustible matter is present; there is no free oxygen, and a reducing agency is exerted. Berzelius well recommends that the situation and powers of these parts of the flame should be learned by operating on a globule of tin about the size of a shot placed in a small cavity on charcoal; the metal will be converted into a white crusty oxide, or be reduced and appear in the metallic state as a brilliant fluid globule, according to the part of the flame directed upon it and the skill of the operator.

213. When the temperature required is not particularly high, but the substance to be heated is large, a greater flame is to be used. It may be obtained from the alcohol lamp, or from an oil lamp with a flat wick, the current of air being directed along the edge of the cotton. A jet with a large aperture may then be employed, and it is occasionally advantageous, by a more powerful or more abundant blast, to break down the quiet tranquil flame into a roaring one, the latter having power to heat a greater extent of surface than the former. A crucible or a capsule may be thoroughly ignited by a broken flame; but the same instrument and lamp with a quiescent flame, though they will heat one part intensely, would leave another part comparatively cold. In heating a glass tube for the purpose of bending or blowing it out, the same advantage is obtained; and it is a mistake to suppose the blow-pipe is useful only for the purpose of increasing and concentrating heat, it being in the laboratory frequently as advantageous merely for directing it. When the mouth blow-pipe is used with the

large spirit lamp before described (182), a platina crucible one inch and a half in diameter may be heated red hot throughout, and a glass tube of considerable thickness be ignited regularly all round and bent. With a smaller lamp or a candle, the blow-pipe is constantly in use for melting cement or other fusible bodies upon particular parts of apparatus, or warming the sides or tops of glass vessels; and it is for these amongst other purposes that the power of directing the flame upwards or downwards, or in any direction at pleasure, is required.

214. The current of air is hot to a great distance beyond the flame, and should have its direction and power well appreciated by observation and experiment. It is frequently useful in warming vessels, and the student will best learn its capabilities by holding pieces of paper in its course, at different distances.

215. The theory of the blow-pipe is simple: its powers depend upon the perfect combustion of the fuel, and the rapid succession of hot gaseous matter against the substance to be heated. The force which propels the stream of air through the instrument is so much greater than the ascending force of the heated gaseous products of the combustion, that not merely is the usual form and direction of the flame destroyed and new ones given to it, but with such power that the ordinary and fluctuating motions of the atmosphere have little or no effect upon it. The heated particles rapidly succeed each other in an invariable direction, and as relates to the position of its parts, a degree of permanency is thus given to the flame. The point at which the particles attain their highest temperature continues the hottest so long as the current is unchanged, and when a body is placed there, it receives the successive action of these particles, and is raised to the highest possible temperature. By far the greater portion of the effect is due to the circumstance, that the moment a particle of flame has touched the body and been cooled by communicating heat, it is removed by the rapidity of the current, and replaced by other particles in the flame of the maximum temperature. All loss of heat from the body by contact of colder particles is therefore

prevented, and the elevation of temperature is limited entirely by the temperature of flame, radiation, and the deteriorating effects of the supports derived from their conducting power.

216. For the attainment of the highest possible temperature in a body subject to the powers of a flame urged by the blow-pipe, it is necessary not only to choose the hottest place in the flame, but to attend to other circumstances. It is found in practice, and easily explained by theory, that within certain limits the smaller the particle to be heated the higher will be the temperature acquired. Hence a reason for diminishing the size of the piece as much as possible. The supports should then be such as, presenting the smallest quantity of matter by which the heat may be conducted away or otherwise dissipated, shall still resist the high temperature necessary to be borne where in contact with the substance, and should also exert no chemical action upon it, or at least none that can interfere with the points to be observed. For these reasons the platina wire, or a thin slip of platina foil, is frequently used as a support; and forceps are constructed with delicate terminations of platina for the purpose of holding such solid particles as will not act upon them. These are frequently made with a pair of strong steel nippers at the opposite end, to break or chop off small splinters from minerals or brittle bodies. When a thin splinter can be detached, the fine edge or point is frequently more favourable for high ignition than a whole fragment, however small, supported in any other way.

217. Mr. Smithson † uses small plates of clay as supports for substances before the blow-pipe. They are formed by extending a white refractory clay by blows with the hammer between the fold of a piece of paper like gold between skins. The clay and paper are then cut together with scissars into pieces about four-tenths of an inch long and two and a half tenths of an inch wide, and hardened in the fire in a tobacco pipe. When cut into small and very acute triangles, they form a substitute for Saussure's sappare. The method of

† Annals of Philosophy, New Series, v. 387. vi. 412.

attaching the particle to be heated to the end of these strips, or what is perhaps still better, to the end of a fine platina wire, which has been since adopted by Mr. Smithson, is to mix a very refractory clay with water; almost the least quantity of this is to be taken up at the very end of the clay strip or the wire, and the particle chosen touched with it: in a few moments it is dry, and may be introduced into the flame with perfect safety. In this way the smallest observable pieces may be readily experimented with. Sometimes Mr. Smithson makes the powder of the substance into a mixture with water, and uses it instead of the clay for attaching a particle to the end of the wire.

Lieut.-Colonel Totten* varies these methods by making the pulverised substance into a paste with thick gum water, and forming it between the fingers into small acute cones the fourth or fifth of an inch in length. When dry they may easily be held at the end of a wire or in forceps, and the apex being moistened and directed to the particle to be experimented with, adheres to it, and will allow it to be subjected to the highest heat of the blow-pipe without suffering derangement.

218. In all experiments upon minute particles, or upon splinters, it will be necessary to examine the results with a glass, and not to trust to the naked eye. Appearances of fusion or porosity will frequently escape the unassisted eye, when very evident under a lens.

219. When charcoal is used as a support for the substance to be heated, whether for the sake of convenience of form, or on account of its chemical relations to the body, that should be chosen which has been made from young succulent wood, has thin bark, and is without cracks or cavities. Alder wood charcoal is by far the best, being soft and generally free from divisions. When used, a little cavity may be made with a knife on its convex surface, or sometimes even at the end of the cylinder where the cross fracture has left a smooth termination, and the substance being placed there, the flame is to be sent obliquely down

* Annals of Philosophy, New Series, IX. 73.

upon it. Small charcoal, from two-thirds of an inch to an inch in diameter, is most convenient, because of its easy approximation to the lamp or candle. It would be difficult to send the flame perpendicularly into the cavity, nor if it were easy would it often be desirable; for the propelled flame would return upon itself, and causing irregularity in the stream, would fail to produce the usual temperature. The blast should be generally propelled obliquely, that the flame entering over one side of the cavity after having struck upon the matter to be heated, may rebound a little and pass out by the other.

220. For ample directions however in the management and use of the mouth blow-pipe, with all that relates to the characters and tests of substances examined by it, the student is referred to Berzelius's Essay,† which being essential to those who would apply the instrument to its full extent, or beyond what have been its ordinary uses in the laboratory, renders any further account of it here unnecessary.

221. The next useful instrument of this kind in the laboratory is the table blow-pipe. It consists of a small table furnished beneath with a pair of double bellows, worked by the foot. A tube is connected with them, which rising through the table is made adjustable above by sliding or moving joints, and terminates in a jet. This jet is of course larger than that of the mouth blow-pipe, being intended to urge a stronger flame, but still it should be smooth and well formed (199.), and its aperture round and symmetrical. It is almost always the work of the instrument maker, but when a temporary jet is required, it may be obtained excellent of its kind, by drawing out a piece of narrow thick green glass tube in the manner before described (201.) The lamp (always sold with the table, though separate from it) should have a burner competent to hold a bundle of twisted cotton half an inch thick and an inch wide, the top of the burner being about two or three inches from the table, that the jet may easily be adjusted to any required position. Oil is the

† Children's translation of Berzelius, on the use of the Blow-pipe, 8vo.

most convenient fuel for it, tallow or dripping perhaps the most powerful.

222. After having trimmed the lamp, leaving the cotton in a compact wick, rising about one-third or half an inch above the burner, light it, and place it on the table before the jet; then sitting on a chair with one foot on the treddle, work the bellows slightly, and arrange the jet by moving the joints of the tube, until, being horizontal, or nearly so, its extremity is a little above the cotton, and close upon, or just within, the edge of the flame. The force of the blast should be such as to gather the flame and make it proceed in the same direction with the jet, without any upward inflection of its extremity. If for want of power in the jet of air this be not at first attained, it should not be effected by working the foot so rapidly as to fill the bellows and drive the air out by the direct force exerted upon the treddle; but the upper board of the bellows should have weights placed upon it in such quantity as to cause pressure sufficient upon the air within to make it flow out with the required velocity. From the natural rigidity and tension of the leather, the pressure upon the included air will be greater when the bellows is nearly filled than when almost empty, so that the force of the blast may be varied by keeping the bellows more or less full without any alteration in the loading weight. When an impulse is required stronger than that which can be produced by the weight and tendency of the bellows to collapse, more or less force may be superadded from the foot by means of the treddle.

223. The pencil need not necessarily include the whole of the flame rising from the wick, but as the remaining part throws off much smoke and fuliginous matter, it is better to conduct these substances away by a small hood and chimney. Such an arrangement has also the advantage of shading the bright part of the flame from the eye, in consequence of which the progress of operations carried on in the pale part are much more readily observed. It frequently happens when the flame of the lamp is too large for the jet, that no attempts to force the whole into a clear steady cone will

succeed; but upon advancing the jet a little away into the flame, the part beyond it will be thrown forward in the greatest perfection, whilst that behind the aperture rises upright in its usual state, and almost undisturbed. It is even generally advantageous to have this superabundance of flame. The pencil of flame should be conical and steady, not ragged or broken, but ending in a blue point, passing into a pale phosphorescent halo, without any luminous or smoky part at the termination.

224. Modifications of this flame are required, resembling those described as useful with the mouth blow-pipe. When the jet is withdrawn a little way, and the blast impelled with considerable force, the flame is broken, roaring, and somewhat diffuse; it is then bluish, burns without smoke, and is useful in heating a crucible, or warming a thick glass tube.

225. The construction of a temporary blow-pipe to supply, in cases of neccessity, the place of a table instrument, is not difficult. A piece of glass, pewter, or any other pipe will convey the air, and being tied to a weight or stand, or even a candlestick, may be arranged at the proper height, that its jet may accord with the lamp to be used. The first rough jet may be made by drawing out a piece of small glass tube in the spirit lamp, or a candle, and being attached to the apparatus, a second and proper jet may be made by means of it, out of a thicker piece of tube, and substituted for the smaller one. Instead of the bellows a large bladder may be used, or what is better, a bag made of oiled silk, or some of those fabrics now sufficiently common, in which cloth is rendered air tight by caoutchouc. This may be placed under one end of a board with weights upon it, or within a portfolio, subject to pressure, and the air may be thrown into it from the lungs by another piece of tube sufficiently long to reach to the mouth. This tube will require a valve to prevent the return of the air, and the simplest that can be constructed for the purpose, in an extemporaneous manner, is perhaps the following.

A piece of any tube of about the diameter of that repre-

sented in the wood cut, having a smooth and levelend,is to



be selected, and also a strip of black oiled silk of a width rather more than the external diameter of the tube, or if that be not at hand, a piece of ribbon of the same width, which has been rubbed with wax, so as to have the interstices in it filled up without destroying its flexibility. This is to be adjusted loosely over the end of the tube, and the extremities folded down on opposite sides, and tied with a piece of thread ; the silk itself not being so tight, but that by applying the mouth to the opposite end air may be easily blown through the tube, and out at the extremity between it and the silk ; and yet so near that a pressure being exerted in the opposite direction, the silk will be carried against the end of the tube, and prevent the air from passing that way. The tube by which air is to be thrown into the bag from the mouth, is to have such a valve constructed at its extremity, which is to be introduced through a hole made in the bag, and tightly tied in it by a few turns of twine. So arranged, the bag is easily filled by air from the lungs, which being gradually expelled at the jet, gives energy to the flame. All the tubes required for this instrument, except the jet, may be made even of paper, in the manner hereafter to be described (1223).

226. A lamp for such a blow-pipe is soon fitted up ; a bundle of cotton threads placed at the side of any small vessel filled with oil, will answer the purpose, and none is more convenient than a little Wedgwood or evaporating basin.

227. The pneumatic blow-pipe is an instrument more portable than the table blow-pipe, and is intended to supply its place. There is nothing relative to its manipulation requiring notice, which has not been already mentioned.

228. Next to these ordinary forms of the blow-pipe, in which common air is used to urge the flame and increase temperature, come those which employ oxygen or other gases to heighten the effect : and by gradual improvement not only has the temperature, afforded by these instruments, been raised to an extraordinary degree, but at the same

time with almost perfect security to the operator. It is only the most simple and effectual of these contrivances which will require attention, and of these merely such points as, from the facility of extemporaneous application, construction, or correction, may be most immediately instructive to the student.

229. A very simple and powerful method of increasing temperature, the application and advantages of which were first shewn by Dr. Marcet,* consists in urging the flame of an alcohol lamp by a blow-pipe supplied with oxygen gas. The oxygen may be furnished from an air-holder, a gas bag, or any other vessel, in which it has been stored. The flame is much smaller than when common air is used; it is also brighter, and its different parts have not the same relation; for instance, when the flame is well urged, there is no point in which an excess of combustible matter can be found, or where deoxygenation can be carried on, as with the common blow-pipe (212), and hence it is never put to such purposes; or when applied to them, it only leads to negative or deceitful appearances.

230. The arrangement called Leeson's blow-pipe is convenient for the application of oxygen gas. It is a bottle of caoutchouc or India rubber, which being distended with oxygen, of which it allows until it becomes several times its ordinary diameter, is then to be attached to a jet. When the jet is opposite to a flame, and the stop-cock opened, the contraction of the bottle causes a regular stream of gas to flow out for a considerable period, and an intensely hot, but small pencil of flame is obtained. Metallic vessels sufficiently strong to contain several atmospheres of oxygen gas have been used in the same manner, and when made of a globular form, small, and air tight, are very pretty and convenient.

231. The use of hydrogen as fuel, instead of oil, alcohol, &c. has introduced many forms of apparatus (some of which are dangerous to beginners) intended for the special application of a mixture of it with oxygen gas. Dr. Hare was

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* Thom. Ann. ix. 21.

the first person who used these gases in conjunction, and described the effects produced. He sent them by different channels to the aperture, where they were mixed and burnt at the same instant There was no danger in this arrangement, and the manner in which it may be repeated, will easily be understood from what has been said, and the directions to be given relative to the manipulation of gases. The heat was very intense.

232. In consequence of the experiments made by Sir Humphry Davy, during the developement of the principles of his safety lamp and researches into the nature of flame, in which it was shewn that the flame of explosive gaseous mixtures would not pass back through small apertures or tubes—blow-pipes were soon constructed, in which the oxygen and hydrogen being mixed in the proportions necessary to form water, were then compressed in metallic boxes to the extent of many atmospheres. Small tubes were afterwards affixed to these boxes, and the mixed gases being allowed to pass out, were inflamed and burnt at the apertures of the tubes. Many circumstances combined to occasion accidents with this apparatus. The tube was at times too large, or it broke, or became heated, or the rapidity of the current in it diminished gradually, and the flame retrograding, ignited the mixture in the reservoir and caused explosion: and notwithstanding the numerous contrivances invented to prevent this return of the flame, there is not one I believe, which from some unperceived or uncertain circumstance, either in the principles of the arrangement, or the accidents to which it is liable, has not failed at one time or another. Hence those only can be considered perfectly safe, where the reservoir of gas, as in Dr. Clarke's arrangement, is separated from the operator by a wall or partition, of strength sufficient to give full security: and those are next perhaps, where, as in the arrangement by Mr. Gurney,† the gases are confined in a receptacle so slight (a bladder), that if blown to pieces the fragments can hardly

† Trans. Soc. Arts. xli. 70.

do harm. The only liabilities then are, that the explosion itself shall shake and injure the neighbouring apparatus, or throw them about with an injurious violence.

233. There are still some points in the economy and application of heat, which require attention before we close this section, as best assimilating with its subject and matter. These principally concern the modes of heating by intermediate agents; some of which are of considerable importance in the laboratory generally, others very valuable in peculiar cases.

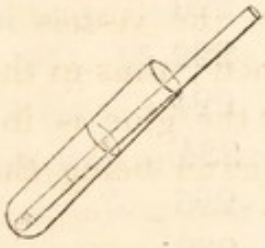
234. All that relates to the general construction and arrangement of sand baths, has been already said (152—156), except what will assimilate with the processes to be performed on them. Water baths resemble sand baths in offering a medium through which the heat can be applied to the substance to be heated; but differ from them in limiting the heat to temperatures below a certain point, and when required, in retaining it for any length of time to one fixed degree, that of 212°. This temperature is important in the maceration and infusion of many organic substances, for which, though a greater heat would be highly injurious, this is desirable and even necessary. Water baths are generally constructed with and attached to the vessels in which the heating operation is to be performed; thus in the carpenter's glue-pot, the vessel containing the glue is inserted into another containing water, the latter being the one placed in direct contact with the fire.

235. A water bath, besides regulating and equalizing the heat when required at 212°, may, from the liquidity of the medium used, have its temperature ascertained by a thermometer, and consequently regulated by attention to the source of heat. Hence it offers the facility of raising substances in close vessels to any given degree, between 212° and ordinary temperatures; thus if it were required to know at what point a certain wax or a new resin melted, it would only be necessary to put a piece into a tube, and the tube, with a thermometer, into a water bath of which the temperature was gradually raised, and moving the thermo-

meter about to ascertain the temperature of the bath, at the moment the substances began to fuze.

236. In the laboratory, the water baths are generally of extemporary construction. A tin or copper saucepan, shallow or deep, according to the vessel to be heated, makes a very excellent one. The immersed vessel should not touch the bottom of the bath; if it be a flask, or there be two or three to be heated, some hay or straw, or in lieu of them a little tow, should be placed at the bottom of the bath, and the flask or flasks upon it. A board should be placed across the bath with holes in it to receive the necks of the vessels, and retain them upright and steady: or even straw put loosely into the vessel or between the flasks will answer the same purpose, and at the same time prevent any bumping or violent ebullition in the water of the bath. When the vessel to be heated touches the bottom of the bath, heat gains access to it by conduction, the temperature is no longer necessarily the same as the boiling point of the water, and may at times rise so high as to do considerable injury.

237. An evaporating basin frequently answers the purpose of a water bath, and the substance to be heated may also be placed in a smaller basin and floated on the water in the first. A glass tube will often form a water bath for a tube somewhat smaller, and frequently when the aqueous vapour would interfere, it is prevented by making the bath tube the shorter of the two.



238. It is necessary that attention be paid to the quantity of water in the bath, that it may not be so far diminished by evaporation, as to occasion injury or derangement, either by bringing the floating vessel into contact with the bottom, or leaving parts of the bath itself uncovered. It is often useful for many reasons to put a little oil on the surface of the water in the bath. Suppose for instance the source of heat be an Argand lamp or small furnace; as the temperature rises, evaporation increases so rapidly, that at last the accession of heat is very slow, notwithstanding the rapidity of combustion, and may at times even be limited before it

has attained the boiling point, the loss in latent heat being equal to the gain in sensible heat. A film of oil upon the surface prevents the evaporation, and consequently the loss of heat in this way, and the temperature rises more rapidly, and to a higher degree than when the water is uncovered. If it be required just below 212°, it is easily retained there with a much smaller flame or fire than would otherwise suffice, the water is not liable to diminution, nor will it require watching or renewal, and the quantity of steam given off is comparatively nothing; a point of some importance at times to the substance in the inner vessel. In all cases when heat is required about a certain point below 212°, it is advisable to have a thermometer bulb immersed in the bath.

239. When temperatures above 212° are required in baths, pure water must be dismissed, and either aqueous solutions or metals used. There are several solutions useful for these purposes, which boiling at different temperatures will of course communicate heat up to their boiling points. A saturated solution * of

Bi-tartrate of Potassa, boils at ...	214°
Alum	220
Borax	222
Common Salt.....	224
Tartrate of Potassa	234
Muriate of Ammonia.....	236
Nitre	238
Rochelle Salt	240

If a particular temperature be required, 234° for instance, it may be obtained in two ways; either by selecting a solution, which when saturated boils at that point, as one of tartrate of potassa, and then the temperature is regulated by the process of ebullition: or a sufficient quantity of some other salt may be added to the water, so as to form a solution which, though not saturated, will require that, or a higher

* Quarterly Journal of Science, xviii. 90. Griffiths.

temperature for ebullition, and the exact point may then be regulated by a thermometer. Rochelle salt and nitre are convenient for this purpose, the temperature being carried by them as high as 238° or 240°. The use of oil over these solutions is equally advantageous as in the water baths (238). Such salts should be selected as have no material action, when in solution, on the vessels used, and are at the same time economical and effectual.

240. Solution baths will produce temperatures up to 360°, but if higher temperature be desirable, recourse must generally be had to metal baths. Solution baths are advantageous for digestions, &c. carried on at temperatures above 212°, and while they possess the useful range of 20 or 30 degrees above that point, they may be prepared with economy in sufficiently large quantities. Metal baths on the contrary are, both from the weight and expense of the material, generally on a small scale, and their principal use consists in subjecting substances in tubes or other vessels to a given or an increasing temperature; or in ascertaining, by the gradual application of heat, which may be measured by a thermometer, at what point any particular effect is produced. For these purposes small baths are as effectual as large ones.

241. Mercury is the substance which first presents itself for these uses: it may be applied with care, from very low temperatures up to 500° or 600°. If the experiments be made altogether in tubes (237), a temperature of 600° may easily be communicated by means of it; but if the bath be an open vessel, a dish or crucible for instance, then temperatures higher than 450° should not be given to it; for the metal soon after rises in vapour, and the fumes not only occasion waste of mercury, but at times produce injury both to the experiment and the health of the operator.

242. For temperatures from 212° and upwards, fusible metal answers the purpose admirably. It consists of 8 parts of bismuth, 5 of lead, and 3 of tin, fused together. It melts at a heat below 212°, and will bear a red or even white heat without evolving fumes; but at dull redness thick films of oxide form on its surface, which increase with its tem-

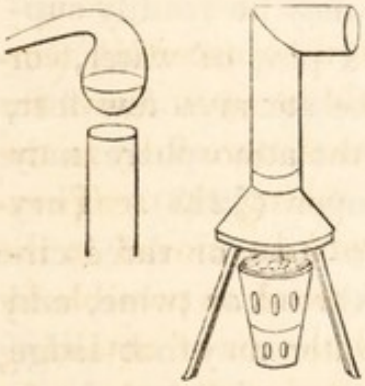
perature. Tin or lead are both good metals for temperatures above their fusing points; the first melts at 441°, the other at 609° Fahr.

243. These metallic baths may be used in glass tubes at temperatures beneath that at which glass softens, or in evaporating basins up to temperatures of 400° or 500°, but only when small. When large, the weight of metal would endanger both the vessel and the experiment. Earthen crucibles are convenient for the immersion of tubes and similarly formed apparatus, but when the mass of metal required is great, an iron crucible or pot, or a small cast iron saucepan, should for safety be resorted to.

244. A thermometer may be employed to ascertain temperatures as high as 650°, but it should be open above for degrees higher than 580°, as will be stated more fully in the account of that instrument (266). In taking the temperature of the bath the thermometer should be moved in the fluid, for the purposes of equalizing as much as possible by intermixture the temperature of the whole, or of obtaining the mean of its different parts: and in order that the tube or immersed body may also acquire an equal temperature by the same means, it should also be moved about. A little tallow or pitch may be put upon the surface of metallic baths not mercurial, at temperatures below 700°, to prevent the surface from oxidising; but at higher temperatures the volatilization and decomposition of these bodies would occasion inconvenience. If a bath be hot and covered with a coat of oxide, the latter should be moved on one side with a piece of card or stick, at the moment the subject to be heated is introduced, otherwise a coat may intervene which will tend to prevent the ready transmission of heat.

245. There are occasions, though not of common occurrence, when a bath is wanted that will not permit a rise of temperature so high as 212°. Thus in the preparation of pure euchlorine from chlorate of potassa and sulphuric acid, it is prudent to heat the tube retort in spirit of wine or a mixture of alcohol and water; for the temperature not rising so high as with water alone, there is less probability of any accident with this explosive gas.

246. Hot air is an excellent heating agent on many occasions, in consequence of the facility with which it is obtained and conveyed; it therefore claims our present attention. If it be convenient to procure it by any slight alteration about the furnace, as for instance, by putting a cast-iron pipe in one corner, such a source should not be neglected, and will be found constantly useful; but in general it will be more advantageous to obtain it by small fires or lamps, the whole of the gaseous produce of the combustion being employed. A shallow charcoal fire in a small crucible furnace (143,) yields an abundant supply of heated gaseous matter. A



piece of funnel pipe (148,) supported on a tripod over the fire, serves as a channel for the hot stream which may be conducted upwards or thrown right or left by adjusting pieces (151), as may be required: and the temperature of the current itself may be regulated within certain limits by placing the funnel pipe at a greater or smaller distance from the furnace, or having different lengths of it, or increasing and diminishing the fire. Such a current is useful in making slow distillations or rectifications, in heating flasks or globes, in warming electrical machines; and the fire is easily renewed or arranged, and its intensity increased or diminished by opening or closing the holes to the ash-pit without disturbing the apparatus above.

247. Occasionally, an Argand lamp may be substituted for the charcoal fire, when an abundant quantity of hot air may be obtained by supporting a plate of metal, as a piece of sheet copper a foot square, about an inch above the chimney of the lamp. It breaks the current of heated gas and vapours from the chimney, becomes hot itself, and heats the air in contact with it. Such an arrangement is very useful in drying papers placed over it, or in warming an electrical machine. Of course every source of combustion for such purposes should yield products free from smoke or fuliginous matter.

248. Steam is in many situations a very convenient agent

for the application of heat up to temperatures not exceeding 212° Fahr. If a source of steam, as a neighbouring boiler, be available, nothing more is requisite than to conduct the steam by a small pipe with a stop-cock into a box or vessel containing the substance to be heated. A tin saucepan, for instance, will hold several flasks or two or three retorts, and being closed by a cover having holes in it to let the necks of the vessels through, the pasage of steam into it in sufficient abundance, will soon heat the vessels it contains up to 212°.

249. If a steam heat be indispensable for an experiment, and a boiler be not at hand, its place may be readily supplied by a tea-kettle containing about a pint of water, or even by a tin can: pipes to convey the steam a few feet, if its pressure be not more than that of the atmosphere, may be readily made of oiled cartridge paper (1223). They should be an inch in diameter, formed of two or three circumvolutions of paper tied round with thread or twine, and placed in an inclined position, that water may not lodge in them. Such pipes should also be surrounded by a loose case, formed by wrapping a sheet of paper round them so as to make as it were an external tube, at least half an inch larger than the internal one. This prevents any great loss of heat and consequent condensation of the steam within them.



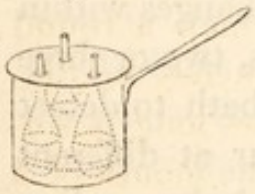
250. Dr. Ure has contrived a very convenient apparatus for the application of heat by steam. It consists of a tin box about 18 inches long by 12 broad and 6 deep. The bottom is hollowed a little by the hammer towards its centre, in which a round hole is cut of five or six inches in diameter. Into this a tin tube three or four inches long is soldered. This tube is made to fit tightly into the mouth of a common tea-kettle, which has a moveable handle. The top of the box has a number of circular holes cut in it of different diameters, into which evaporating capsules of platinum, glass, or porcelain are placed. When the kettle filled with water and with its nozzle corked is set on a stove, the

vapour playing on the bottom of the capsules heats them to any required temperature; and being itself continually condensed, it runs back into the kettle to be raised again in ceaseless cohobation. With a shade above to screen the vapour chest from soot, the kettle may be placed over a common fire. The orifices not in use are closed with tin lids. In drying precipitates, the tube of a glass funnel may be corked and placed with its filter directly into the opening of a proper size. For drying red cabbage, violet petals, &c. a tin tray is provided, which fits close to the top of the box within the rim which goes about it. The round orifices are left open when this tray is applied.

251. A temporary steam bath sometimes readily and advantageously supplies the place of a water bath. Suppose it were required to evaporate a solution at temperatures not higher than 212°, two evaporating basins should be selected nearly of equal size, and putting water into the smaller, it should be placed on the sand bath, or over a lamp or fire, and covered with the larger, into which the solution is to be put. The smaller is in this way converted into a chamber containing water at the bottom, and, when heated, steam at the top; the steam rises, condenses against the bottom of the upper basin, heating it and its contents, and the condensed water returns back to that below. The excess of steam, if there be any, passes out at the side where the lip of the bason leaves a little opening, and at such a distance from the interior of the upper basin, as not to interfere with the concentration of its contents.



252. In other cases the water and steam bath may be usefully combined. The figure represents an arrangement in which a saucepan is converted into a temporary steam chamber. Three flasks are arranged in it, the necks appearing through holes in a tin plate, which serves as a cover, and which should be dished a little, or depressed in the middle. Water to the depth of an inch or two is to be put into the saucepan, and when the vessel is placed over a little charcoal fire, becomes converted into steam, which rising and coming in contact with the flasks, elevates them and all



within the vessel to its own temperature. The water condensed on the under surface of the dished cover trickles back to that at the bottom of the vessel, and by management the flasks are retained for any time at a temperature of 212°, with very little escape of steam or evaporation of the water. This arrangement is frequently more convenient than a water bath made deep enough to receive the whole of the flasks, because of its lightness and the superior steadiness of the flasks, from their not being buoyed up by any quantity of circumambient fluid. A similar arrangement is often useful for distillation or rectification, the body of the retort being introduced into the vessel and heated by the steam which rises from the water beneath.

253. Upon occasions of refined investigation relative to the force of vapours, or the conversion of liquid bodies into vapours below temperatures of 212°, or even as high as 240°, it is useful, for the observation of the immersed apparatus, to have baths of water or solutions in glass jars or other vessels, to which the fire cannot be directly applied, and which yet require to have their temperatures sustained for a certain period of time. In these cases the end is best obtained by throwing steam into the bath itself, through a tube descending to the bottom of the liquid. Such steam must be obtained from a boiler, because of the pressure of fluid it has to overcome; but small experimental boilers from four to six inches in diameter, that may be placed over a lamp, are sufficient. The tubes must be of metal or glass, not of paper. During the experiment it is well to cover the bath with oil, to prevent loss of heat by evaporation; and also to wrap it round with a dry cloth, or a few folds of paper, when it is not necessary to watch the changes within whilst the temperature is rising. In these cases, two or three thermometers should be introduced into the bath to detect any difference of temperature that may occur at different parts; for where the surface is so large, and the cooling agencies powerful, whilst the source of heat is confined to one spot, it is necessary that great care should be taken that all parts of the bath agree in temperature.

Thermometer.

254. The thermometer being an instrument in constant use for the ascertaining of temperature within certain limits, it is essential that the student should be made acquainted with the errors to which it is liable, the means of correcting them, and the general circumstances by which its indications are influenced. It will be unnecessary to describe the method of making these instruments, for in consequence of the general diffusion of chemical science and the practice of chemical arts, they are constructed and circulated in such quantities in commerce, that it is difficult to imagine a place in which such pursuits are likely to be carried on, where they may not be found. Besides, the construction of a thermometer, though simple in theory, is difficult in practice. It requires great tact and dexterity to produce one of very moderate goodness, and without steadily watching the process as performed by another, or previously possessing much practical knowledge in glass-blowing, &c. it would be a vain attempt to make one from a written description. Here therefore we shall confine ourselves to the examination and correction of instruments which are made by others; and this is the more necessary, since ordinary thermometers are frequently inaccurate, sometimes considerably so, and would lead to gross errors in some delicate experiments, though sufficiently correct for common purposes.

255. The most usual thermometer is that which contains mercury, and is sealed hermetically at the top. It should not include air. To ascertain whether it is perfect in this respect, invert it, and by a short sharp shake or two endeavour to make the column of mercury descend in the tube. If but little mercury be in the tube, nearly the whole being contained in the ball, it may be difficult to effect this; it is then facilitated by warming the bulb until a longer column is propelled into the tube, when the shake will generally cause it to descend. As the mercury moves in the tube, it will either leave an equivalent void space in the bulb above, or it will part in the tube itself, a portion only of the column passing downwards. In either case the indication with

regard to the presence or absence of air in the tube will be the same, for if the metal traverses the whole length freely and descends to the extremity or nearly so, no air of any consequence can be present. On the contrary, if it passes but a little way down the tube, air is present. If it will not descend at all by any effort that can safely be made, air may be suspected. When air is present, it occasions irregularities in the indications of the instrument, which can only be accurately ascertained by comparing it experimentally with another thermometer known to be correct.

256. Supposing no air to be present, the accuracy of the graduation is next to be ascertained. Thermometers are generally graduated by having two points marked upon their stems corresponding to the melting temperature of ice and the boiling temperature of pure water under the pressure of the atmosphere, and the intervening space is then divided into a certain number of equal parts, each being called a degree. Of these there are 180° in Fahrenheit's scale and 100° in the centigrade scale. If the scale is to be continued above or below these points, it is done by making divisions equal in length to the degrees thus ascertained. To try the accuracy of the point marked 32° Fahr. mix some pulverised ice or snow with a little water so as to make a thin paste; introduce the bulb of the thermometer into the mixture, and agitate it there for a few minutes until the mercury is stationary. If it accords with the point marked 32°, it is so far correct. To try the point 212° Fahr. put some distilled water into a metallic vessel, into which also introduce the bulb of the instrument, holding it in or near the surface of the water; cover the vessel and make the water boil so as to yield abundance of steam, the barometer being at the same time at 30 inches or very nearly so; observe the thermometer after a few minutes, when it has attained its maximum of heat, and if the metal correspond with 212°, that point is also correct. Finally, to ascertain if the intervening degrees are equal, and in that respect likewise correct, separate a portion of the column of mercury in the tube of one, two, or three inches in length from the rest, by inverting and jerking the instrument as before mentioned (255); bring it to

different parts of the tube, and consequently of the scale, by inclining the instrument more or less in various directions, and by tapping it if there be occasion; and observe in all these situations whether the portion of mercury so separated occupies the same number of degrees: if it does, the instrument is accurate; if it does not, the degrees are of different value in different parts of the scale, and the instrument is incorrect.

257. Should it be found impossible thus to separate a small part of the column to serve as a test of the scale between 32° and 212°. then the instrument must be compared with one known to be correct either from its having undergone such trial, or from having been formed from a piece of glass tube, previously examined with regard to the quality of its bore, by forcing through it a small cylinder of mercury, and thus measured in different parts. If on comparison three or four equidistant points prove to be correct, and the scale is found to have divisions of equal length in all its parts, then it may be considered as good.

258. The method of ascertaining whether the scale is equally divided, is to lay it by the side of another scale, an inch rule for instance, and observing how many degrees are equal in extent to a given space on the second scale, and moving it up or down, to ascertain that in other parts the same number of degrees are also equal to the same space. The student should understand that ascertaining the points of 32° and 212° and also the equality in length of the divisions on the scale, is not sufficient to ensure the accuracy of the instrument; since, if the tube be conical or otherwise irregular in the bore, a correct graduation would give degrees unequal instead of equal in length.

259. If neither 32° nor 212° be contained on the scale of the instrument to be examined, then it must be verified by trial with a thermometer known to be correct, and three or four points having been found to accord, the regularity of the divisions must be examined as already described (258). If one of these two important points be included it should be verified as before.

260. If the thermometer to be examined contain alcohol

instead of mercury, there is no opportunity of separating a small cylinder of fluid to measure the equality of the division, or of ascertaining the point of 212°. That of 32°. and three or four others, must then be ascertained as already described (257), and the equality of the scale observed by comparison as before (258).

261. When the scale passes above 212° or below 32°, these parts are examined only by observing that the degrees are equal in bulk to those between the two points. This equality is of course measured by the little cylinder of mercury, as before described (256).

262. In all experimental comparisons of thermometers, essential care should be taken that time be allowed them to acquire the temperature of the bath in which they are immersed; and they should be constantly moved about in it, and made to change places, or serious differences may exist between them. A large and a small bulb, or a mercury and spirit thermometer, will take different periods to heat and cool, and if observed hastily may not only be examined whilst of different temperatures, but also whilst both differ from the liquid in which they are immersed: treated in this way good thermometers may seem bad, and more harm than benefit will result from the investigation.

263. It is for this reason that trials made by putting a good thermometer and the one to be examined into a hot liquor, and observing whether they sink together as the temperature falls, are often fallacious. If the thermometers be dissimilar in bulk or some other circumstance, if the bath be small, and the time occupied in observing the fall of several degrees be short, the instruments will frequently appear to be a degree or two different, when, if properly examined, they would prove to be alike; and neither of them will indicate during the process, the temperature of the bath in which they are immersed. It is easy for the student to gain practical proof and experience of the extent of this effect, by taking two thermometers, so far resembling each other, as to indicate alike when immersed in the same bath, and introducing the bulb of one of them into a thin tube with a little mercury in it. Upon immersing that tube in the same

bath with the uncovered thermometer, and allowing the heat to gain access to the instrument through the intervening mercury only, he will find on comparing the two instruments how great a difference will be occasioned between their indications, as the temperature of the bath rises or falls. This effect is due to the thin tube and the mercury it contains, which obstructing the passage of the heat, retard the changes of temperature in the thermometer itself. The effect varies with the thickness of the glass, and the quantity of metal, and illustrates sufficiently the differences that may be introduced in hasty experiments (224), by the variable thickness of the bulb and quantity of mercury in the thermometers.

264. There are some causes which slightly interfere with the permanency of the indications of a thermometer; but they are of a delicate nature, and need not, except in particular cases, be attended to. It is said that the constant pressure of the atmosphere on the exterior of the bulb, gradually alters its bulk, rendering it smaller, and thus elevating the mercury, and causing it to stand higher in the scale than it ought to do.* It is also said that a thermometer, when cooled or heated considerably, and then returned to its former temperature, does not immediately give the same indication that it did before, but is lower than it should be in the first case, and higher in the second, from the tardiness with which the glass regains its original bulk.† These are refinements which it will not be necessary for the student to consider, until he has advanced so far in the science as to be competent to enter into a consideration of their presumed effects. All that will be necessary is to try the thermometers should they be old, to ascertain that the graduation corresponds to the height of the mercury, and that they have not suffered a change by time like the first of those referred to. If any opportunity occurs of observing peculiar changes or appearances, it will be proper to note them, for the illustration and explanation of those presumed and delicately influencing causes.

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* Bibliotheque Universelle, xx. 117.

† Giornale di Fisica, v. 268. Bib. Universelle, xxi. 254. xxii. 265.

265. It will be unnecessary to describe the peculiarities and uses of all the varieties of thermometers. No other liquid than alcohol and mercury is now used. Ordinary alcohol thermometers must not be employed for the indication of temperature above 180° for if subjected to higher, they would either yield wrong indications, or burst; but that fluid having never yet been congealed, they may be applied to the indication of exceedingly high temperatures. Mercurial thermometers may be used for temperatures 20° or 30° below 0° or up to 500° or 600°. At these high temperatures they are very liable to vary from each other in their graduation, for want of an unexceptionable and natural standard point by which they can be corrected.

266. A good mercurial thermometer hermetically sealed, will not indicate temperatures higher than 580°. (244), for above that point the mercury boils in the bulb; but when open at the top, and consequently subject to the pressure of the atmosphere, it will indicate temperatures from 60° to 70° higher. If wanted for delicate experiments these instruments should be small, not merely in the tube, by which the divisions are rendered larger and the indications consequently more minute, but in the bulb also. A thermometer indicates temperature, by taking or giving heat from or to the body to be examined, until on an equality with it; hence the body changes in temperature upon the introduction of the instrument, and if it be small, whilst the thermometer is large, the heat which results when they are both alike, may be considerably different from that of the body at first. This would cause a considerable error, which is only to be avoided or rather diminished, by using a thermometer so small that it shall not occasion a material change in the temperature of the substance into which it is introduced. A large thermometer is also longer in heating or cooling than a smaller one, and may from the lapse of time necessary to allow of its proper change, occasion an alteration of temperature, by allowing the body tried to cool or warm (244). Small thermometers are therefore frequently more useful and accurate than larger ones; and in order to compensate for the diminished mass of mercury whose ex-

pansion is actually measured in the instrument, and to prevent the degrees from lessening in length and delicacy with the bulb, the tubes have been made of a proportionately smaller internal diameter. A great advantage is then gained by using a tube with a flat bore, the capacity being rendered very small, and consequently the degrees comparatively long, whilst the surface to be looked at is large.

267. When a bulb is thin or large and the column of mercury in the tube long, the instrument will occasionally be affected in its indications by the position in which it is held. Suppose a thermometer having a column of mercury of 15 inches in the tube, to be held perpendicularly, and afterwards inverted, and the bulb held uppermost: if the column did not descend or part in the latter position, there would be occasioned a difference of pressure upon the exterior of the bulb, equal to a whole atmosphere by this simple change of position; for the column of mercury of 15 inches first exerting a pressure into the bulb, would, in the latter state, be equivalent to an equal pressure added upon its exterior. It is this difference of pressure which, when sufficient to affect the bulk of the glass bulb, causes a difference in the two positions. It will therefore be advisable to try the instrument by change of position, to be aware of any effect of this nature to which it may be subject.

268. Another error occasionally introduced by a long tube, depends upon the variable quantity of mercury submitted to the heat at the time of graduation and the time of use. If a thermometer with a tube three or four feet long be graduated by immersion of its bulb, and two or three inches of stem only, into melting ice and boiling water, and then used in situations where the greater part of the stem, as well as the bulb, is exposed to heat; the indications may be two or three degrees higher than the temperature to which it is really exposed. A thermometer existed at Whitbread's brewery some years ago, which, belonging to a deep evaporating vessel, passed through the top, and descended perhaps three feet before the bulb entered the fluid; this instrument indicated a heat in the boiling wort beneath, some degrees higher than the same wort

brought up in a bucket, and tried by another instrument, and yet examined in the usual way, it appeared to be correctly graduated: the difference depended upon the expansion of the mercury in the stem by the heat of the steam above the liquor, to which it was exposed when in use, which was added to the expansion of that in the ball, the only part heated at the time of graduation.

269. Some thermometers are formed with a chamber or bulb in the upper part, so that if accidentally raised to the boiling point of the fluid within, the fluid and vapour may pass into this space, and the bursting of the instrument be prevented. These are so far advantageous, but they cannot be made free from air, and are in that respect inferior to the others.

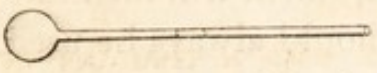
270. Thermometers should not be introduced suddenly into hot or cold substances, for then the glass is liable to crack at the stem, and the instrument consequently is destroyed.

271. The graduation of these instruments is sometimes made on the glass, and sometimes on a separate scale. When examined, the eye should be brought perpendicularly to that part of the stem where the mercury stands, so as to look directly through and on each side of the tube, that the correct coincidence of the surface with the scale may be observed. If the graduation be looked at obliquely, through or upon the tube, the apparent places of either the mercury or the degrees are not the real ones.

Although accurate graduation has been thus far spoken of, it is with reference only to the mode generally acknowledged and practised, namely, that of ascertaining the freezing and boiling points of water, and dividing the interval into a certain number of equal parts, each of which is called a degree, and being the model for other degrees, made upwards or downwards on the scale. Whether such a process is strictly philosophical is not the question; all divisions must be arbitrary, and that adopted has the essential quality of producing instruments strictly comparable amongst themselves.

272. Air is a substance, which though not in general use

in the construction of thermometers, is adopted in peculiar trains of experiment, and the student, when engaged in considering the researches of Mr. Leslie and M M. Petit and Dulong, will have occasion to observe the valuable uses to which these philosophers have put instruments containing it. The simplest air thermometer consists of a thin glass bulb at the end of a tube, in which is placed a small cylinder of clean mercury. As the bulb changes in temperature, the air within expands and contracts, and has its changes of bulk indicated by the motion of the metal.



273. The great expansion of air by small increments of heat, makes these instruments very delicate, but they are liable to actions and accidents which render them quite unfit to replace mercury and alcohol thermometers. In the first place, the bulk of the air is readily affected by pressure, so that alterations in the barometer cause movements in the mercury without alteration of temperature. For the same reason difference of position causes different indications as the cylinder of metal presses upon, or draws against the air within; causing consequent changes of volume. In the next place, the mercury is liable to change its situation, and to allow air to pass, if the tube be large; and on the contrary if the tube be small, the mercury has a tendency to adhere, and will not readily give way before the air pressing on one or the other side of it.

274. When another fluid than mercury is used, the instrument not only remains liable to the effects of pressure, but is subject to other inconveniences; for if the fluid be water or an evaporable substance, it sends a variable portion of vapour into the globe according to its temperature, and thus occasions expansion not due to the temperature of the air within; if it be sulphuric acid, it gradually attracts water, and becoming diluted, is then liable to the same objection; and if oil be used, it, together with the other fluids, flows within the glass tube, adheres to it, and does not leave it as the mercury does; such adhesion is incompatible with accurate measurement.

275. These instruments can only be used in connection

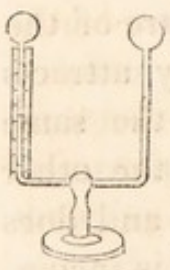
with the barometer. They merely give comparative results, unless indeed their scales be laid down at the time from a mercurial thermometer; and then from the largeness of the degrees, they serve to indicate very minute changes. When mercury is the substance in the tube, which by its motion indicates the change of bulk and consequent alteration of temperature, a few taps given to the instrument will facilitate its change of place. The instrument should always be used in the same position, and if the experiment admits of a horizontal one, it is an advantage, for then the results are not complicated by the pressure of the metal.

276. The air thermometer has had numerous forms given to it, but it will be unnecessary to consider all of them. Sometimes it is placed with the bulb upwards, and the lower



end immersed in a fluid which, rising and falling within, indicates the change in the volume of the air: some objections are thus avoided, others are originated. Sometimes in place of dipping into a fluid, the end is turned up, and terminated in a bulb open to the air, and this being partly filled with fluid, a portion of it rises into the tube, and indicates changes in the inclosed air as before. The scales attached to these instruments are usually of a temporary and arbitrary nature; for as, from various causes, the latter differ at different times, they will not admit the application of permanent portions of the scales of other thermometers.

277. The instrument used by Mr. Leslie differed in construction from those described, and was by him named the differential thermometer. In this instrument the aperture, instead of being left open, is attached to a second ball, similar to the first, the tube connecting them being bent



twice at right angles, as in the figure, and the whole closed, so that the indicating fluid within is entirely free from the pressure of the external atmosphere. The fluid used is sulphuric acid tinged by a little carmine; it yields no vapour to the air in the bulb, and should be in quantity sufficient to fill one of the perpendicular legs and the horizontal part of the tube. When in use, the situation of the

fluid is observed whilst both balls are of equal temperature, and then one is subject to the heating or cooling influence, whilst the other is retained unchanged; the motion of the fluid in the tube indicates whether heat or cold has been occasioned, and, comparatively, to what extent.* The scale is generally arbitrary, but may at any time be compared experimentally with that of a good thermometer.

278. With respect to instruments fitted to measure higher degrees of heat than those which can be borne by mercurial thermometers, we are yet deficient; nor does it seem likely that the want will soon be supplied. The student will do well to observe the appearances of a furnace or a substance, as it rises from a dull red heat, to the highest possible temperature that can be given to it; to form in his mind a clear idea of the colour and appearance of the light emitted in succession; and to select three or four distinct periods of the ignition to serve him, as it were, for degrees. The terms dull red, red, full red, yellow, white, bluish white, or any others he may choose, should not be quite indefinite, but so far understood and appreciated, and the appearance he intends to express by them so fixed in his mind, that he may be able to say at once whether a fire is above or below any required degree; or, having registered a particular heat by its appearance in his note book, that he may be able to attain it again with considerable accuracy.

279. The instrument called Wedgewood's pyrometer, at one time claimed much attention, for the apparent facility of its application, and accuracy of its results. It consisted of pieces of clay which, being heated to a higher or lower degree, contracted more or less; and the contraction being measured, was considered as proportionate to, and therefore a measure of, the temperature to which they had been subjected. Sir James Hall, however, shewed that the indications were fallacious, inasmuch as the same contraction was produced by a long low heat as by a shorter and higher one; even supposing this could to a certain degree be guarded

* Leslie's Experimental Enquiry into the nature and propagation of Heat, page 9.

against by attention to time, the instrument is inapplicable, because the pieces of clay are no longer prepared and sold, in consequence, as it is understood, of irregularities in the kinds obtained from different sources.

280. Daniell's pyrometer, the best instrument of the kind* which has been constructed, claims our attention. Its indications result from a difference in the expansion and contraction of a platina bar, and a tube of black lead ware, in which it is contained. These differences are made available by connecting an index with the platina bar, which traverses a circular scale fixed on to the tube. The degrees marked on the scale, though arbitrary, are in each instrument, compared experimentally with those of the mercurial scale, and the ratio marked on the instrument; so that its degrees are convertible into those of Fahrenheit. The instrument, after use, will return on cooling to the point from which it set out, and when applied to ascertain a particular temperature, the fusing point of silver for instance, will give nearly the same indication every time. It is therefore much superior to any other that has yet been constructed to measure high temperatures, but it has the inconvenience of requiring a large heated source at a uniform temperature, and must be protected from contact of the fuel or of metals. It cannot be plunged into a crucible to indicate the temperature of its contents upon inspection; such an instrument is yet a desideratum; nor can it be immersed wholly in the fire, so as to try in succession the different parts of a puddling furnace for instance; but where circumstances admit of its application, and the situations are very numerous, as in glass-houses, potteries, &c. it far surpasses any other instrument, and furnishes indications of great comparative delicacy.

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* Quarterly Journal of Science, xi. 309.

SECT. V.

COMMINUTION.

Trituration, Mortars, Granulation, Precipitation.

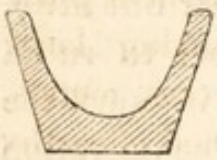
281. The division of matter is often highly advantageous in facilitating chemical action, and various processes have been devised for effecting it in the laboratory; some suited to the nature of the substance to be divided, others to the particular state of division required. These processes are both mechanical and chemical; for fusion and solution are more frequently referred to as means of separating the particles of matter one from another, than for any other purpose. The latter processes will not be dwelt upon at present; what relates to them, connected with the object of this book, arranges more conveniently in other sections, and hence, in this, the references to them will be only incidental. The operations now more immediately in view, are those which, while they divide a substance, do not alter its physical state. These of course apply to solid bodies only, and the substance, after the operation, is still in the solid form, however minutely the particles may have been separated from each other. No merely mechanical division can bring a solid body into a state comparable, as to physical properties, with the same body when it has had freedom of motion given to its particles by fusion or solution.

282. Of all the processes adopted in the laboratory for these purposes, none is more extensively useful than that of trituration; nor is any vessel more generally convenient for the purpose than the mortar and pestle. Chemical operations cannot proceed well without it, and hence to meet the quantities and qualities of different substances, several of these vessels, of various sizes and materials, should be included in the laboratory apparatus.

283. In the first place a large one of iron, with its pestle of the same material, and of a proper size and weight, should stand on a block in some corner or convenient place in the laboratory (15). It is useful for breaking large lumps into smaller, and for the pulverization of ores, metals, and heavy coarse materials. Two or three, formed of earthy materials, and of moderate sizes, from a pint to three pints in capacity, should be provided for table use, and a smaller one for rare substances. Those which are intended to effect the pulverization, and at times the solution of various bodies, ought to possess requisites which it is difficult to find combined. A vessel is required of a material so hard, as to bear the blows and friction of other hard bodies for any length of time, without suffering injury or abrasion of its surface; of an uniform and compact texture; not brittle; not permitting the absorption of fluids, or penetration by them; not subject to the action of acids, alkalies, or other solutions, and of a requisite capacity.

284. The difficulty of finding these properties united, has caused the introduction of a variety of mortars for various uses. Those for common occasions should admit of the pulverization of most substances, and the preparation of acid, alkaline, and metallic solutions. These purposes were well answered formerly by mortars of Wedgewood's ware, and there were some excellent ones to be bought with the name of *Mist* upon them; but at present no mortars made of Porcelain or artificial ware, can be procured fit for the laboratory. Both form and material have deteriorated. A mortar of this kind should scarcely allow of being scratched by the edge of a piece of quartz or flint, and absolutely resist steel, not by any glaze on its surface, but on an accidental fracture, as well as other parts. It should not be stained by having a strong acid solution of sulphate of copper or muriate of iron left in it for twenty-four hours, but should allow the salt to be washed off without any difficulty by cold water. On rubbing down an ounce of sharp sea sand in it to fine powder, the sand should acquire no appreciable increase of weight. It should be sufficiently thick at the bottom, to resist the blows to which it will at times be subject, as well as to

give weight and steadiness. It should not be of brittle material, and therefore fragile or apt to shiver, though if unavoidable, that fault is more easily borne with than any other of those mentioned. The proportionate thickness of the vessel in different parts relative to its capacity may be represented by the accompanying wood cut.



285. The pestles should be of one piece, and of the same material and qualities as the mortar. If in two pieces, as is sometimes the case, the handle being of wood and the bottom only of ware, the cement by which they are fastened occasionally falls out, and produces injury to the materials in the mortar; or by the contraction of the wood and other causes, a space is formed, which sometimes receiving and sometimes delivering dirt, may injure an experiment. The pestle should be strong, and its size such, as may be sufficient above to allow of its being grasped firmly in the hand, and below to permit a considerable grinding surface to come in contact with the mortar. Its diameter in the lower part, may be about one-third or one-fourth of the upper diameter of the mortar. The curve at the bottom should be of shorter radius than the curve of the mortar, that it may not touch the mortar in more than one part, whilst at the same time the interval around may gradually increase, though not too rapidly towards the upper part of the pestle. A mortar and pestle of the relative convexity figured in the margin, may, by inclining the pestle, or bringing it to different parts of the mortar, allow portions of such different convexity to be placed in juxtaposition, that the intervening space shall increase more or less rapidly from the point of contact, in almost any proportion; a variation which it is of considerable consequence in pulverization to obtain with facility.



286. Neither pestle nor mortar should be quite smooth at the grinding surfaces, or the materials will slip about between them, and not be retained and pulverized. The roughness of unglazed ware is quite sufficient for this purpose. A roughness of this kind is sometimes obtained by use, and is the best that can be produced; but it indicates

that the mortar is abraded by the substances rubbed in it, and if it happens quickly, shews that the vessel is deficient in hardness. When the mortar is such as to wear but little, and is good in other respects, it is then proper to rub a quantity of sharp sand or emery to powder in it, until the required roughness of surface is produced. The operation will be long and laborious, but a good mortar will repay the pains it requires. Besides these mortars, a couple of small ones of the same materials should be procured. They should all of them be lipped, for the convenience of pouring out fluids or fine powders.

287. Excellent porphyry mortars are brought to this country from Sweden; they are very hard and resist all ordinary chemical action; but they cannot be obtained of large size, and are expensive from the difficulty of making them out of a solid block. Their forms are variable, being in part dependent upon the pieces out of which they are worked. They should be accompanied with pestles of the same substance.

288. Small mortars and pestles are also made of agate, and are exceedingly useful for the pulverization and mixture of small portions of matter, which have either been weighed out, or are scarce. They are generally made more shallow than ordinary mortars, and in consequence of their form, size, hardness, and closeness of surface, allow of the matter being collected with less risk of loss than from mortars of ware. Their hardness is such as to enable them to resist abrasion better than any others. They should not be inconsiderately subjected to blows, being more brittle than the porphyry or ware mortars, and occasionally having numerous and almost imperceptible cracks running through them, which, though so close as not to interfere with their ordinary use, render them weak. If agate mortars be not left roughened within by the workman, it takes a long time by ordinary wear to render them so. It is better therefore to effect it in such cases by means of the pestle and a little emery or sharp sand.

289. Mortars of wood, marble, or iron, are unfit for ordinary laboratory service, because of their softness, and

the action of different fluids and substances upon them. A wrought iron mortar of from a pint to a quart in capacity is useful in particular cases, not merely for the pulverization of substances which, not acting upon it, would be too tough or require too many blows for a common mortar, but also as a vessel to contain mercury in its ordinary or in a heated state; it should have an accompanying pestle of iron. Glass mortars are generally unfit for the laboratory, being too soft and brittle, and yielding both alkali and lead to particular solvents. Their uses are indeed so confined as to render it wise to exclude them altogether.

290. With respect to the operations in which a mortar is available. If a substance in mass, not too hard, as many salts, ores, and other bodies, is to be broken into smaller pieces, it is very conveniently effected in a mortar without loss or dispersion of the fragments. For this purpose it should be placed in the mortar, and struck with the pestle in successive sharp firm blows, but not too forcibly. If the body be rather tough, as a piece of sal ammoniac, the pestle should be held firmly in the hand and impelled, not merely by its descending weight, but the force of the arm should be added and continued, until it is stopped by the substance, something like a thrust being given to it as well as a blow. On the contrary, if the substance be brittle, as glass or many ores, it is better to hold the pestle lightly in the hand, and having urged it downwards, to let it fall upon the substance with little more than its own force, using it rather as the head of a hammer, than in the former manner.

If there be any risk of the fragments being thrown about, the mortar should be covered with a flat piece of pasteboard or mill-board, having a hole in the middle, through which the pestle may be passed. The fragments broken from the piece, pass from under the pestle, and have a general tendency up the sides of the mortar; hence a cover of this kind is quite sufficient to oppose their passage, and retain them within the vessel, notwithstanding the hole in the centre should be considerably too large to be filled by the pestle. For this reason one such cover, in a clean state,

will suffice for mortars of different sizes, and should have its assigned place on the walls of the laboratory. When such a cover is not at hand, a clean cloth with a hole in it for the passage of the pestle may be used, being drawn by one hand tightly over the mouth of the mortar, whilsts the other holds the pestle. This is better than to cover both mortar and pestle with a whole cloth, and to grasp the pestle through it, whilst breaking the body; for then the cloth hangs in folds, is considerably agitated, and frequently catches, and even scatters portions of the substance.

291. If the piece to be broken be too hard for the mortar, whilst large, which is now and then the case, or there be reason to fear its injury; then it must be split or crushed by a hammer on the anvil. When of convenient size, it should, after being laid upon the anvil, be surrounded by the hand, or by the thumb and one, two, or three fingers, according to its size, so that when struck by the hammer, and split into several pieces, these should not be scattered, but retained together, and afterwards separated by the hand. The blows should be steady, small at first, and increased in force, until sufficiently powerful. It is not desirable to crush the substance to pieces at once, but to break it into large, and afterwards into smaller fragments; and if the body be one which gives way by degrees, the fracture should be effected by successive blows and not on a sudden. It is desirable that the chemist should, in every thing he does, endeavour to obtain a command over the agents he is using, and not apply them to such a degree, or so carelessly, as to render the results accidental. Even in the breaking of a stone, advantage is gained by a cautious mode of procedure, not merely as confirming a good habit, but as most effectually preventing waste, and sometimes in preserving peculiar internal appearances.

292. When the substance requires a blow so hard, that it is unpleasant to expose the hand or fingers to the effects which may happen upon its fracture, it may be wrapped up in one or several folds of strong paper or cloth, and then be struck. If the blow break it, the result will be indicated by the sound, and the feel of the hammer in the hand; if it

does not, but at the same time cuts the paper or cloth through, it is not necessary for that reason to change the envelope, but the blow must be repeated upon the same place, until the body does separate. In both cases the fragments will be held together by the envelope, and it is easy to separate them from the wrapper when opened out by a little motion and friction.

293. Some substances, and especially some of the metals, as cast iron, copper, alloys of copper, &c. when in mass can scarcely be broken into smaller pieces on the anvil, when cold, except by blows so powerful as to endanger neighbouring bodies, and yet will crack and crumble with facility when heated. In these cases, the substances should be made red hot, and struck in that state, until they are sufficiently cracked, and the separation completed, either immediately, or when cold, in the vice.

294. Before leaving this subject of the division of large pieces into smaller, it will be proper to observe that many substances may be separated by nippers or a knife. In these cases it is necessary to attend to the grain of the substance, and take advantage of the greater facility of division which exists in one direction. Muriate of ammonia will separate readily with the grain into pieces without much crumbling. If it is to be pulverized, place it in the mortar with the grain upright, and not horizontal.

295. It may be remarked that there are many substances, which, though when in mass, they are too hard to be broken in the mortar, without endangering its fracture, or the abrasion of its surface, still may be readily and properly pulverized when in smaller pieces.

296. If the object be to reduce the substance into minute fragments only, of the size of a pea, or pin's head, or smaller, but not to powder; then, having broken it down as before described, the operation is to be continued in the mortar, by a series of blows from the pestle, all grinding action being avoided. The pestle must be held lightly, and allowed to fall sharply on the substance, being directed to those places where the largest pieces are. A slight, lateral, or shaking motion of the left hand, holding the mortar be-

tween each blow, will help to return the larger pieces from the edge toward the middle of the mass of fragments, where they ought to be when struck, and no blow should be given towards the edge, if it can be avoided; it there only tends to reduce those particles smaller, which are small enough; and if a large piece be struck there, its fragments are apt to fly up the sides of the mortar; whereas if it were in the middle of the mass they are caught and retained by the surrounding matter.

297. It will be found that a process of this kind, in which all grinding action is avoided, will reduce a substance to small fragments or particles, with the least production of fine powder, and this is highly desirable with some substances which are in a more favourable state for experiment, when crushed or broken into small pieces only, than when more minutely reduced. Flint glass is as convenient a substance as any for the student to practice with for the acquirement of these methods and illustration of their effects.

298. In *pulverization* a very different action of the pestle and hand is required. The object then is to reduce the whole of the substance into fine particles as rapidly as possible. The process of striking or stamping would now be found too slow; a grinding action is necessary to expedite the operation, and this it will be proper to adopt as soon as possible. Even, therefore, whilst breaking down the larger lumps into smaller, it will be desirable to alter the character of the blow; and instead of holding the pestle lightly in the hand, and letting it almost drop on to the middle of the substance, it should be grasped firmly and forced down by the muscles of the wrist and arm, pressure being added to the blow; and it should be made to fall on the substance at the side of the mortar, the pressure being continued till the pestle has reached the middle. The blow is to be oblique in its direction, going down the side of the mortar to the centre. It is best given on the part farthest from the operator, more force being then exerted, as it is continued by a downward pressure to the middle of the mortar. This kind of stroke breaks the larger fragments, grinds both these and the smaller, and mixes and alters the position of the whole,

and if continued in the same direction whilst the mortar is turned a little way round by the other hand between each stroke, every part of the substance is brought in succession under its comminuting action.

299. The substance is thus soon reduced to particles so small, that the pressure of the hand is sufficient to continue the division without the force of a blow. After this it is most expeditious to advance the operation by rubbing. For this purpose, the pestle being grasped firmly, should be moved in larger or smaller circles around the center of the bottom, at the same time pressing hard and regularly upon it. It is in vain to expect a rapid effect in this operation without pressure, or to give pressure without labour, but certainly much labour is exerted in vain by those who give an unequal and uncertain pressure. The motion of the pestle should be in circles, commencing at the centre, and gradually expanding outwards: this, whilst it grinds the substance gradually displaces it, turns it over, and mixes it. When it has arrived at the exterior of the mass, the circles described should gradually be contracted, until they have again closed in the middle, when they should again expand, and thus the operation should be continued until the powder be sufficiently fine. The process is least fatiguing to the hand when the circles are up the side of the mortar, towards the limits of the substance, and the grinding proceeds most rapidly there. By making a smaller circle now and then, it is easy to urge the fragments outwards in that direction, so as to take advantage of the most favourable circumstances. Occasionally, deviations from this regularity may be convenient, for the purpose of moving the substance in different directions; but it will be found that the more nearly they are adhered to the more rapid will be the operation.

300. The pestle may be held in both hands in succession, for the relief of the wrists; but the hand not occupied by it should take charge of the mortar, and holding it firmly and steadily, should sometimes turn it a little way round, especially if the force of the hand holding the pestle be unequal in different parts of the circle. The motion of the pestle may

be either in one direction or the other, and an inversion of it is now and then advantageous for the more effectual mixture of the fragments. During the whole process it should be observed, that every part of the powder is rubbed, and the tendency should be to grind those parts first which appear coarsest, and not to finish one portion before another.

301. The opportunity already referred to of obtaining different inclinations between the surface of the pestle and that of the mortar (285), by either inclining the pestle or carrying it to different parts of the mortar, may now be taken advantage of. At the commencement of the grinding for instance, whilst the particles are coarse, it will be proper to incline the pestle so, that the preceding part may pass over them; by which they are included between it and the mortar, and are crushed by the following part. Particles are thus instantly broken down, which, if the pestle were held upright, or if inclined in a wrong direction, would merely be pushed forward. In the same way, even when the powder is of considerable fineness, the pestle may be made to have more of a mixing or a grinding effect, according as it is inclined one way or the other, both being peculiarly desirable at times. Many other advantages of this kind are attainable, which are however better learnt by practice than from description, which would necessarily be very minute and tedious, and at the same time very imperfect.

302. The student should be aware also of the peculiar uses of the different parts of the inner surface of the mortar. The powder lies quietly at the bottom of the mortar; on the sides, a little way from the centre, it also rests with facility, but with a tendency to pass to the middle as the pestle moves over it; farther outwards it arrives at a part so inclined, that when forced upwards as the pestle passes, it falls back again when left at liberty; here consequently a mixing agency may be exerted, whilst the operation of grinding goes on more effectually at a part nearer the centre, not merely because the powder rests there and awaits the approach of the pestle, but also because, from its being nearer to a horizontal position, the hand has more command over the pestle, and power in pressing it down.

303. The quantity of a substance put into the mortar at once, should bear a proportion to its particular qualities and to the ultimate state of fineness required. If the substance is to be finely pulverized, only small quantities should be operated on at once, so as to form but a thin layer at the bottom in those places which the pestle has passed, and to ensure the subjection of the whole to trituration. If the layer under the pestle be thick, a grain may be imbedded in it, and remain uncrushed by the pressure. If the substance be in great quantity, a particle may be pushed about from side to side enveloped in the mass, and without coming under the pestle at all; and what may happen to one particle may happen to many, and thus the powder be a mixture of coarse and fine. For coarse powders larger quantities may be taken. Hence also when a lump is to be broken down into a fine powder, it is frequently better to reduce it to a coarse powder, and then removing it from the mortar to return it in small portions, each of which is to be brought to the state of fine powder by itself.

304. A soft or readily pulverizable body may be put into the mortar in larger quantities than a hard one; thus a large quantity of chalk may easily be reduced to a fine powder at once, whereas if as much siliceous sand were operated upon, the attempts to reduce it to a powder as fine would fail, or be interminable. It is easy to understand that any substance whose particles are so hard as to require direct pressure between the mortar and pestle, is in too great a quantity when there is so much present, as to prevent the approach, almost to contact, of the two grinding surfaces.

305. The state of fineness to which a powder has been reduced is judged of principally by the appearance. If the body be coloured, the colour becomes paler as the powder is finer, and generally at last almost disappears. When the powder, in place of flowing freely down the sides of the mortar, begins to adhere and clot as it were, it is also a mark of considerable division; and when it is in such a state that, previously dry and granular, it now seems almost moist, and being moved about by a spatula preserves the form

given to it even when the lateral surfaces are perpendicular; it is then in an extreme state of division.

306. The student may observe all these appearances by operating upon a few fragments of bottle glass (not flint glass, for then some fallacies are introduced) or a few pieces of calcined flint.

307. Passing from this general consideration of the process of pulverization, it may be observed that particular bodies require slight variations in the process for particular purposes. If the substance be poisonous, or if it be in exceedingly fine powder, and liable to dispersion from the motion of the air, it may advantageously be moistened with a little water, provided that fluid has no action upon it; but the trituration is then more laborious, from the greater difficulty of mixture and the adhesion of the substance: it is however a precaution continually adopted with substances subjected to the grinding-mill. When the pulverization is finished the substance may be dried, if that be necessary, or if not, left in the state in which it comes from the mortar. At other times, to confine the powder, the mortar may be closed up by a cover, a mill-board, or a cloth, as described in the directions for breaking down substances (290), but the aperture should now be as small as possible, or the finer particles will escape by it.

308. When the substance to be pulverized is stony and hard, advantage is frequently gained by igniting the mass, and quenching it in water. Flints, many siliceous and other hard stones, are thus rendered more brittle and divisible, and their comminution is considerably facilitated. Charcoal is a substance which is found to pulverize with far greater ease and rapidity when hot than when cold; ignite it therefore, and in this state introduce it into the mortar, and instantly rub it to powder. Camphor, which has a toughness under the pestle, is easily reduced to powder when moistened with a few drops of alcohol. Gum, when pulverized, should be kept perfectly dry. Zinc may be reduced to powder when hot, in a heated iron mortar, the pestle also being heated.

309. Shell-lac, some resins, and other substances, when divided for the purpose of facilitating solution, are better in small fragments than in fine powder. Adhesive organic substances which would knead together under the pestle, are frequently rendered capable of division in the mortar, by being mixed with clean sand or glass; such substances being chosen in these cases as will be inert with respect to the agents to which the bodies are to be subjected.

310. The transference of materials to and from the mortar, and generally of substances in powder or small grains, is most conveniently effected by the use of spatulas or similar instruments. Common broad bone, paper-knives, make excellent spatulas for the laboratory for this and other uses, and may be used to disturb or separate the substance when it adheres together in the mortar or to the sides of the vessel. But the precaution must be taken of not using them in those cases where they may affect or be affected by the substance, or where, from its strong adhesion to the mortar, the removal may cause such abrasion from the spatulas as to communicate so much matter as to be injurious to the experiment. In these cases the platina spatula before referred to in weighing (54) is to be used, and hence a reason for the degree of thickness and strength already recommended.

311. When the substance to be pulverized is coarse, and its quantity unimportant, a piece of pasteboard or a card is very useful in supplying the place of the spatula in clearing the substance from the mortar; it at times even surpasses it in effect and convenience from its pliability and consequent adaptation in form to the mortar, and also from the larger quantity which it will lift at once. Some waste cards should always be kept in one of the laboratory drawers for these and similar uses.

312. Where a hard substance is to be pulverized for the purpose of delicate analysis, it is sometimes necessary to take into account the matter which may be removed from the mortar during the process, and estimate its influence in increasing the quantity of products ultimately obtained. In such cases a mortar of known composition should be used, one of agate for instance, where the substance removed may

be assumed to be silica, and thus the correction made at the proper time by subtracting so much weight from the silica evolved in the analysis.

313. The diamond is most conveniently pulverized in a steel mortar, having a cylindrical chamber; the pestle is replaced by a steel cylinder of such size as to pass easily into the cavity. The diamonds are first introduced, and afterwards the cylinder; and the latter being struck with a hammer, the gems are crushed and reduced to powder of any degree of fineness required without the risk of dispersion and loss. When first used, a portion of diamond is lost, as it were, by adhesion to the steel surface: this should be left, because it prevents a similar loss at a second or third operation. Such a mortar should be reserved exclusively for the pulverization of these gems; for besides avoiding a repetition of the loss already referred to, it would be laborious and difficult to clean the instrument so completely from diamond, that if sapphires, for instance, were afterwards pulverized in it, a portion of diamond should not be mixed with the produce.

314. In analysis and other operations, a given weight of a substance in powder, as 100, or 200 grains, is often required. This quantity should not be first weighed out, and then pulverized, because probably a little loss would occur during the operation from adhesion to the mortar and to the transfering tools; but more than the weight required should be reduced to powder, and when in a proper state, the exact quantity should be weighed out.

315. Pulverization is sometimes useful, not for the purpose of accelerating chemical action, but on other accounts. When substances are to be heated which decrepitate in the fire by which portions of it are dispersed and lost, the effect is prevented by previous pulverization. Decrepitation is generally occasioned by the expansion of the outer portions before the interior has had time to heat, and in that respect resembles the breaking of a glass vessel by a sudden increase of temperature. By comminuting the substance, this difference in different parts of the same mass is avoided, and the body sustains the heat without disturbance. If the substance

be liable to a similar effect from included moisture, pulverization, by opening passages for the vapour, is equally effectual in preventing it.

316. Pulverization is sometimes effected by grinding the body under a muller, upon a flat stone; but the process though useful in some of the arts, especially where the substance is to be mixed with fluid into a paste, is so inferior to the use of the mortar, in the laboratory, that it will be unnecessary to describe it here.

317. It seldom happens, perhaps never, that the operations of pulverization reduce the body into a powder consisting of particles of equal size, and in by far the greater number of cases the difference between them is evident. This, though of no consequence on some occasions, renders it necessary on others, to separate the mixture of differently sized particles into portions containiug such as more nearly resemble each other in magnitude. The ordinary and well known operation of sifting is so simple as to require no notice here, except to point out the use of two or three sieves in the laboratory, which if used for different substances, should be cleaned after every operation, either by a brush, or, which is better, by passing a stream of water through them.

318. The sieve may also be had recourse to as an excellent means for effecting the mixture of powders, provided the particles are of such size as to pass very freely through it. Two or more such powders, first mingled by the hand or a spatula, and then passed twice or thrice through a sieve, will be very uniformly mixed.

319. Another mode of separation in very frequent use, is that of washing; for as light and minute particles are suspended in a fluid, whilst the larger and heavier descend, it thus affords a ready mode of separating them. This operation, however, can only be applied to such bodies as are insoluble in water, that being the fluid constantly made use of. It may often be conveniently effected in the mortar in which the pulverization itself is carried on. Suppose a stone were to be reduced to a powder, no particle of which should be beneath a certain degree

of fineness. The stone should be pulverized in the mortar in the usual manner, and when from the appearance, it is concluded that a considerable quantity of fine powder is produced, two-thirds of the mortar should be filled with water, and the powder mixed well up in it; being now allowed to stand a very short time, until the particles which are considered as too coarse have descended to the bottom, the supernatant mixture should be poured off into a large basin or jar, leaving the heavy powder only in the mortar, with a little water. Then, without adding more water, or endeavouring to remove that which is still present, the pestle is to be used again, until from the ready mixture of the substance with the water, and the production of a smooth soft paste, it is assumed that much more of it has been reduced to fine powder. Water is to be added to wash this off as before, the finer part being put to the first portion separated, and the operator is again to proceed with the comminution of the residuum until it has in this manner been entirely removed from the mortar.

320. If by this process the powder be sufficiently reduced, and a greater regularity as to size amongst its particles be not required, then the mixture of it with water should be left quiescent until the liquid be clear, and the powder in mass form a stratum beneath. The former should then be poured off, and the latter dried, and if during desiccation it adheres and produces soft lumps, these are easily broken down in the mortar.

321. If on the contrary more uniformity in the powder be required than is thus obtained by a first set of operations, it may be effected by a second, and this will often be necessary when the substance pulverized is such, that a very short period only can be allowed for the deposition of the larger particles; for the motion of the water not having subsided, and being unequal in different parts, some large particles will pass over with the finer. In such cases a return of the matter to the mortar and a repetition of the washing, will frequently separate much of the substance that requires further trituration. This second washing need not be deferred till the whole has settled from the water of the first

washing, but all being stirred together, and allowed to stand for rather a longer period than before, the suspended portion may then be poured off, and the rest operated with as directed.

322. The longer the period allowed for subsidence so much the finer will be the particles still remaining in suspension, and hence an easy process for obtaining the substance in powder divided to any degree required.

323. Another method of washing is to use a small mortar, and, after having powdered the dry substance in the usual way, to place the vessel in a large strong dish, and then directing a small stream of water into it, to continue trituration in a steady slow manner. The water, after filling the mortar, will flow over into the basin, carrying the smaller particles with it, and as the trituration proceeds, the current will continually separate the finer part until the whole has passed from the mortar into the dish. The fineness of the particles washed over is regulated by the depth of the mortar, the size and force of the current, and the degree of agitation given by the pestle in grinding. To ensure a powder of considerable uniformity, the operation should be repeated as before described (321).

324. The same principles and processes may be applied to the separation of insoluble substances of different specific gravities. If an ore contain metallic silver diffused through an earthy matrix, the processes of pulverization and washing will almost entirely separate the earths from the metal. Or if platina ore be treated in the same way, a separation of the iridium and osmium, and other substances, from the grains of metal, may in this simple manner be effected to a great extent, and the platina will be very much cleansed.

325. It is rarely that any other washing agent than water is had recourse to; but in peculiar cases, and for small quantities of matter, oil may be used. From its tenacity it requires a longer portion of time before deposition takes place, and the division may consequently be more accurately effected. It may be burnt off so as entirely to leave the powder, provided the latter be of such a nature as not to be affected by the joint or single action of oil and heat.

326. If silica be required in a state of extreme division, it may be obtained by mixing (318) one part by weight of finely pulverized flint glass, with two parts of pulverized white marble, heating the mixture to bright redness for half an hour, rubbing it in the mortar and again heating it; then acting upon it in an evaporating dish (344) by muriatic acid added till in slight excess, evaporating to dryness, and redissolving in warm water with a little muriatic acid. The insoluble portion is to be well washed in abundance of pure water until free from salts of lime or lead, and being then dried, the silica will be in a state of division far surpassing any which can be obtained merely by mechanical means. The alkalies cannot be used in place of lime or its carbonate, for this purpose.

327. Of the metals, all that are brittle may be pulverized. The division of zinc in this way when hot, has been before mentioned (308). Some metals may be obtained in a useful state of division by granulation. This is particularly the case with zinc, copper, tin, and lead. For this purpose the metal is to be melted in a crucible, and then poured from a height of two, three, or four feet, into a pail or pan, full of water: a considerable depth of water should be allowed, as the slight explosions which sometimes happen are then less likely to take place. If the water be hot the pieces become filmy and blown up as it were into bubbles; if cold they have more solidity, are smaller, and approach nearer in their form to shot, differences which are dependant also in part on the temperature of the metal itself. The crucible should be moved during the time the metal is running from it, that the descending stream may continually change its place in the water.

328. Some metals are brought by lamination into a state equally advantageous for chemical action, from the extent of surface exposed, as that produced by pulverization; and the process is applicable in cases when the latter cannot be resorted to. Thus platina, tin, lead, zinc, copper, gold, and silver, are obtained in the state of foil; platina, gold, and silver, in the state of leaf; and are highly advantageous in certain experiments, when thus attenuated. The che-

mical action which takes place between platina and tin, is in no way so effectually exerted, or so advantageously shewn, as when pieces of each metal in the state of foil, are laid together, folded up into a ball, and heated red hot. They combine in that case with such force as to produce vivid combustion.

329. The same advantage, dependant upon extension, is obtained to a considerable degree by drawing the ductile and tenacious metals into wire, their state being then for many purposes equivalent to that of actual division. Pure iron, which would resist the processes already described, is successfully attenuated in this way.

330. At other times the tough and ductile metals, as well as some others, may be divided by the action of the file. In such cases the files should be very clean. If new, attention should be paid to the oil with which they are in that state generally covered. If they have been used, the absence of dirt, metals, or other substances, from between the teeth, should be ascertained and secured, and the clean state of the surface upon which the filings are to fall, should not be forgotten. Iron and zinc are most generally required in the state of filings.

331. Silver, copper, gold, platina, and lead, may be usefully divided by chemical means. Silver, by introducing a plate of copper into a solution of acid nitrate of silver, until about one half or three-fourths are precipitated, the metal not being allowed to accumulate upon the copper, but shaken off from time to time, and at last (removing the copper plate and solution) washed with distilled water until tasteless, and then dried. Copper may be prepared in the same manner by immersion of a plate of iron in a solution of sulphate of copper with a little sulphuric acid added to it, and should afterwards be washed with dilute sulphuric acid, then with water, and afterwards dried. Gold may be prepared in very fine powder by adding a solution of protosulphate of iron to one of muriate of gold, and then washing with a little muriatic acid and pure water. Platina is procured in a state of extreme division, though the particles adhere slightly together, by heating the ammonio-muriate of

platina to dull redness in a crucible, until fumes cease to rise. It has the appearance of a sponge, though perfectly metallic. By heating the tartrate of lead in a close vessel or a tube to dull redness, a mixture of charcoal and lead is obtained, in which the latter is in such an extreme state of division, that on exposure to the air it takes fire. It is the pyrophorus of Dr. Gobel, and seems to owe its property only to the state of division of the metal; the action of oxygen, which in general is only sufficient to tarnish the surface of lead, being here, from the comparative absence of all solidity, and the existence of surface to an almost infinite extent, so simultaneously exerted upon every particle as to cause ignition.

332. Organic substances, which are not sufficiently brittle to admit of pulverization, such as wood, horn, &c. may be cut, or crushed, or rasped, or grated, according to circumstances; a division sometimes gross, sometimes minute, being required.

SECT. VI.

Solution, Infusion, Digestion, &c.

333. There are two great and general objects to be gained by solution, which render it a process of constant occurrence in the laboratory. The first is that of preparing substances for the exertion of chemical action; and from the perfect manner in which it separates the particles one from another, every obstacle dependant upon the attraction of aggregation is removed, at the same time that other advantages are obtained. The second object is that of separating one substance from another; this being continually effected by the use of such fluids as have a solvent power over one or more of the substances present.

334. These great uses of solution render it proper here to shew the means by which to effect and facilitate it; in what

manner to select the vessels and solvents, and to point out any peculiar circumstances or conditions attending it, which may assist the process. But it will be right to premise that the solution here to be considered relates almost always to solid matter, sometimes to liquid matter, but not at all to gaseous substances; for any processes or directions for the solutions of gases in liquids, will be more intelligibly and more instructively considered in the section on gaseous manipulation. Indeed the processes requisite are so different to what are here to be considered, as of themselves to suggest the propriety of the separation. The course of this section will be generally from inorganic to organic matter; for in that way the simplest instances and methods will come first into view.

335. It may be remarked at the outset, that solution is of two kinds, being effected either by fluids which have no chemical action upon the substances to be dissolved, or by others which have such an action; both are of constant use in the laboratory. For where, as very often happens, solvents of the first kind fail, recourse must be had to the latter, and then much care and judgment is required in the selection of those which will effect the desired end. Attempts have been made to distinguish between these two methods, by the use of the terms *Solution* and *Dissolution*, but they have been partial and imperfect, and chemical works now constantly speak of solution of the metals, of earths, &c. and therefore virtually reject the distinction.

336. Water is the great solvent whose aid is first to be called in; others are to be resorted to only when that is insufficient. So general and important is its use, that in speaking simply of the solubility of a body, water is always understood to be referred to. All aqueous solutions of solid bodies are heavier than water; upon this difference is founded a very convenient indication of solubility, frequently useful, always easy. It is to suspend a piece of the substance in a glass of clear undisturbed water; if the body be soluble, a descending current will be seen to fall from it, and be visible upon looking through the water horizontally. If it fall rapidly and in dense striæ, it will indicate rapid solu-

bility, and the formation of a dense solution; if it fall in a very narrow stream, it will indicate only moderate or slight solubility; and by its descending rapidly or in a slow broad stream, or by resting about the substance, a judgment may be made of the comparative density of the solution produced. If no descending current appear, nor any fluid round the substance of a refractive power or colour different to that of the water, then the body must be very nearly if not quite insoluble at common temperatures.

337. Another indication of solubility is gained from the taste. The saliva in the mouth is as to mere solubility nearly the same as water, and, generally speaking, those substances which are most sapid are most soluble. The impression of taste in the mouth is however frequently a mixed sensation, being dependant in part upon the olfactory nerves; and consequently odorous bodies will frequently appear to be highly sapid, when they are not so upon the tongue.* This is the case with camphor, which, if taken into the mouth after the nostrils have been perfectly closed by the fingers, so that no air can pass through them, will seem to have little or no taste, whereas the moment the fingers are removed, and the aroma has access to the olfactory nerves, an intense taste, using the word in its ordinary acceptation, is perceived. A similar effect may be observed with a peppermint lozenge or a piece of chocolate. Still however the indication may in many cases be useful, and has the advantage of requiring no apparatus, and being easy of performance.

338. If the substance appear to be insoluble, or if it be necessary to know whether it be soluble in alcohol, ether, oils, or any other body, for the purpose of selecting a solvent from among them, a portion should be pulverized finely, and introduced into a small tube with a little of the fluid to be tried, and heated; if the substance disappear, it is of course soluble. But if it be supposed to be a mixed body, and partly soluble, though not altogether so, then the presumed solution should be poured from the tube into an earthenware or platina capsule, and evaporated carefully

* Chevreul. Memoires du Musée. x. 439.

and slowly; if any substance remain, it of course indicates a degree of solubility. Trials by evaporation cannot be made with oil unless the body be fixed and will allow the oil to be burned off; nor can trials of very volatile bodies be made in this manner. It is almost needless to add, that cases may occur requiring much chemical skill and judgment; and that it would be impossible to give directions for every possible case.

339. Indications of solution dependant upon chemical action are obtained from the changed appearance of the substance. A body not soluble in water except by the use of acids or alkalies, is generally, though not always, rendered so by chemical action, and has its properties changed. It is rarely that these chemical agents are applied with any other liquid than water. Indications of their power may be obtained in the manner before directed.

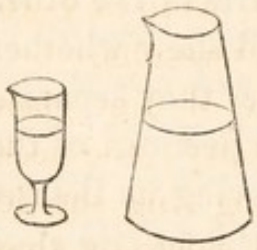
340. With regard to the solution of one liquid in another, no difficulty will occur in ascertaining whether it takes place or not. A small portion of the most valuable should be put into a tube, and then a very little of the other added to it; agitation, followed by rest, will shew whether the two have permanently mixed, or whether they separate again. If the latter be the case, let further portions of the second liquid be added, agitating and observing as before, and this should be done until the whole becomes one clear fluid, or until the volume is increased to many times its former bulk. A conclusion must then be made according to the appearance.

341. It may here be proper to warn the student of an appearance which sometimes takes place during mere solution, which has been frequently misconstrued into an indication of chemical action. Common salt, and several other salts, as well as their strong solutions, and also alcohol or spirit added to common or even distilled water, which has been exposed to air, frequently causes the evolution of a number of small air bubbles; these have the appearance of being the direct result of some chemical action, but are occasioned merely by the expulsion of the air dissolved in the water, which being incompatible with the substances

added, is separated. Some of those solutions which dissolve air, produce the same appearances when added to the bodies mentioned.

342. Whenever a dissolving power exists at common temperatures, it is generally heightened, and sometimes to a great degree, by an elevation of temperature. There are only two known cases in which heat diminishes the effect; these occur with lime and magnesia. But there is I believe no instance of a body not soluble at common temperatures being rendered so by the mere application of heat: it is the quantity of effect only, and not its existence, that is thus influenced. The change is nevertheless very important as favouring and facilitating the desired object: and comminution is also of great value preparatory to solution for the same reason.

343. The vessels required in the laboratory for the purposes of solution are numerous. They should be competent to resist the action of heat, acids, alkalies, all aqueous solutions, and for convenience should as often as possible be transparent. Hence the necessity of a dozen or two of glasses; they should always be lipped, and ale glasses will answer the purpose very well. Glass jars will also be required, and are best of the form depicted in the wood cut, as they then answer other purposes, to be referred to in Sect. viii. They should be from one to two or three pints in capacity.



344. Lipped earthenware basins, from $1\frac{1}{2}$ to 10 inches in diameter, are also necessary. Those called Wedgewood's basins are excellent in shape, but not so good in material as they were formerly. They should be tried by a solution of muriate of iron or sulphate of copper, both on the glazed and unglazed part, in the manner directed with respect to mortars (284), for which purpose a little of the solution should be put into one basin, a smaller basin dipped into it, and heat applied. The old Wedgewood's basins when boiled in a solution of logwood, resisted the penetration of the fluid so well as to remain unstained when washed. Basins which will stand a trial of this kind are in that respect excellent.

If such as these cannot be obtained, those of more moderate quality must suffice. Of whatever kind they be, they should resist the action of acids and alkalies in solution. They should also be chosen thin rather than stout and thick, though some of both are desirable; but when intended to sustain the application of heat, the thinner they are the better, so that they have sufficient strength to bear safely the utmost weight of fluid they can contain.

345. A dish or two made of pure silver, and a few platina capsules, are also necessary. They should have a projecting tongue of metal to serve as a handle by which they may be held with a pair of pincers. The silver dishes may be as large as can be permitted up to 6 inches in diameter. The platina capsules should be about $1\frac{1}{2}$ or 2 inches in diameter. Very useful glass dishes and capsules are made out of old retorts, receivers, and flasks, in the manner to be described in Sect. xix.; and they will admit of the application of a heat carefully applied. It is not advantageous to purchase glass dishes for the preparation of solutions; they are so brittle and liable to fracture from heat, as to be both expensive and dangerous to the experimenter's results.

346. Flasks are very useful. Those made of flint glass should vary from an ounce to a quart in capacity; the neck should expand at the mouth, or a projecting ring should be formed on it, that the flask may be held safely by that part without danger of slipping. They should be examined with respect to thickness, and the most uniform should be chosen, provided they be not so thick as to be liable to rupture by heat, or so thin as to burst by the weight of the fluid or by handling when filled. The thinnest that are of sufficient strength should be selected. The bottoms should be particularly observed: they are frequently much thicker than the other parts, and then almost invariably break when placed upon the sand bath or over a lamp. The thickness of a flint glass flask from half a pint downwards in size, should be about that of an ordinary florence flask: when larger they should be somewhat thicker. The indications by which irregular or excessive thickness is judged of, are dependent upon peculiar appearances of the reflection and

refraction of light, and are best learned from an ocular examination of a good and of a decidedly bad flask.

347. Florence flasks are very useful vessels, and for most purposes are superior to flint-glass flasks. They are always thin, and require careful handling when filled with a fluid, or they will be crushed from the attempt to support the weight. If resting upon the bottom they should be supported by a large surface (59). It is seldom that they are knotty, but should that be the case, the flask ought not to be subjected to the action of heat lest it should fly. Liquids should never be put into a cracked flask or glass vessel, for the purpose of heating them. Florence flasks may be obtained of two sizes, by application to oil-men or to foreign wine-merchants: the pints having been used to contain olive oil, the quarts to hold wine.

348. Besides these vessels, stirrers are frequently required in the progress of these operations. They should be made of solid glass rod and not of tube. The diameter may vary from the quarter to the one-third of an inch; the length from six to ten inches. After being cut off from the glass rod, the ends should have the sharp edge round them removed by a fine, or a dull file; or they should be softened in the blow-pipe flame, and in that case some should be left round at the extremities, and others conical, each having its particular uses (61). Enamel rod is sometimes used for this purpose, but glass is harder and not so brittle. Thick glass tube is not good, because the sealed end is apt to crack off in hot solutions, and then the cavity opened is a receptacle for dirt.

349. All these utensils are equally useful for evaporation and other processes, as for solutions, requiring in these cases generally no other qualities than those before mentioned. This being understood they will not be referred to again.

Proceeding now to the operations of solution, the following method is very ready, and of constant use in the laboratory relative to salts and similar substances, which are entirely soluble, and form a solution of sufficient strength without the application of heat. The substance should be put into a clean mortar, a little water be added, and by the action

of the pestle the solid matter reduced to a thin paste; this is done in a few moments, more water should then be added, and the whole stirred together, in consequence of which the finest particles will rapidly disappear. When upon continuing the trituration, the fresh portion of small powder which is produced does not seem to dissolve, the whole should be allowed to stand a moment, the fluid poured into a glass or jar, the residuum triturated, water added, and the process continued until the whole is dissolved. The solution when altogether should stand a few minutes, to deposit any minute particles that may not have been dissolved; or a little water added to it, and the whole agitated, when it will immediately become clear or nearly so. If there be occasion it should then be filtered, and in this way a solution nearly saturated, and always strong enough for ordinary laboratory uses, may be made in a few minutes.

350. This method of facilitating solution by mechanical division is very useful in numerous cases. If one substance be embarrassed or enveloped by another, it is thus more easily exposed to the solvent; and from the great utility of this practice, when chemical solvents are used, as acids or alkalies, arises the necessity of having mortars which are competent as before mentioned, to resist the action of these and similar substances.

351. The use of heat in assisting solution is very great, and though heat and division may in many cases be resorted to almost indifferently for effecting the required end, yet the student should understand that they attain the object in different ways, that he may know in peculiar cases when to apply the one and when the other. Division is favourable merely by increasing the surface of contact between the solvent and the body to be dissolved; thus offering an immense number of points where the action may simultaneously be exerted, and in this way bringing it sooner to a close: whereas heat acts directly by increasing the power of the solvent and enabling it to take up a larger quantity, and incidentally by causing a multitude of currents in the liquid, by which fresh portions are continually brought into contact with the body to be dissolved. Hence

heat does not merely expedite the action, and in that way do what comminution effects, but it does actually increase it, and cause a greater portion of the solid body to be dissolved than would otherwise be the case.

352. The simplest step in the application of heat is to obtain a solution saturated when cold. It would take a long time for instance, to prepare a saturated aqueous solution of white arsenic, by contact of the powder with water, or even by agitation; but by boiling the water with the powder for half an hour, leaving it to cool, and afterwards filtering it, a saturated solution will be at once obtained. The same is the case, though not so strikingly, with more soluble substances, as sulphate of potash, nitre, &c. and in these instances the object is generally effected by warming the pulverized substance with the water in an evaporating basin or flask, over a lamp or sand bath, or by using warm water with trituration in the mortar. With the exception of the two or three salts which are scarcely more soluble in hot water than in cold, the attainment of the object should be ascertained by observing whether the hot solution has deposited any portion of the solid substance during its cooling: if it has, it proves the saturation, if it has not, there is reason to doubt it, and heat with more of the solid substance in powder should again be applied.

353. An easy method of testing this point of saturation, even whilst the solution is hot, is to dip a glass rod into the liquor, and by means of it to transfer a drop to a cold glass plate: if a deposition of crystals or solid substance appear in a few moments, then the solution will be saturated when cold. If they do not appear immediately, still the student should not be satisfied, until he has stirred the drop with the platina spatula, and repeatedly struck the glass beneath the solution with the metal; this will frequently cause a precipitation of crystals to take place, which would not otherwise have appeared except in a long time, and they equally indicate that the solution when cold will be saturated. Ultimately the solution should be filtered, if necessary, to separate any mechanical admixture.

354. When the object of applying heat to increase the solvent power is not simply to obtain a saturated solution, but to accelerate a process which, either from the previous combination of the substance with other bodies, or the want of action at ordinary temperatures, would be tedious and imperfect, if not urged by all the means at command; the application has then to be continued for a longer time, and frequently in vessels which will retain the vapour more perfectly than a basin. The ebullitions and digestions which are sometimes continued for a long period, are processes of this kind, and the choice of the vessel will depend upon the circumstances attending the action. Basins and open vessels are convenient, because they afford ready access to the liquid, either for the purpose of removing portions for examination when necessary, or for stirring and agitation. For this reason, when the dispersion of a little vapour, or even of a little of the substance by ebullition is of no consequence, basins are very convenient, and they are necessarily used when the substances are operated upon in such a form as prevents their introduction into flasks. But when it is desirable to retain the vapour as much as possible, as whilst using acids, or when it is necessary that all loss from ebullition be avoided, or all possible contact of extraneous substances prevented, then flasks are most useful, and especially Florence flasks. Hence almost all solutions relative to analyses, if they require the aid of heat and occupy time, are most safely made in flasks. The selection of a basin or a flask in any particular case, must be left to the judgment and experience of the operator.

355. In these and similar cases, all sudden applications of heat, especially to glass vessels, should be avoided. A glass flask, unless it be very thin, when filled with a cold fluid and set suddenly in a hot sand-bath, is almost sure to break. If it be required to heat a basin in a sand-bath, the bottom should previously be dried, for if wet, the water by contact with hot sand becomes rapidly converted into vapour, which, causing a slight explosion, sometimes throws the sand into the vessel. The elevation of temperature is accelerated by covering the basin and preventing evapo-

ration. This is often conveniently done by putting a second basin somewhat larger over it, its cleanliness having been previously ensured. If the fire or sand-bath be such that it is advisable to obtain the heat as rapidly as possible, no fear of injury being entertained, then on putting down the basin it should not be set upon the top of the sand, or pressed down a little way only, but the sand should be removed with the iron spatula before mentioned (155) to the sides, the basin set down upon the bottom of the bath, or with only a very thin layer of sand intervening, and then the sand returned round the sides of the basin. The thickness of sand which may be allowed to remain between the bath and the bottom of the basin, must be left to the judgment of the experimenter, being proportionate to the heat of the fire under the bath, the previous heat of the sand and the quantity and nature of the substance to be heated. It is in general advisable not to heap the sand round the sides of the basin to a greater height than the solution inside, at least if the sand be hot, or likely to become so during the operation; for it then sometimes makes the part of the dish above the solution very hot, and when ebullition happens and raises fluid over it, the sudden change occasions fracture, or gives rise to the production of much steam, which endangers the boiling over of the contents of the vessel.

356. When a flask is put upon the bath, it should be sunk more or less deep according to the heat of the sand and the heat required, and hotter or cooler parts of the bath may be selected for the same reasons. Hence one advantage of the table-furnace before described (152) whose sand-baths present every required degree of temperature. If a situation be too hot for a flask, making its contents for instance, boil too rapidly, the heat is easily diminished by raising up the flask more or less, and allowing the sand to sink under it; this not only causes a thicker stratum of sand to intervene between the bottom of the bath and the flask, but also removes a part of the flask out of the sand altogether.

357. When a flask on the bath is to have its contents heated as rapidly as possible, it is frequently safer, instead of endeavouring to apply a stronger heat at the bottom to

prevent dissipation of heat above. This is very usefully effected by a tin cone about seven inches in diameter at its base, six inches high, and having a hole where the apex would otherwise be about an inch in diameter, through which the neck of the flask may pass. This case, slipped



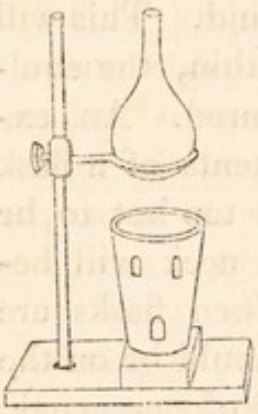
over the flask, and resting at its lower edge on the sand, forms a hot chamber round the upper part; the air within it actually assists at times to heat the flask and its contents, and in all cases materially interferes to prevent cooling. Even the space left open round the neck may be closed when desirable, by passing a piece of card with a hole cut in it over the neck, that it may rest on the upper edge of the cone.

358. When a flask in a state of ebullition on the bath, seems on a sudden in danger of boiling over, it should instantly be lifted up if possible, but at the same time the operator should blow from the mouth against that part of its surface which is above the level of the fluid. This will generally cause condensation of the steam within, the ebullition will recede, and the contents be secured. An expedient of this kind will often save the contents of a flask when the neck, from being full of froth, is too hot to be touched by the hand; upon its descent the neck will become cool, and may be laid hold of. When flasks are upon the sand-bath, a list ring (59) or two should be on the side, ready for the reception of the flask in case of emergency.

359. When a small charcoal fire or a lamp is the source of heat, the basin or flask has to be supported above it. This may be done either by a ring tripod, as delineated in the wood-cut, or by what are called retort stands. With the tripod the height is fixed, and hence the lamp or furnace may require elevating. For this and numerous other purposes of adjustment in the laboratory, the wooden blocks before described (16) are continually of use. Retort stands are sold by the instrument makers, and consist of an upright brass rod fixed on a heavy turned foot, and furnished with rings, which



being each fixed to an arm, and that to a socket, the latter passes freely up and down upon the brass rod, and is made tight at any particular height by a screw-nut at the back. In this way the facility is obtained of fixing the projecting rings at any height required, and as several of different sizes accompany each retort stand, vessels with globular bottoms, or indeed of many other forms, may be supported at any required height. It is easy by these stands to support the flasks or basins at the proper distance above the lamp or furnace. When from the weight of the vessel and its contents it is too heavy for the arm, or would cause the stand itself to tip over, then two stands may be used on opposite sides, the ring of one being placed under the other, and the flask or basin on the uppermost. These stands are generally made with small circular brass feet, filled with lead, but which still are insufficient to retain the whole upright when a heavy vessel is on the ring. It is much better to make the foot of a piece of stout board, about twelve inches in length, six inches in width, and an inch thick. The upright rod should be fixed about one inch and a half from one end of it, the lamp or furnace should be placed upon it, and the ring of course in a corresponding direction. Such an arrangement is perfectly steady, and cannot be overset by any weight which it is strong enough to bear. When the usual stands only are at hand, it may now and then be necessary to put on a second ring in an opposite direction to the first, and to add weights for the purpose of equipoising the whole.



360. When a crucible furnace is used, it should always be placed on a tile, and not immediately upon the wooden table or stand, lest, during a long operation, it should become heated to the bottom and burn the wood beneath. The tile also catches hot falling ashes or sparks, which would burn the wood, and facilitates the removal of the furnace in the hottest state without inconvenience. A lamp requires no precautions of this kind. When operating with flasks and retort stands, care should be taken that a

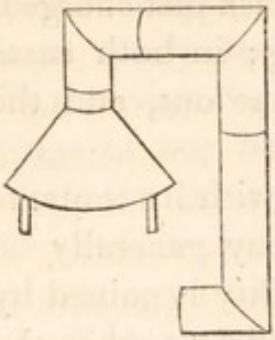
flask which with its contents has been heated, be not suddenly put upon a cold ring, and that a cold flask just charged, be not placed over the fire upon a hot ring; in both cases the bottoms of the flasks will probably come out, and the contents be lost.

361. When it is desired to keep a flask with its contents in a state of ebullition over a lamp, it may generally be effected by adjusting the flame. But a facility is gained by having the heat somewhat greater than is sufficient when the lamp is under the centre of the flask, and adjusting the effect by moving the lamp a little on one side. The application of the heat is smaller or greater in proportion as the lamp is removed from the centre; but at the same time being applied on one side, a cooling process goes on more decidedly at the other than before, and this, with the uniformity of the current established within, makes the whole operation more regular.

362. If the effect obtained by a lamp is hardly sufficient, and yet from circumstances is the most desirable source of heat, the tin cone (357) is then a very essential adjunct. When slipped over and allowed to rest upon the flask, it confines an atmosphere of very hot air about the upper part, by which the time of heating is shortened, and in many cases it assists in the attainment of a temperature which could not otherwise be acquired. The cone should be guarded at the upper part within either by a layer of thick paper, thin pasteboard, or some such substance, or by a ring of cork, to prevent the metal from touching the glass; a circumstance which might now and then produce fractures from difference of temperature. The exterior should be preserved clean and bright.

363. In many cases of solution, the vapours emitted either from their acid nature or noxious qualities, are highly injurious; whence it is desirable, as much as possible, to convey them away and to prevent their mixture with the atmosphere of the place. Hence the use of the large hood before referred to (7), which, receiving such vapours, conducts them into the flue.

364. A temporary moveable hood is a useful appendage to the table-furnace before described (152).



It consists of a cone having its lower diameter equal to that of the round sand-bath (153), supported on three short legs to rest within the edge of the bath, and opening above into a funnel-pipe, which by three bends at right angles, is made to terminate opposite the fire door. The pipe is conveniently formed in two or three pieces, the whole being of copper; the cone itself, and the pipe and joint above, may be made of copper, or very advantageously of stone-ware. When placed upon the sand-bath, with the door of the fire partly open, and the end of the pipe opposite the aperture, such a draught is occasioned through the whole as will carry off any fumes which may be liberated beneath it into the chimney.

365. The inside of a hood of this kind should be kept clean, to prevent the possibility of dirt falling from it into the vessels beneath. When the vessel is a flask, an additional security is obtained by covering the mouth loosely, either by inverting over it a short tube closed at one end and sufficiently large, or by placing upon it a convex fragment of old glass from a retort or flask. When the vessel is a basin, it may in some cases be similarly guarded by another basin, placed over it as before mentioned (251); when that cannot be done, the cleanliness of the hood should be particularly attended to.

366. When the contents of a flask evolve vapour spontaneously, or require but little heat to create them, the flask may be placed upon a listed ring (59), in an inclined position, and have its mouth directed to the ash-pit of the furnace: the draught will carry away the fumes whilst it is in that position, and at intervals, it may be placed for a few minutes together on the sand-bath. Where the spare flues exist, which have been before referred to (3, 151), they are very useful in carrying off vapour. The mouth of a flask brought near to one, will deliver all its vapours into the flue, and from the height of the latter, it is easy to arrange the flask, with its

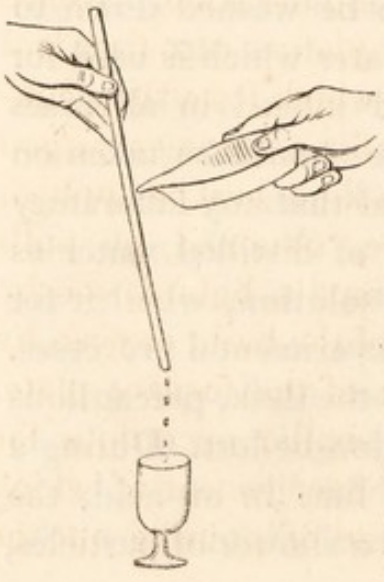
lamp or furnace, in a proper position. When the portable hood just referred to (364, 151) is adapted to the aperture of the flue, which may easily be effected when the pipe, as mentioned, is in two or three shifting pieces, nothing more can be desired; for so arranged, a good flue is competent to carry off all the fumes from any basin which the hood can cover. Where the table-furnace is favourably situated, as against the side of the laboratory, no difficulty occurs in using a piece of pipe, which may be put up in a moment, and connect a moveable hood over any part of the sand-bath, with the flues behind.

367. Besides these general directions for the process of solution, there are numerous precautions requisite to ensure accuracy when results of the utmost precision are required, as in cases of analysis; amongst which are the following. If the quantity of solid matter operated upon has been weighed, it is of consequence that not a particle be lost in introducing it into the flask, supposing such a vessel to be used. The experimenter should not venture to pour it into the neck directly from the glazed paper in which it may have been weighed (53), or from any vessel that may contain it, but should use a small clean funnel for the purpose. If dry, the powder will probably pass freely through it, without adhering to the glass; but before removing the funnel, it should be washed with a little water, which will carry down any adhering particles. If in passing through the funnel some of the powder has struck against and adhered to the inside of the neck of the flask, that should also be washed down to the bottom with a little water. The water which is used for these purposes should be distilled, and indeed in all cases where accuracy is required, equal care should be taken on that point. It is much to be regretted that any laboratory should be so far restricted in the use of distilled water as not to have sufficient for every case of solution, whether for refined analyses or the most ordinary experimental processes.

368. When effervescence happens in the flask, precautions should be taken that none of the solution be lost. During a cold effervescence, as of carbonate of lime in an acid, the breaking of the bubbles will throw up a shower of particles,

many of which will ascend several inches perpendicularly. In these cases it will be right to incline the flask at an angle of about 45°, for then the rising drops will meet with and break against the side of the flask, and be retained. At other times, when strong currents of vapour or gas are produced at the same time with this dispersion from the breaking of bubbles, many of the particles may be carried away by the current, even when the flask or vessel may be considerably inclined. In these cases, the addition of the acid, or the application of heat, should be made cautiously, that the current may not become so rapid or attain such power as to do harm. For the same reason, operations which are liable to occasion much effervescence, should be performed in flasks of the largest size, that the current of gas within may have less velocity, and that the particles may have room and time to fall.

369. Finally, on pouring solutions from glasses, flasks, or basins in the ordinary way, it is scarcely possible to operate so that, on ceasing to pour, and on returning the vessel to its first position, a small portion of the liquid shall not flow down the outside; or if successfully done once, there is no certainty that it can be performed whenever required. An effect of this kind occasions a loss of substance which when repeated is quite incompatible with the accuracy of analytical processes. It may be avoided however by very simple means. A clean glass rod is to be dipped into the solution to be poured, so as to have its surface at the end wetted, and then, the vessel being inclined, the rod is to be applied in a vertical or highly inclined position, so that its wet surface shall touch the lip or edge from which it is intended to pour. When by further motion of the vessel, the fluid at last runs over its edge, it will proceed down the rod, being conducted by it in any required direction. When a sufficient quantity has in this way been removed, the vessel is to be restored



to its first position, the rod not being withdrawn until the fluid is decidedly below the inside edge; all that is without will be confined to the surface of the rod, not a particle having flowed down the outside of the basin. The rod may be left in the solution until a fresh portion is to be poured; or if no more be required, may be washed by a little water from the dropping bottle, which being added to the original solution, prevents the loss of a single particle of the substance contained in it.

370. This application of the rod is not merely useful in preventing loss or waste, but also in conducting the fluid when other means are wanting. A solution or liquid of any kind which wets the rod, may be poured very accurately and securely into a narrow-mouthed bottle by it, if a funnel be not at hand, and occasionally it even surpasses the funnel in convenience. Thus in pouring successive small quantities of a valuable fluid, a rod enables it to be done safely, and at the same time with considerable minuteness, by allowing a very small stream to flow from its end, the vessel being in contact with the rod, but a little way above it; between each operation of pouring, the rod is conveniently and securely placed in the fluid. With a funnel a much larger surface is moistened, which drains for some time after, and the quantity is by no means so well estimated as by the former method: neither in the intervals of pouring is the funnel so conveniently disposed of as the rod.

371. The operations which have been described have frequently to be performed on a very minute scale. Hence the use of small earthenware dishes, platina capsules, and especially fragments of broken flasks, which from their concave form are exceedingly convenient for experiments upon drops of fluids. In operations of this kind heat is applied, either by a small spirit-lamp flame, obtained by pulling down the cotton before the lamp is lighted, or by touching the glass with the hot sand of the bath, or even by letting it stand upon the hotter part of the furnace plate. Instead of flasks, tubes are used in similar operations for making minute solutions, the general management of which will be described in Sect. xvi. Instead of pouring out the

fluid, it has now to be transferred in portions, each less than a drop, and this is best done by dipping a glass rod into the solution, and then, whilst more or less adheres to it, according to the quantity wanted, to touch a clean glass plate or a piece of a flask with it, and allowing the adhering portion to run down. If but little be required, only a small length of the rod should be dipped in, and if still less be required, even that small portion should be allowed to drain for a moment or two, before it is brought into contact with the substance to be moistened. On the contrary, if a large quantity be wanted, two or three inches of the rod should be dipped in, and the adhering fluid quickly transferred to the desired place; or if the most be wanted that the rod can lift, it should, upon dipping it, be taken out horizontally, and carried adroitly in that position to the place required, taking care by slight but proper motions of the rod, to prevent such accumulation of the fluid in one spot as to cause a drop. By these means a glass rod may be made to carry very different quantities of fluid, affording great facilities in the practice of minute chemistry.

372. There is an instrument which cannot be dispensed with in the laboratory, and which in the order of our arrangement first comes into service in the present chapter—it is the dropping-bottle. Its use is to supply small quantities of water, and the laboratory should be furnished with two of them, one to deliver large and rapid drops, or a small stream, the other to supply very minute portions for such experiments as those just referred to. The larger one may be a bottle holding about half a pint, and should have a good cleanly-cut cork fitted into its mouth. A piece of strong glass tube, of an internal diameter not more than the eighth of an inch, should be selected and drawn out, so as to have a contracted aperture, which at the same time should be bent on one side; the piece of tube should be about two and a half inches long, and fitted tightly into the cork, its extremity not passing inwards beyond the cork; and it is an advantage that the surface of the latter should be slightly concave or conical,



as in the accompanying section. Lastly a notch is to be cut in the side of the cork, diminishing from above downwards, so that when the latter is in its place the notch may form a passage into the bottle, with a narrow opening at the inner surface. This slit is to be on that side of the cork from which the upper extremity of the tube inclines. The bottle is to have distilled water put into it, and being then placed in different positions, it will supply a stream of water variable in its quantity at pleasure. If inverted, it will be found that a small stream will flow out at the beak, and a current of air enter at the notch to supply its place. If the bottle be inclined, keeping the notch uppermost, the stream will not be so rapid, and in consequence of the diminished perpendicular height of the column of water tending to descend, occasioned by bringing it nearer to a horizontal position, the stream will at last break into single successive drops, which by a still further motion of the hand, also cease to fall. If a small portion of water be required to make a solution, it is readily supplied even to single drops, and smaller quantities are easily lifted and transferred as before described, by a glass rod. Or if a stream be wanted to wash the solution from a rod or a funnel, or to wash out a glass, it is instantly obtained. By allowing the stream or drops to fall from a greater or smaller height, variations in the descending, and consequently washing force, are produced; this may even be increased occasionally, by a downward jerking motion of the hand, which will throw out forcible independent jets of water.

373. It is proper to have a smaller dropping-bottle ready for use, because, from the infinite variety in the quantities to be operated upon by the chemist, such an instrument will at times be found advantageous. By making the tube smaller, a similar set of capabilities to those just described with a smaller stream of water are obtained, and a minute quantity of a rare substance of which it is desired to save every atom, may be operated with, yet without more dilution than is absolutely necessary.

374. The selection of solvents for particular substances is an important point, which must however in a great measure

be left to the judgment and knowledge of the student. If the object be to ascertain the properties of a substance by working with its solutions, water should be first tried. If it have no action, alcohol may be used, and after that ether, pyroligneous ether, and finally, on some occasions, oils. As a general rule, those solvents are to be preferred which are evaporable, and may therefore be dissipated by heat, and which at the same time least affect the chemical powers of the substance to be dissolved. In these properties and in economy, water surpasses every other body that can be used.

375. Mixtures of water and alcohol are frequently useful, where neither water nor alcohol alone is applicable. Thus if muriate of soda and sulphate of lime were mixed together, the muriate is best dissolved by water; this however would occasion the solution of a portion of the sulphate of lime, whereas by a mixture of one part of alcohol and two or three parts of water, a solvent is produced which will separate the former salt and reject the latter.

376. When an aqueous solution of a vegetable substance has been made, which on examination is found to contain different substances, some soluble in alcohol and others not (and there are few infusions of vegetables that do not yield such a mixture), it has to be subjected to the action of alcohol for the purpose of effecting a separation. The first step is concentration by evaporation; but it is adviseable not to carry this to dryness, or as far as may be without injury to the substance, and then to act by alcohol, for generally a soft mass is obtained, upon which alcohol acts only imperfectly except in a long period, because the last portions of soluble matter are protected by the mass of insoluble substance. It is better to suspend the evaporation when the substance is a thick fluid, and then to add a small quantity of alcohol; which, although it will cause a partial solution and partial precipitation at first, will, upon being stirred, mix with the fluid, and be overpowered as it were by the water still remaining, so that the precipitated portion will be redissolved, and the whole again rendered fluid. This should be repeated twice or thrice, stirring each time, and keeping the mixture of uniform consistency; a precipitation will gradually take

place, increasing as the proportion of alcohol is increased. The particles thus rejected as insoluble will be perfectly free from any mixture of substance soluble in the alcohol, and thus a ready solution of the one part, and its separation from the other, may be effected. The quantity of alcohol added, must be such as at last to surpass by many times the quantity of water left at the close of the evaporation, otherwise its powers will be diluted, and a complete separation of that which is soluble from that which is insoluble will not be obtained. Hence the evaporation should be carried as far as possible, so that the residue be fluid and will mix readily. If it be so thick that it clots upon adding the first portion of spirit, a few drops of water must be added. The solution should be in such a state that the first portion of alcohol, equal to about a fourth of the bulk, should cause precipitation, which disappears upon stirring; the second portion cause a turbid liquor after stirring; the third, an increase of turbidness but still no clotting; the fourth, when an equal volume has been used, a separation of the precipitable part in softer or harder masses. When three or four times the volume has been added, it will generally be found that the separation is complete.

377. Some of the acids frequently act as mere solvents—their power apparently not being due to any combination effected between them and the substance by which a change of character is produced. Thus acetic acid dissolves caoutchouc, and acetic, nitric, muriatic, and some other acids, dissolve phosphates and borates. Muriatic acid dissolves sulphate of lead, and to a slight degree muriate of silver, and many other such actions will be observed in the course of experimental investigations, all of which should be remembered, and may in turn be put to important uses.

378. When acids and other energetic chemical substances soluble in water are used, either as simple solvents or as producing compounds by combination, attention should be paid in their selection to certain general advantages which each possesses. Nitric acid is distinguished as a chemical solvent by the solubility of all the salts which it forms; by its imparting oxygen to metals generally, so as to bring

them into a soluble state; and by its ready separation from all its compounds at a sufficiently high temperature,—three circumstances of very great importance. When used, care should be taken that it is sufficiently diluted: very strong nitric acid will sometimes seem to have no power over a body at common temperatures, when upon the addition of a little water, action will immediately commence. This circumstance never occurs with acid which has been diluted with one half its bulk of water. Any further dilution therefore can only be required to moderate chemical action, and not to commence it. Muriatic acid yields salts generally soluble, though some of them are but slightly so; and muriate of silver not at all so in water. Many of the resulting compounds are fixed at a red heat, some few sublime, some are decomposed. The muriatic acid has the advantage of being separated from the bodies it has taken up by solutions of silver. Sulphuric acid forms many insoluble salts, but it has the advantage of being removed readily by solutions of barytic salts. The circumstance of its producing insoluble salts makes it valuable as a chemical solvent for those bodies with which it combines and remains in solution, inasmuch as it causes their separation from the others. Hence it is frequently added to solutions made by muriatic and nitric acids, and displacing these, they are afterwards separated by heat. It should not be used in its concentrated state, but more or less diluted, or the same effect will occur as with nitric acid. Acetic acid forms soluble salts with all the substances with which it combines, and it may be burnt off by heat, with access of air.

379. When an alkaline solvent is required, ammonia, if effectual, is most convenient, because of its ready volatility and dissipation when uncombined, and the volatility of all its ordinary salts, except phosphate, borate, and those containing metallic acids. When ineffectual, the fixed alkalies must be resorted to.

380. It is necessary that the student be on his guard respecting certain variations in the solubility of bodies arising from the presence of other matters. He will continually find that small portions of substances generally considered as

insoluble in water will remain in neutral solutions when some other substance is present, or because of slight mutual decomposition; and he will also frequently find that matter usually considered as readily soluble, is so with difficulty when in contact with substances with which it is not apparently in combination. Thus water boiled upon muriate of potash and phosphate of baryta will be found to contain more baryta than if boiled alone upon the phosphate; and on the contrary, if oxide of iron and alumina be precipitated together from a solution, it will be found much more difficult to dissolve the alumina by solution of potash than if it had been thrown down alone.

381. The alkaline earths are remarkably soluble in solutions of sugar, and also, though to a less degree, in solutions of extract and other vegetable matters: hence they are retained in solution at times in very unexpected situations, and might give rise to much uncertainty in the appearances and characters of other substances, unless the experimenter were aware of the fact. Platina is not itself soluble in nitric acid, even when spongy and in its most comminuted form, but when alloyed in small quantities with metals dissolved by that acid, it becomes soluble with them, and in consequence appears now and then in situations where it is not expected. Tartaric acid or tartrates have an extraordinary power in rendering many metallic oxides soluble, which are not so by other acids without it; and still more in holding them in solution when such substances are added as in ordinary circumstances effect their separation. The oxides of bismuth, antimony, tin, and titanium, are easily dissolved by acids when tartaric acid is present; and being present, ammonia no longer has the power, upon its addition, of separating the oxides of iron, titanium, manganese, cerium, cobalt, nickel, lead, antimony, and the earths, alumina, magnesia, and yttria, from their solutions, and in certain cases even potash or soda fail so to do. Great advantage may be taken of this property occasionally, but sometimes it is equally disadvantageous in preventing the usual action of re-agents.*

* Annales de Chimie. xxiii. 356.

382. A very numerous class of aqueous solutions is produced by metallic salts. These, in consequence of the varied quantity of oxygen with which many of the metals can combine, are susceptible of changes dependent upon the oxygenation of the metal whilst the state of solution is continued. These changes are eminently useful in fitting the solutions in one way or another for experimental purposes. If the object be to oxidize the metal, whether to render it soluble, or for any other purpose, the agents to be employed are the acids generally, nitric and nitromuriatic acids especially, chlorine and chlorate of potash, and in some peculiar cases even alkalies. No metal will dissolve in water or an acid until it is combined with oxygen, and in obedience to this law sulphuric and phosphoric acids, and perhaps muriatic acid, frequently cause the decomposition of water for the oxygenation of the metal. Nitric acid is often decomposed, supplying a portion of its own oxygen to the metal with which it is in contact. Proto-salts in solution are frequently converted into per-salts by it, and also by nitro-muriatic acid and chlorine. A proto-sulphate, muriate, or nitrate of iron, may be converted into a per-salt by a little nitric or nitro-muriatic acid and heat; and a proto-nitrate by heat alone. The same agents are equally effectual in converting proto-salts of tin into per-salts. In these cases of conversion care should be taken that no acid be added that will interfere with the future experiments, or that may not be dissipated by heat.

The influence of alkali in causing oxygenation may be observed by putting a little oxide of chrome or a salt of chromium into a solution of alkali, so that the latter may be in excess; by evaporation to dryness in a platina capsule, and heating the mixture with access of air the oxide of chrome will absorb oxygen, and become chromic acid, through the influence of the alkali, with which it will ultimately combine.

383. If deoxidizing agents be required for the metal in solution, then an efficient one is most likely to be found amongst such bodies as alcohol, ether, sugar, gum, &c. Of the known metals, per-salts of manganese are reduced to the state of proto-salts by being boiled with alcohol or ether,

and become quite colourless: solutions of platina and palladium are actually reduced by boiling with alcohol. The per-oxides of lead and manganese, when mixed with any of the bodies enumerated and an acid, are reduced to the state of protoxides, and dissolved if the acid be such as to form soluble salts. If a chromate have excess of acid added to it with a little of any of the same substances, and be heated, it loses oxygen and becomes oxide of chrome, which, with the excess of acid, forms a salt. These facts are mentioned generally rather than particularly, that, being combined with the pupil's previous knowledge, they may assist him in surmounting a difficulty, and in devising the most expedient process by which he may attain his objects. The processes of analysis and research require to be so infinitely varied under different circumstance, that every possible action and every expedient is necessarily resorted to in turn to enable the experimenter to proceed.

384. The general principles and directions given with respect to the solution of inorganic matter, will apply to a great extent to that of organic substances. The few differences that occur depend upon the situation of the matter to be dissolved, and upon its destructible nature. The active principles to be separated are generally in small quantity compared to that of the inert enveloping substance, and the latter is often easily affected by powerful agents, such as acids and alkalies, and converted into bodies which, though useless, are soluble, and would contaminate the solution. Hence it is necessary to select such agents as, at the same time that they act with energy on the principles to be dissolved, have no power over the accompanying matter. Acids and alkalies are therefore objectionable. Indeed a still more cogent reason exists for their rejection in general, namely, a reaction upon and destruction of the peculiar principles themselves. Hence a frequent recurrence to such solvents as water, alcohol, and ether, either cold or aided by heat, and if acids or alkalies are used, they should be diluted and applied only after the other solvents have exhausted their powers, or in the separation of known principles to which their action is favourable.

385. M. Robinet has lately recommended the use of neutral saline solutions in particular cases,* stating that a separation of principles may be sometimes effected by them, where water dissolves the whole, or acts only imperfectly.

386. The original vegetable or animal substance, if dry, may be rasped or bruised (309, 332), so as to be divided into small pieces, but not generally into powder. If the action required be but short, hot water poured over the substance in a basin may be sufficient: but if a longer time be required, the mixture must be retained in a sand-bath, or over a lamp, as before. When hot water is merely poured upon the substance, the process is named *Infusion.* When the heat is continued for some time by the application of fire, *Decoction;* and when it consists of pouring cold or warm water on the substance, and allowing it to stand for some time, it is called *Maceration.*

387. A very excellent and useful process of solution is called *Lixiviation.* It is applicable only to such substances as, from their porous nature, are permeable to water, and consists in the separation of a soluble body from an insoluble one by washing, For this purpose the mixture is to be loosely arranged, and water added till it fills all the cavities, and covers the surface of the mass. In the laboratory it may be conveniently performed in the small way in a funnel, and shall therefore be so described. Suppose it were necessary to wash salts from a quantity of ashes: a funnel of sufficient size should have the lower aperture stopped by a cork, and should be supported on a stand, so that it may steadily retain its proper position. A few pieces of the ash, of such size that they shall not pass through the neck of the funnel, should be introduced in the first place, to prevent the descent of the matter to be placed over it. Having added pieces rather smaller, until the surface exposed in the funnel is an inch in diameter, the rest should be crushed in a mortar to a coarse powder, or rather to small pieces or grains, and put into the funnel above that previously arranged: if the substance be such that it will not afford lumps of suf-

* Annales de Chimie. xxx. 208.

ficient size or strength to remain in the neck of the funnel and support the rest, then its place should be supplied by some pieces of broken glass, which may be continued to the height before mentioned, and which, while they support the substance, afford abundant passages for the fluid when required. Being thus far arranged, hot or cold water is to be poured into the funnel according to circumstances, its quantity being such that it will just cover the mass. The whole is to be left in that state for a time proportionate to the solubility of the substances present. The water which has penetrated the fragments will gradually dissolve the salts, and forming a heavy solution, will descend in the free spaces, changing situations with the water not yet saturated. In this way a solution will be produced of much greater strength below than above, and the upper part of the mass will be washed almost perfectly at the first operation. When sufficient time has been allowed, according to the quantity and nature of the salt, and the manner in which it is enveloped, the cork beneath should be withdrawn, and one-half or two-thirds of the solution suffered to run out gradually, not hastily, lest greater disturbance of the solid matter in the funnel be occasioned than is necessary or advantageous. The cork is to be replaced, fresh water added above, so as not to disturb the arrangement: and being left as before for a time, the second solution should then be withdrawn, and this operation repeated till the water which passes is perfectly free from salts, or contains so little as to make further attention unnecessary.

388. As before remarked, this operation can only be performed on such substances as permit access of water to all parts. When the particles fall together, or adhere slightly, and so prevent contact of the water, and choke up the channels, then recourse is sometimes had to the intermixture of inert matter, as hay, straw, coarse sand, or broken glass; but it is better in such cases, when they occur in the laboratory, to put the substance into a basin or glass with excess of water, and by agitation every now and then, effect the solution in the usual way.

SECTION VII.

Distillation.—Sublimation.

389. Distillation and sublimation have the same object and require the same means; both consist in the conversion of a body into vapour, its transferrence in that state, and consequent separation from other substances, and its ultimate condensation. The difference generally consists in the state assumed by the vapours when condensed; if the product be solid, the process is called sublimation; if liquid, distillation. All that is required is, that the substance to be distilled or sublimed, should be raised to such a temperature that it will assume the gaseous form, and in this form conducted into a receptacle of such temperature, as to cause its resumption of the fluid or solid state.

390. Simple as is the process in theory, there are few that are liable to greater variety of arrangement. The range of temperatures at which different bodies rise in vapour is very extensive; for sulphurous acid or chlorine assumes that state at temperatures below the freezing point of water, whilst mercury or zinc require one verging upon, or even surpassing, a red heat. Thus on the one hand very low temperatures are required to effect condensation, and on the other very high ones to cause the requisite vaporization. The vessels and the apparatus to be employed must not only be adapted to these points, but also effectually to meet the innumerable varieties in the quality and quantity of the substances operated upon.

391. The common still will serve best to exemplify the ordinary points requiring attention in the process of distillation. It may be used both for water and alcohol, and if the laboratory be not otherwise supplied with distilled water, must continually be had recourse to for that necessary article. The still consists of a metal boiler to contain the water to be purified; to this is adapted a head, which ter-

minates in a beak, and the latter is made to fit into the commencement of a spiral tube called the worm, fixed in a tub, the whole of this part being called the refrigerator. The process consists in raising the water into vapour in the still, and condensing that vapour in the worm; the condensed water runs out, and is received at the lower extremity, which ought in all cases to be left open.

392. It will be necessary to preserve a sufficient fire under the boiler during the distillation, not merely to produce ebullition, but also to cause the water to boil rapidly, so as to afford a quick succession of vapour, otherwise the operation will be very tedious. It is important in all cases to keep the top of the still hot, or the vapours will condense there, and flowing down the sides to the water below, will be again vaporized, and cause great waste of heat. For this reason it is useful when the top is exposed to the air to cover it with a dry cloth, this precaution being continued to the descending part of the beak or pipe. It is also necessary to observe that this pipe be sufficiently capacious for the passage of the steam to the condenser without any obstruction: every thing in this part of the apparatus should be arranged so as to generate vapour with great rapidity, and to convey it with corresponding readiness to the worm. The student must not forget that as the water is distilled, its quantity will diminish in the vessel, and should be replenished before any injury is occasioned from its deficiency.

393. The vapour having reached the worm is there to be condensed; and the worm is put into a tub and surrounded with cold water, the low temperature of which causes the substance to lose its elastic form, and flow out in the liquid state. From the quantity of heat communicated to the refrigerating water, which is greater as the operation is more successfully carried on, it will become necessary to change it readily and quickly, and many contrivances have been resorted to for this purpose, amongst the best of which are those that supply a constant stream of cold water to the bottom of the tub, and draw off an equal quantity of hot from the top. Whatever the arrangements are, the water must never be allowed to become hot, or if it does so

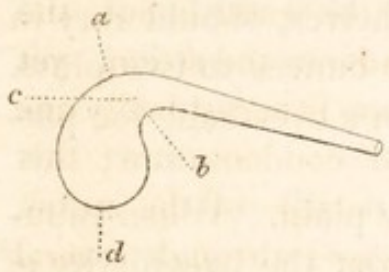
at the surface, it should be but moderately warm at two or three inches beneath; for although in some cases it may happen, that when the upper half of the water is hot, the lower half may still be sufficient to condense the steam, yet inconveniences often arise. Amongst these is occasionally one of more consequence then mere failure of condensation; this is, the obstruction occasioned to the passage of the steam, when it has to force its way uncondensed through several coils of small hot pipe, and which at times may rise so high as even to lift off the head of the still. As before mentioned, any obstruction to the free liberation and condensation of the steam, interferes with the effectual working of the still, and causes a consequent loss of heat and expense of fuel.

394. The water which flows out at the end of the worm, should never be more than warm. It may be received and preserved in stone bottles, and should always be tested that its purity may be known. The end of the worm should not be allowed to dip into water, so as to close the aperture, as in that case from irregularities in the liberation of steam, much agitation is now and then produced, and at a moment of inattention the water which has been distilled may actually return back into the boiler, from a partial condensation there.

395. The vessels in which most laboratory distillations are effected, are retorts and flasks. Retorts are of every size and shape, and of very various materials; those made of glass are equal to all operations which may be conducted at temperatures less than that at which the glass softens, and by luting may be used at much higher. They admit of constant observation of the materials within, are acted upon or injured by very few substances, and may be cleaned, generally, with facility. Their great point of failure is that of brittleness, which endangers both the apparatus and its materials.

396. With regard to the general form of glass retorts, it is not of any very great consequence, as regards their use in distillation and sublimation: they will be wanted with necks of very different lengths and dimensions, and with bodies of various proportion as relates to the necks; the

general proportions may be nearly those of the accompanying figure. But the case is different when they are required for exhaustion, as in numerous pneumatic experiments; for having then the pressure of the atmosphere to support on their exterior surface, their form should be carefully attended to. Retorts that are carelessly bent in the making, are liable to two imperfections of form, which frequently weaken them so much, as to render them unable to bear exhaustion; the one is a flattening of the convex surface at *a*, and the other is a sharp fold or double in the glass at the opposite part *b*, which expands the two sides (as at *c*), so that a section made through those parts would have a resemblance to a long flat ellipsis. Such a shaped retort will rarely bear the pressure of the atmosphere on the flattened parts, but will crack during exhaustion at *c* and the opposite corresponding side, or will be shattered and crushed to pieces. Retorts should therefore be generally chosen sufficiently convex in all parts, the degree of curvature of one part passing gradually into that of the neighbouring portions, as is represented in the figure. Such a retort, though very thin, will bear exhaustion with perfect safety; and that a sufficient number may be on the shelves when required, let *all* be selected with a view to such an application.



397. With regard to thickness, retorts should be examined as directed for glass flasks (346), the bulb should be uniform, or nearly so, throughout: if there be any difference, the part at *d* should be thinnest, gradually thickening to the neck. All should be rejected, of which the part at *d* is thicker than elsewhere, the application of heat being almost sure to break them. The general thickness should be that of flasks of about the same capacity, except that small retorts are better rather thicker in proportion to their size, or even, occasionally as thick as the large ones, because they are more frequently subjected to temperatures, at which glass becomes soft. All retorts with spots or grains of sand, in the part

to be heated, should be rejected; they are liable to fly at those places.

398. The sizes of retorts, on the shelves, should vary in the capacity of their bulbs, from two ounces to two pints. A few large ones may be at hand, on a bye-shelf, for particular uses.

399. Retorts are either tubulated or plain. When tubulated, they are more likely to crack from the irregularity of form and thickness of glass at the juncture than when plain; but, being very convenient in particular cases, by allowing easy access to the interior of the retort, some will be required. The aperture should be in such a position as to open into the body of the retort freely, admitting a funnel or a rod into it without interfering with the neck, and yet as little beyond the curve where the neck commences as possible. The tubular is safest when it is not much thicker than the retort at the part where they join, but should thicken upwards, and be sufficiently strong to admit of having a glass stopper ground into it in a tight and secure manner. When the tubulars are put on like a thick knot of glass, they soon break off, and the retort is of course destroyed.

400. In all cases where ground glass stoppers are used, and they are very numerous, though this of the tubulated retort is the first we have arrived at, they should be examined, and the accuracy of the grinding ascertained. They should be so ground as not to be liable to fix and become immovable, and be so accurate as to remain air tight for months and even for years, when a little pomatum, or rather, hard tallow is put round them. A stopper should be slightly conical, so that when introduced, it may at once obtain its place, and bear on every part of the ground surface. Being moved round in its situation, it should feel perfectly steady and firm in the aperture, in every part of the revolution; and more accurately to prove the regularity in the hole and the stopper, by which they come in contact in all parts, the stopper should be pressed sideways in different directions, and in different parts of the revolution,

to find out, if possible, any one position in which it shakes a little in its place ;—none such ought to occur. This ascertained, a little tallow should be put upon the stopper, both that and the aperture being clean and dry, and being then again introduced and turned round, a film of the tallow will intervene between the two surfaces of glass, which at the same time that it occasions perfect freedom of motion in the stopper as regards its turning round in the hole, does not at all render it less firm and steady in its bearing than before; and it perfectly closes the passage so that no portion of liquid or of gas can pass between them.

401. Finally, with reference to the state of the retort, it should be observed, that no retort when once cracked in any part near the bulb, should be used in cases where heat has to be applied to liquid contents. Their use must then be confined to cold operations, or to sublimations in unimportant experiments.

402. A student has many points to attend to relative to the charging of retorts, or the method of introducing substances into them. If a substance in the state of lumps or of powder is to be put into a plain retort, and it is required that the neck be preserved in a clean state, the best preparatory step is to insure the cleanness and dryness of the retort, so that no portion of the substance shall have any tendency to adhere to the glass. If it be a powder, it should fall down one side of the neck, being introduced, if there be occasion, by a small clean funnel, (367). It should not be thrown down in a careless way, while the neck is held in a perpendicular position. By holding the retort in an inclined position, the powder is less separated, and adheres less to any part of the internal surface. If it be in lumps, they should be made to slide down one by one, the neck being inclined at an angle of 40° or 45°. If held more upright, or the pieces be heavy, there is a probability of their passing through the retort by their momentum. The retort must not be held with the bottom of the bulb downwards, for then the pieces as they pass from the neck will fall suddenly upon, and almost certainly break it; but it must be turned

half way round, so that as the piece descends it may pass over that part which, when the retort is in its right position, forms its internal upper surface. In this manner masses of metal and other heavy substances may be introduced without endangering the vessel. When the retort is tubulated, precautions relative to keeping the neck dry and clean are not so necessary, because there is no occasion for soiling it. The powder may be introduced by a funnel as before, and even washed in with a little water (367), and masses may be introduced also at the tubular, not dropping them, but allowing them to slide in safely.

403. No instruction is necessary for the introduction of liquid, if a little waste, or the soiling of the vessel, be unimportant points; but when either of these are of consequence, the student should be acquainted with the methods of avoiding them. If the neck is to be preserved clean, as is often the case when acids are introduced, the end is easily obtained with the tubulated retort, by the use of a funnel with a beak so narrow and long, that it may pass into the body of the vessel. A few moments should be allowed for the funnel to drain, and it should at last be drawn out adroitly immediately after a drop has fallen, and before another is ready to descend; and during its removal the wet beak should be held so steadily, as not to touch the side of the tubular.

404. If the retort be not tubulated, then a funnel with a long narrow beak, sufficient to pass down the neck of the retort, and to reach the bulb at the end, must be used; or if such a funnel be not at hand, and the case is imperative, a piece of glass tube rather longer than the neck, may be employed for the purpose, the fluid being carefully poured down the interior of the tube. In using this long-necked funnel or the tube, care should be taken that the end do not dip into the fluid already in the retort, for the exterior should be preserved clean and dry, that its removal may be effected without soiling the neck. For this purpose, when the funnel or tube has drained a few moments, it should be inclined with the retort, until the neck is nearly in a horizontal position, or even has passed it a little; that which was the lower end

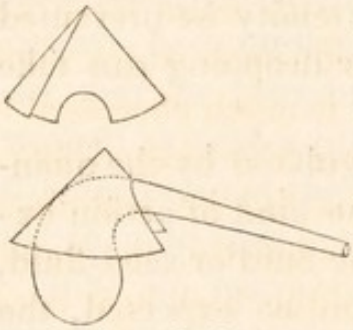
will now be the upper; and the fluid, still adhering to the inner surface, instead of flowing as before to the extremity, and gathering there in a drop, will tend to return upon its former course, leaving the end almost dry. In this state the tube or funnel may easily be withdrawn from the retort, without any risk of soiling it, if its extremity be prevented from touching the glass; for no further dropping can take place.

405. The size of a retort must be regulated by the quantity of substance to be used, and by the kind of action expected to take place. If the contents be fluid or semi-fluid, and the liberation of gas, or ebullition be expected, the charge should not occupy more than one-half or one-third the capacity of the bulb; or if the action be likely to be rapid, not so much: but if no expansion or swelling take place, nor any commotion by which particles may be thrown over; or if, in other cases, although portions are liable to be thrown into the neck, it be desirable to act on as much of the substance introduced as possible, the charge may then occupy much more of the body of the retort.

406. The general methods of applying heat to glass retorts, is the same with those adopted for heating flasks (355, &c.); and the spirit lamp (176—181), hot air (246), water, steam, and sand-baths (236. 248. 355. 156), oil lamps (188. 359), and small crucible furnaces (359), may all be used in turn with the precautions before given. Sometimes a little variation is required, dependant upon the following circumstances. In certain forms of distillation the heat is applied merely to excite and increase chemical action; this is the case in the production of several gases from mixed materials; and in such cases, when the temperature has attained the necessary point, the application of heat must be diminished, until it is merely sufficient to preserve the temperature already acquired. In other cases a greater resemblance exists to the process of distillation already described (391), and it is required not merely to allow a certain temperature, but to communicate heat for some time with more or less rapidity, that the liquid in the retort may be converted into vapour, and carried over. Hence the necessity

of a command over the fire, so that it may be increased or diminished at pleasure.

407. The oil lamp is of great service in chemical distillations from its ready management, but sometimes scarcely yields heat enough for the performance of quick operations. In such cases the upper part of the retort should be covered, to prevent its being cooled by contact of the air, and this can often be effectually done by a thick paper or card-board cone, with a broad notch to admit the neck; this interferes with a ready change of the air at the top of the retort, and saves much heat, which would otherwise escape at that part from the condensation of the vapour within.



408. The evolution of vapour is in many cases very much facilitated by the addition of substances having apparently no chemical action, and the process of distillation is not only thus facilitated, but rendered possible and easy, in cases where otherwise it would be almost unattainable. If diluted alcohol, spirits of wine, or certain alcoholic solutions be distilled in glass vessels, the vapour frequently seems to be evolved with difficulty, the contents of the retort at one moment not boiling at all, and at another bursting throughout into a mass of vapour and fluid, which fills the whole body of the vessel. This endangers the sudden expulsion of part of the contents, causing serious derangement of the process, and is also accompanied with such agitation of the fluid, such bumping and shaking of the retort, as at times actually to endanger the safety of the whole: for when the vapour is evolved, it is with such force as to produce a dull explosion. This is prevented by the introduction of a few angular or fragmented pieces of solid matter into the retort, of such nature as not to be acted upon by any of the substances present. A piece of platina foil cut by scissars into narrow slips, so as to resemble a fringe, or seven or eight inches of silver, platina or copper wire pressed up loosely, or platina and silver filings, are then very useful. So also is a fragment of cork or a piece of torn cartridge

paper, any of which will generally cause the regular and tranquil evolution of vapour, and occasion the distillation to proceed quietly and satisfactorily.

409. The same effect takes place with sulphuric acid when distilled in glass vessels, but from the weight of the fluid and the high temperature employed, with more force and more danger to the retort. The ill consequences which would result from the fracture of the vessel, is much encreased by the highly corrosive power of this substance at exalted temperatures. If however a piece of platina foil be introduced into the retort, the operation proceeds quietly, the vapour rises readily, and with the exception of the high heat necessary, the distillation goes on as freely as that of water.

410. The student should be cautioned against the sudden introduction of these promoters of vaporization, whilst the fluids are hot. If upon the occurrence of bumping during a distillation of alcohol, sulphuric acid, or any other fluid, in glass vessels, a piece of any one of the substances mentioned were suddenly introduced by the tubular, it is probable that the burst of vapour would be so instantaneous and strong, as to do more harm than the bumping itself. The safer method is to remove the source of heat for a moment, then opening the tubular to introduce a platina wire, letting it touch only the surface of the fluid at first, and introducing more of it as the ebullition occasioned by it ceases; when that is over, the wire should be withdrawn, the cork, the platina, or whatever, according to the nature of the fluid within has been selected, be introduced, the stopper closed, heat applied, and the distillation proceeded with.

411. The effect of these promoters is best observed upon sulphuric acid. If two or three ounce measures of strong sulphuric acid be put into a clean glass flask and heated over a small charcoal fire, as soon as the acid begins to boil, it will exhibit the irregularity described. The foil is then to be dropped in, and its power in creating vapour will be sufficiently visible. Sulphuric acid will boil several degrees lower in a glass vessel containing a piece of foil, than in one not so assisted. Professor Oersted has stated, that the introduction of brass wire into brandy very much accelerates

the process of distillation; * and Dr. Bostock has noticed similar effects with regard to ether. † For these and other facts I must refer to the authorities quoted beneath.

412. The products evolved in distillatory operations may be considered generally as of two kinds; vapourous, or such as may be condensed at ordinary pressure by the low temperatures we can command; and gaseous, or such as resist these means, and hence have been called permanently elastic. Since the general relation of gases and vapours to each other has been confirmed by experiment, this distinction is known to be very unscientific, but it is convenient in operations, and being generally retained in chemical language, there can be no objection to it in this place. The operations of distillation here verge upon pneumatic manipulation, but as in consequence of the peculiar means required for the retention and transferrence of that form of matter, all processes relative to gases will be more conveniently considered together; the further directions in this chapter will be confined entirely to such operations as relate to condensible substances.

413. Retorts being used for the purpose of raising substances into vapour, receivers become necessary for their condensation. Receivers are vessels which perform a cooling as well as a retaining office, and are as variable in their kinds as retorts. Sometimes a simple tube is used, at others flasks, globes, and bottles; these receive the vapours, condense them, and retain the resulting fluid. On other occasions the receiving apparatus is more complicated in form; one part serving to condense the vapours, and another to contain the products. These varieties and the methods of managing them will be best illustrated by examples.

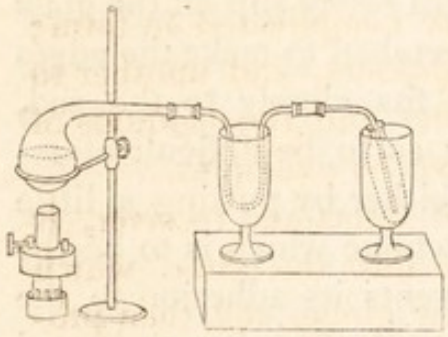
414. The simplest arrangement of retort and receiver, is to introduce the beak of the former into the latter, which may be a flask or globe, and then proceed to distil. This is an arrangement readily made, and in constant use in



* Ann. of Philosophy N.S. ix. 157. † Ann. of Philosophy N.S. ix. 196.

experiments upon inexact quantities. The receiver is frequently kept sufficiently cold by the air to condense the vapours; or if it be desirable to increase the refrigerating power, it may easily be done by putting the globe into a basin of cold water. During the distillation the globe may be turned now and then, to bring different parts into contact with the water in the basin, and if at times it becomes quickly heated from a rapid production of vapour, the cooling power may be increased by covering the upper surface with a doubled piece of filtering paper, and pouring a little water, at intervals, over it. Water, and most substances not less volatile than it, may in this way be distilled in ordinary experiments, with very little loss. Nevertheless as the vessels are open, and the cooling process is not fitted for the condensation of a sudden or large production of vapour, the arrangement should not be used except in experiments in which the substances remaining in the retort are the same with those which are condensed, or where a little loss of matter is of no consequence.

415. On other occasions, although an open apparatus may be convenient or necessary for the ready substitution of one receiver for another, yet great cooling power may be required. An arrangement requisite for the distillation of sulphurous acid, will illustrate some of the means which either separately or in conjunction, are then advantageously applicable. The retort in which the sulphurous acid is generated is attached, by a caoutchouc connecter, with a bent piece of glass tube, of the form represented in the figure, and that again by another caoutchouc connecter, with a second bent tube, also figured in the cut. The first tube is to be placed in a glass or other vessel, convenient for holding a frigorific mixture; the second is for the purpose of conducting the gas into the receiver, and is represented as passing into a small stoppered flask. These tubes should be of sufficient diameter to allow of the free passage of all the gas that may be liberated.



416. The caoutchouc connecting pieces are easily made, and are of such constant use in attaching tubes and apparatus for the conveyance of vapours and gases, that a number of them, from an inch to two inches long, and from a quarter to half an inch in diameter, should be kept ready in a box or drawer. They are most easily made of the sheet caoutchouc, prepared by Mr. Hancock, which is about the tenth of an inch thick, and may be had in pieces ten or twelve inches square. A piece of this caoutchouc about an inch and a half square, is to be slightly warmed till it becomes flexible and soft, and then put round a glass rod or other cylindrical body, rather smaller than the intended tube; the projecting edges are to be pinched together, and when they have slightly adhered, cut through with a pair of sharp scissors; this will remove the superfluous caoutchouc, will expose perfectly clean surfaces upon each edge, and leave the two edges slightly adhering together. The junction is to be completed by immediately bringing these edges into contact throughout the whole extent of cut surface; which is best done by applying a thumb-nail upon each side the section, and pressing the surfaces together, the glass rod within supporting the caoutchouc, and thus assisting to obtain the desired adhesion. This operation, if neatly performed, will cause the cut surfaces to apply so accurately to each other, that no part of either will appear. When firmly pressed together whilst warm, the adhesion is such that the tube will tear elsewhere as readily as at the junction. The tube should be made so loose that it will easily slip off the glass rod. If the caoutchouc has been stretched to make the edges meet, and the tube consequently fits closely to the rod, it will frequently adhere so tightly as to be difficult of removal; but this may be obviated either by putting a little flour over that surface of the caoutchouc which is to be the inside of the tube, and which prevents its adhesion to the glass; or by using a thin tube instead of a glass rod, and breaking it to pieces when the tube is finished, if it should happen to adhere. Great care is necessary in using the flour, that none get to the surfaces to be joined, for any kind of

dirt or extraneous substance prevents the adhesion, and the tube is rendered imperfect.

417. If Hancock's sheet caoutchouc cannot be obtained, the tube may be made of thin India rubber. For this purpose the smallest and thinnest bottles should be chosen, selecting only the most straight and uniform pieces that can be obtained. They should first be softened by being placed in a warm place for some hours, and rubbed frequently, or by being boiled for half an hour; then being dried, they may be formed into tubes. The caoutchouc in bottles is more rigid and stiff, and less adhesive than that in sheets, and for this reason greater pressure and more care are generally required in making the joint firm and tight; the tubes will probably require warming two or three times on the rod during the operation of pressing the edges together.

418. Although these tubes have been described as cylindrical, yet they are frequently useful of a conical form to connect tubes or apertures of different sizes. There is no ordinary agent, except perhaps chlorine and strong nitric and sulphuric acids, which act upon them; hence they are very generally applicable. When tubes are connected by them, as in the present case of sulphurous acid, one of these flexible connecters should be selected of a size near to that of the tube to which it is to be adapted. If small, it easily admits of extension, and is then slipped over the ends and tied with two or three turns of fine twine or thread, which should not be drawn tight, or it will cut the caoutchouc; indeed when the caoutchouc tube has required a little expansion to make it pass over the glass, it contracts with sufficient force to form a joint impervious to gas at ordinary pressure; very little stress therefore upon the thread is sufficient to secure any joint in a perfect manner. If the caoutchouc tube be a little too large, so contractile and manageable is the substance, that tying is quite sufficient to make it tight.

419. Where the object, as in the present case, is merely to connect different parts of an apparatus, the ends of the glass tubes should be from the eighth to the fourth of an inch apart within the caoutchouc connecters. This is quite sufficient in ordinary cases to allow of that flexibility in

complicated glass apparatus, which is so valuable as permitting motion and the minute adjustments of one part, without endangering another.

420. The apparatus for a distillation of this kind at low temperatures being thus connected together and ready for the operation, the next step is to apply the necessary means of cooling the parts where condensation is to be effected. For this purpose some ice should be pulverized, the glass *a* half filled with it, and then nearly filled up with water. For the glass *b*, where the actual condensation is to take place, a more powerful cooling mixture must be prepared; for this purpose ice and salt should be used, the glass being filled with the mixture to within half an inch of the top.

421. In making this mixture, a little ice should first be put into a mortar, and having been broken small, during which operation the mortar will have been cooled considerably, should have about a fourth of its bulk of salt added and rubbed with it: fusion of much of the ice will take place, and a cold of 0° will be produced. After a few minutes this portion is to be thrown away, for being fluid, it would not long retain its low temperature in a warm atmosphere, and its use should therefore be confined to cooling the mortar and pestle. The operator should now proceed to pound ice and salt together for a mixture to be used in the distillation. The quantity of salt used should be about one half the weight of the ice, or nearly one-third its bulk; this is far more than the water from the ice can dissolve, but the excess is necessary, easily to ensure the cold of 0°, as long as ice continues undissolved. The pulverization of the ice, and its mixture with the salt, should not be discontinued as soon as the temperature in the mortar is at 0°, but continued until the ice is as small as possible, consistently with a quick operation; otherwise, after being put into the glass and standing for a time, a quantity of liquid will form, the solid salt will sink, the lumps of ice float, and it will be found difficult by stirring to keep the temperature down to 0°; whereas if the ice be in fine particles, when from the production of brine a partial separation does take place, very little stirring will be sufficient to keep the tem-

perature at 0°, until nearly all the ice be dissolved. The state of the mixture in the mortar is most advantageous when, with a due proportion of salt, it contains most *solid ice* in a small state.

422. Neither a cold mixture, nor ice and water, should be poured suddenly into a glass at common temperatures: it is safer to cool the glasses previously by putting a few pieces of ice into them, and then upon removing the ice, to introduce the mixtures. The receivers, which are to be placed in the cooling mixture, should also have their temperatures lowered gradually; this is easily effected by allowing them to remain for a few moments among the loose ice.

423. It may be observed that so long as the glass *a* contains ice mixed with water, the water will be at 32° or nearly so; and in the glass *b*, if stirred now and then, the temperature of the whole will remain at 0° so long as both ice and salt in the solid state are present. But if the operation should continue until nearly the whole of the ice in both is dissolved, it is better not to wait till all has disappeared, but whilst a fifth or sixth part remains, to prepare a fresh mixture for *b*, and removing part of the water from *a*, to replace it by ice.

424. These cooling mixtures receive heat so rapidly from the atmosphere, especially in summer, as often to have their power exhausted in one half or one third the time during which they would remain effectual, if such influence were prevented. When operations therefore of any kind in which refrigeratory mixtures are used, are continued for a long time, it is highly advantageous to prevent the effect as much as possible, that the trouble, expense, and loss of time attendant upon the frequent renewal, may be avoided. All that is necessary is to hinder the access of air, either by wrapping a dry flannel or cloth round the sides of the cooling vessel, or even a large sheet of paper three or four times loosely round it, so as to form a cylinder, which is to be tied with packthread. This case should rest upon the table beneath, so as to prevent as much as possible the passage of air at the bottom: not that small apertures need be attended to, but free way for a descending current should not be permitted. The tops of the vessels may be covered

temporarily by laying on them loosely a card or a couple of cards with notches, to receive the tubes. Small portions of freezing mixtures may in this way be preserved for hours together, at 0° in the middle of summer.

425. Having properly arranged the preparatory means, the distillation of the sulphurous acid may be commenced and carried on. The gas being liberated from any of the usual materials in the retort, passes first through the bent tube, retained at a temperature of 32° by the ice and water. Several advantages result from the use of this vessel. In the first place, water brought over with the gas is in part condensed and retained; in the second, the temperature of the gas is reduced to 32°, and consequently its complete condensation more easily effected in the receiver at *b*; in the third, being evolved in a warm state, much of the heat which must necessarily be abstracted from it before it will assume the liquid form, is removed here, where the refrigerating agent (ice and water) is easily restored, and consequently less of the cooling power of the mixture in *b* is required for its ultimate condensation, and the latter remains effectual for a longer time.

426. Leaving the part of the apparatus at *a*, the sulphurous acid travels on to *b*, and there enters the receiver. Being heavy it soon displaces the air, and then coming in its unmixed state against the sides of the receiver at 0°, it is condensed, and assumes the liquid form. This condensation, as the student will know from his scientific sources of chemical knowledge, evolves heat, and will consequently tend to raise the temperature of the mixture around the receiver in this and in all similar operations; a thermometer should therefore be immersed in the mixture, to indicate whether its temperature is such as it ought to be.

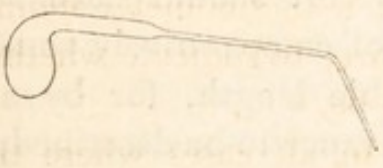
427. It will be found advisable in all cases where the substance distilled is so volatile as to require these low temperatures for its condensation, to collect it in small receivers; not only that it may soon come into contact with their cold sides during condensation, but also that it may be in convenient portions for operating with in experimental investigations. The vessel in which the body is condensed should

generally be that in which it is afterwards preserved, and, as in most experiments, the quantity in one vessel will (unless with peculiar management) be used at once, it is better in the first instance to receive the substance in such small portions as, being sufficient for each time, shall leave no overplus; so that waste may be avoided. Operating in this way, it will be necessary to change the receivers frequently: this is easily done in consequence of the flexibility of the arrangements. Those receivers which are to replace in succession the one sufficiently full, should be preserved cool by a mixture in a separate glass.

428. The receivers may in many cases be small flasks or stoppered bottles, but the latter are generally so thick at the bottom as to fly to pieces when one of them containing such a volatile body as sulphurous acid, is opened, in consequence of the sudden cold produced by its evaporation. Very useful receivers for these purposes will be described in Sect. xvi.

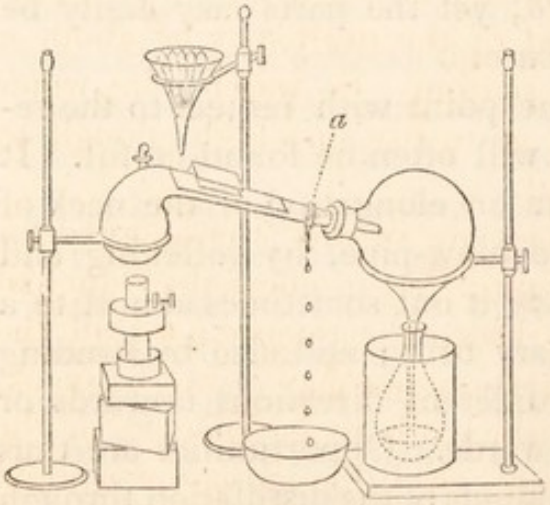
429. The various circumstances necessary to an effectual arrangement for a distillation of this kind have now been described minutely. It will be unnecessary to point out the applicability of parts only of the arrangements, their uses in the present instance will be so evident as to indicate their sufficiency in other cases; and though a particular form of the tubes has been described, yet the parts may easily be altered and arranged at pleasure.

430. There is however one point with respect to the retort worth suggesting, as it will often be found useful. It is the advantage derived from an elongation of the neck of the retort itself at the table blow-pipe, by softening and drawing it out sometimes almost to a capillary tube; and also by bending it in different directions upwards or downwards. Opportunities are thus obtained of delivering the products of the distillation through minute apertures, and upon particular spots, in a very advantageous manner. Similar opportunities of course exist with respect to the tube which terminates the distillatory apparatus (415).



431. In the apparatus and arrangements hitherto described the passage is free from the retort to the air, and in the distillation of sulphurous acid it will generally be found that much of the substance escapes and is lost. In some operations this is carefully to be avoided: thus in the distillation of wine for the purpose of ascertaining the quantity of alcohol it contains, if vapour be lost, alcohol is lost, and the results are inaccurate. In other cases, as in the preparation of concentrated hydrocyanic acid, though the exact quantity of the product is not required, yet being valuable it is desirable to prevent loss as much as possible. Some arrangements will therefore now be described tending to secure all the results, and allowing at the same time of the introduction and illustration of other contrivances.

432. Let us suppose the object were to distil some wine for the purpose, as already intimated, of separating the alcohol it contains from the other principles, that its quantity may be accurately estimated; and let us consider it as having been introduced into a retort with the precautions already described to prevent soiling the neck (404), and with the introduction also of some clipped platina foil and two or three pieces of cork which may have little pieces of platina foil stuck into them (408). The wood-cut represents this retort connected with a quilled receiver which is to assist in the condensation, and of which the quill descends into a flask which is to receive the distilled spirit. The retort should have a neck of comparatively considerable length, for by a contrivance to be described, a large portion of it is to serve as a refrigerator. If from 14 to 16 or 18 inches long it will answer the purpose.



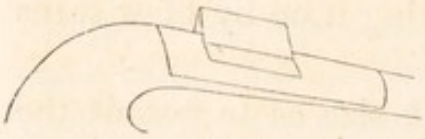
The retort and receiver are connected by a cork, and it is better that the neck of the retort and the opening of the receiver should be of very different dimensions than that

they should nearly fit. If the aperture of the receiver be about two inches in diameter it will be large enough to admit the necks of most retorts. A bung of good cork, chosen of such size that it will fit tightly into the aperture of the receiver, should be pierced as before described (58), the hole being of such dimension that, when the neck of the retort is thrust tightly into it and then connected with the receiver, the beak may pass in about as far as is represented in the wood-cut. If the cork be good, well cut, and the hole neatly made, this junction will be air-tight, or nearly so, and may be made quite secure by drawing a slip of moist bladder tightly round it several times, and tying it on by a few turns of twine.

433. The flask should be of such a size as to permit the quill of the receiver to approach close to, or to touch the bottom. It should be immersed in a jar of water, and a few pieces of ice should be put into the jar and allowed to float on the surface for the purpose of keeping the temperature at or below 40°. The flask, whilst empty, will be so much buoyed up by the water, as to press against the end of the quill if its aperture be large enough to admit the quill so far through it. But this should be prevented, as it endangers the bottom of the flask; which is to be retained by a little slip or wedge of wood introduced between it and the quill at the neck, so that the end of the quill may be about a quarter of an inch from the bottom. So much pure water should be put into the flask as to rise just high enough to close the aperture of the quill.

434. Both receiver and flask are in this way adapted for refrigeration, but the intention is not to effect the principal condensation there, but to insure the retention of all the spirit by liquefying such portions as may pass the neck, where the condensation is principally to be effected in the manner now to be described. A little loose tow should be drawn out into a sliver, wetted, and wrapped twice round the neck of the retort, the ends being so long that they may be twisted together beneath, with a few threads of the tow pulled out from the part that has already passed round, and hang down for about four or five inches in

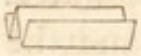
length. The ring of tow which thus surrounds the neck should be placed about half an inch or an inch above the junction before mentioned, as at *a*; it should be moderately tight round the glass, and should be carefully separated from the bladder or cork beyond, so as to have no part in contact with it, touching indeed nothing but the neck. A single piece of filtering paper should then be selected, long enough to reach from about half an inch above the tow to the part where the neck begins to turn and blend with the body of the retort, and wide enough to go two-thirds or nearly the whole way round the neck: it should not pass quite round, as it then does not apply itself so readily in the wet and dry state to the glass. Being laid on the neck of the retort and moistened, it will adapt itself to the glass, adhere closely to it, and will serve the office of conveying water to every part of the neck to which it is applied: and it should be observed that all parts of this surface is of such inclination that the fluid condensed within will run down the neck into the receiver and not return again to the body of the retort.



435. The water is to be supplied to this paper from a filter in a funnel placed above, in such a position that the drops shall have to fall about half an inch or an inch, which assists in spreading the water over the paper, and also shall descend upon the paper a little way from its upper extremity. If they fall on to its edge, or on to the glass, a few particles may splash upon the hotter parts of the retort, or portions may run down its outside. Water should be put into the filter in such quantity, that it may descend sometimes in a small stream, and sometimes in rapid drops; it will wet the paper and the glass under it, and running down to the tow, will there descend and be caught in a basin placed beneath, not a particle passing beyond the tow to endanger the introduction of any portion into the flask, either by soaking through the bladder or by running down the outside of the receiver and the quill.

436. Still however the water, in its tendency to descend, will not wet all parts of the paper fully and equally if it be

of much extent; and the upper surface of the lower end incurs the risk of being sometimes dry. This is avoided, and the paper freely wetted in all parts by the use of another piece of filtering paper folded as at *b*. Being placed with its two lower edges upon a moist surface, it will absorb water, the two sides or flaps will bend down, and accommodating themselves to the wet surface beneath, will adhere to it, and the central part will stand up in a ridge, leaving an acute angled space between it and the moistened surface. Being therefore applied to the neck of the retort, it adheres, is stationed there like a saddle, and answers the purpose of a channel for the water. Its proportions and position may be gathered from the former woodcuts. The water which drops upon the neck, just above its upper opening, partly enters into the channel there formed, and whilst about a third of it is carried through, and delivered at the lower end of the channel over the upper surface of the neck, the rest flows out along the sides of the saddle, and being distributed all over the paper adhering to the glass, keeps it thoroughly wet and even flowing with moisture.



437. All is now prepared for distillation: heat is to be applied to the retort, and when the upper part becomes warm, water is to be kept in the funnel that the condensing arrangement on the neck may be fully moistened. Upon commencing ebullution, the temperature of the neck will rise, water will rapidly evaporate from the moist paper, and care must be taken that the supply be sufficient, not merely to keep the paper fully wet, notwithstanding the evaporation, but to have a surplus running off in a small stream from the tow. The distillation should not be hurried, and the quilled receiver should never be more than warm about the part where the retort is inserted. If it become hot, or if vapour enters it visibly from the retort, rising and causing rapid condensation over the whole of the upper surface and elevating its temperature, then either more water must be suffered to fall upon the neck, or if that be fully moistened, and still does not effect a sufficient condensation, the heat must be diminished.

438. The tightness of the junction between the retort and receiver, will be rendered evident upon the application of heat, by the expansion of the air within, and its passage from the bottom of the beak in bubbles through the water. This will continue until much of the air is expelled, and the retort and part of the neck is filled with vapour. As the distillation proceeds, the condensed liquid will flow down to the water in the flask, and mix with it. The first portion which rises is the most volatile; but, combining with the water, and being diluted by it, at the same time that its temperature is reduced to about 40°, no appreciable portion will escape. As the quantity of fluid increases, the quill will be more deeply immersed, but this is of no consequence: the fluid will rise and fall in it, and occasionally when the heat slackens, or when fresh water has been put into the filter, the condensation within may be such that nearly all the contents in the flask may pass up into the globe and even air enter it. This is of no importance, there is abundant space in the globe for the liquid, so that it cannot be drawn back into the retort, and it even has the advantage of cooling that vessel; in a few minutes the expansion within will cause it again to return into the flask, and probably a portion of the air previously absorbed may now be expelled. When about five-sixths of the contents of the retort have passed over, all the alcohol will have been separated, and the operation may be concluded. The diluted spirit in the flask or flasks, if a second has been required, being reserved for the prosecution of the intended experiments.

439. It is sometimes necessary in distillatory processes to keep a part of the neck hot, for the purpose of there preventing the condensation of the vapours. This is readily effected by wrapping it round with two or three folds of dry flannel or cloth, or even of paper, the envelope being loose and tied with twine. The refrigerating arrangement, although described of such a size as to occupy nearly the whole of the neck, may vary in extent and form, and be applied to other apparatus, as well as the neck of a glass retort.

440. In other cases of distillation, it may be required to condense the liquid products out of contact with other sub-

stances, and yet to retain the uncondensed portions, so as to pass them through water, or if gaseous to conduct them to their proper receptacles. The accompanying figure will illustrate a case of this kind, which may be supposed to be a distillation of nitric acid from nitre and sulphuric acid. The retort containing the charge is connected with a globular receiver of the form *a*, from which a bent tube proceeds and passes into the Woulfe's bottle *b*. The junctions between the receiver and the retort and tube, are best made by ground glass joints; but if that plan cannot be adopted, other means must be resorted to. Good pierced corks will answer the purpose, the junction being made vapour tight, either by some glazier's putty put over it, or a paste of linseed meal, or a little plaster of Paris (sect. xviii.); and where the neck or tube nearly fits the aperture, it may be made tight without a cork by plaster of Paris alone; the open space being first closed by rather a thick paste of it, and the joint made smooth and tight outside by a thinner portion. The plaster will resist the action of the acid vapours; cork and other substances will be somewhat acted upon, which with care will cause no injury to the results. If bodies, not corrosive, are distilled in this way, these precautions, as to the nature of the closing substances, are not necessary (sect. xviii.).

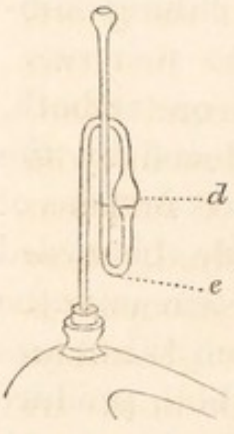


441. The receiver *a*, and the bottle *b* may, one or both, be cooled, according to the temperature produced by the vapour, being for that purpose immersed in jars or pans of water; the neck of the retort may, occasionally, be cooled as before by paper and the filter (434). Caution must be used in applying that method however to such substances as, from the high temperature at which they boil, produce very hot vapours, lest the cooling be so sudden as to break the glass. Bodies not more fixed than water may, when distilled in glass retorts, have that process applied; but when substances requiring higher temperatures, for example, nitric acid or oil of turpentine, are distilled, then hot water should be put into the filter instead of cold, or the

refrigeration should be carried on farther down the neck, where the contents are of a lower temperature.

442. At the commencement of the operation, it is supposed that the receiver *a* is clean and dry, and that the bottle *b* contains water enough to cover the end of the tube. In the distillation, therefore, any product condensed in the neck of the retort or in the receiver, will be retained in an undiluted and unmixed state ; but the portions which, from their particular nature, or the comparatively high temperature of those parts remain uncondensed, will be conducted into the bottle, and their condensation facilitated by the solvent powers of the water, or the still lower temperature which may there be applied. If any gaseous matters are evolved, they may be conducted away by a second tube, and treated as hereafter to be described (sect. xv.).

443. There are one or two additions now and then required to this and other arrangements, in consequence of the peculiar circumstances to which they are subject. It may be observed that if partial condensation of the vapourous atmosphere in the retort and receiver takes place, the solution in the bottle *b* will be forced back into the receiver *a*, and mix with its contents. One method of avoiding such an effect is by the use of Welter's safety tube. This instrument is figured in the wood cut, and may be



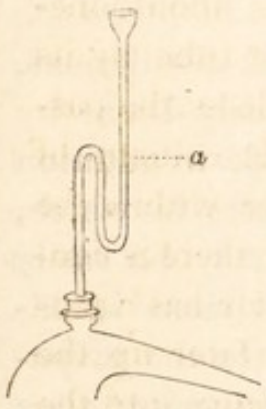
fixed in the tubular of the retort. Mercury is to be introduced until it fills about one-fourth of the little bulb, and the tube by its side, to the same height ; this closes the passage, but admits of a variable column of metal, according to the pressure within the retort and receiver. Whenever there is condensation within, the external air has a tendency to enter by forcing the water up the tube *c* (in the former wood cut), and the mercury into the ball *d*, and will gain entrance where the fluids exert the least pressure. Hence it is necessary to have the height of the tube *c* above the water in the bottle *b*, more than fifteen times that, from the bend of the safety tube at *e*, to the level of the mercury, when nearly the whole of it is

in the bulb; for in that case, the air will enter by passing through the mercury in the bulb, and not by forcing the water into the receiver at *a*.

444. It is to be observed, that a few bubbles of air entering by the safety tube, are more effectual in preventing further contraction of the vapours within the retort, than the entrance of the whole of the water by the tube *c* would be. These bubbles come at once into the hottest part of the vessels, are there much expanded, and at the same time actually lessen that tendency of the vapour to condense, which is at the moment threatening the mischief; whilst on the contrary the water on entering would rapidly increase the tendency to condensation, both by cooling the receivers and by its absorbent powers over the vapours, with which it would be brought in contact. It will generally be found in such cases, that when one drop of water enters, all the rest will rush violently after it.

445. Another arrangement of a safety tube may now and then be adopted, but being more applicable to gaseous manipulations will hereafter be described (sect. xv.).

446. A contrivance something resembling the safety tube just described, is often useful in feeding a retort with fluid during the progress of distillation. For this purpose a piece of tube may be bent into the form of a double syphon, as in the figure, and fixed into the tubular of the retort.



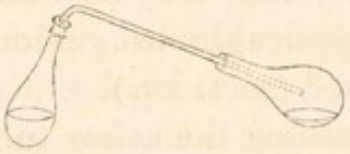
Acid poured into it will rise in the first two portions to the height of the second bend, and then further additions will flow into the vessel. The part *a* should be of sufficient length to contain a column of fluid, heavy enough to counteract any pressure outwards that may occur within: its length should be at least twice that of the middle portion. Its upper extremity should be opened out at the blow-pipe table into a funnel form, and the tube should be so large, that the fluid may be poured down without carrying air-bubbles with it. If it be so small that air mixes with the passing fluid, the relative weights of the columns are

deranged, and sometimes the acid thrown back and even out of the apparatus.

447. A sufficient number of instances have now been adduced, to illustrate the different arrangements that are useful in distillations, performed with glass retorts. But little has been said relative to the methods of supporting the different parts in their respective positions. The delineations, and the descriptions relating to flasks (359), retort stands (359), bricks (20), rings (59), wooden blocks (16), &c. being sufficient for the purpose. When these conveniences are wanting very useful tripods may be made, by tying three sticks together at the middle, and confining them beneath by string, to prevent them from slipping down.



448. In cases of necessity, Florence flasks may often be substituted for retorts in distillation; a neck being formed of a piece of bent tube and attached to the flask by a good sound cork, made tight by accurate fitting without bladder or lute. Corks thus circumstanced, sometimes swell by the heat and moisture, so much as to endanger the neck of the flask, and if it be discovered by the expansion of the part outside, that such danger is to be apprehended, the cork should be partly withdrawn and in that way relieved.



449. Before leaving the consideration of distillations, which may be performed at temperatures easily borne by glass, there are one or two remarks to be made in addition to those already given. There are some cases in which, although the heat necessary for the operation may be easily sustained by glass retorts, circumstances will make it advisable to prefer retorts of other substances. In the preparation of fluoric acid, a vessel of lead will be superior: glass would then be easily acted upon, and at the same time that the retort would be destroyed the product would be obtained in combination with some of its principles. There are some substances which, though sufficiently volatile, are very diffi-

cult of distillation in glass vessels. Of such kind are bone oil, Dipple's animal oil, sometimes naphtha, and some of the common essential oils, when free from water. These are distilled with great facility in a tin plate or copper retort, but as they frequently require a high temperature, the vessels should not be soldered, but be either brazed or the joints lapped over, and then made tight by a small quantity of solder.

450. The essential oils are generally distilled with water: they rise in conjunction with its vapour, at a temperature far below that at which they would distil alone. Advantage may be taken of this circumstance in many cases where the contact of water is of no consequence; and bone oil, naphtha, and other substances of that kind, may be distilled in a similar manner. It is to be remembered, however, on future occasions, that the substances generally retain a small portion of water, which may be injurious in particular experiments, unless previously removed.

451. In small distillations, other cooling agencies, besides these mentioned, are useful. With this view, alcohol, ether, carburet of sulphur, and even sulphurous acid, are employed; being dropped upon the condensing vessel, they effect their object by rapid evaporation. These are more particularly serviceable in small operations, where the substances are distilled by cooling the receiver, instead of heating the retort. Processes of this kind will be described and illustrated in Section xvi. on *Tube Chemistry*.

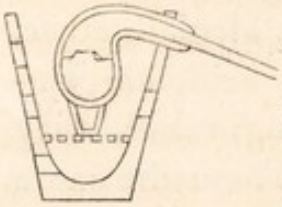
452. As a heated tubulated retort cools, it is advisable to loosen the stopper from time to time, lest the differences of contraction from previous difference of temperature, should cause it to fix so tightly that it cannot be removed without risk of breaking the vessel.

453. In operations of distillation requiring temperatures so high that glass would melt, either earthen ware or iron retorts must be used, or the glass must be protected and strengthened by an exterior coating of lute (Sect. xviii.) Notwithstanding the fusibility of glass, and its liability to chemical action at high temperatures, and in a softened state, it is still when coated often superior to earthen ware,

because of the permeability by air of the latter substance when hot, and its great risk of fracture at high temperatures, either during the heating or cooling; and it is often preferable to iron, because though liable to chemical action, it is generally less so than that metal. For the choice of the lute and the method of applying it, see section xviii. *Lutes, Cements, &c.* (996.)

Glass retorts should be coated at a leisure time, and several of them kept ready for use in a warm place. Their perfect dryness is then secured, and time is allowed for the stopping of any cracks that may have been formed.

454. When perfectly dry and prepared for the fire, and charged with the materials to be distilled, they have to be supported in a furnace that they may be heated. They should not be allowed to hang from the neck as is frequently permitted in ordinary distillations, but must be supported beneath, that when the glass is red-hot and soft, there may be as little stress or weight to disturb its form as possible: for the lute is generally so much cracked by the heat, that though it will adhere to the glass and hang together, it gives on the whole very little strength unless supported below; but even its weight sometimes does more harm than good. A very excellent support on many occasions is a small round crucible filled with sand and placed on the bars of the furnace, the bottom of the retort being allowed to rest upon it. At other times a couple of bars of iron crossing the furnace are used, and now and then stands, either of wrought or cast-iron of the form figured, and of different sizes. The upper wood-cut represents the section of a coated glass retort, placed within a crucible furnace (143), and supported on a crucible. The furnace is notched at the side to admit of the passage of the retort neck.





455. Earthen-ware retorts are made of very different materials. The ware sometimes is close and compact, like that of Wedgewood, for the puspose of rendering them less permeable to air, and sometimes more open and coarse, like

the red or brown ware, being then less liable to crack in the fire. They should be heated very gradually, and also cooled with the same precautions, if it be desired to save them from fracture; but it is scarcely worth the attempt to use an earthen-ware retort a second time, from the difficulty of ascertaining the clean state of the inside, and from the almost inevitable existence of fissures. In some cases earthen-ware retorts may be rendered tight, i. e. impermeable to air, by washing their surfaces with a solution of borax, or rather with a cream of 1 part powdered borax, 2 of finely pulverized glass, and water. These materials fuze and cover the surface with a glaze, which effectually prevents the passage of air.

456. Earthen-ware retorts should rarely be put naked into the fire; when luted as has been directed with regard to glass retorts (453, see sect. xviii.) a great degree of security beyond what they possess when naked, is afforded. They should be carefully dried before being heated, and if washed with the mixture of powdered borax, glass, and water, previous to the application of the lute, are rendered impermeable to air or vapour.

457. Small iron retorts are more frequently used for the distillation of oxygen and carbonic oxide gases, than for any other purpose. They are usually in the form of bottles having an iron tube fitted to them by a ground joint, which answers the purpose of a neck. By frequent use this joint oxidizes, scales, and is no longer quite tight; it may then be rendered so by mixing up a little fine lute, as Cornish clay, into a thin paste, with either water or oil, and putting it round the tube before it is thrust into its place: in these cases the retort should be introduced very steadily and carefully into the fire, lest by shaking, the joint should be loosened.

458. Distillations with the iron retort are best effected by a coal or coke fire. The table-furnace fire (152) answers perfectly well, the tube of the retort being brought out either at the door or through the rings put on above, in place of the sand-bath (156).

Sublimation.

459. The apparatus for sublimation in the laboratory, consists generally of tubes, flasks, retorts, capsules, and crucibles. Those which are adopted in manufactories being confined to particular operations, are therefore constructed of such materials and form, as fit them for their exclusive purposes. The use of tubes in the sublimation of small quantities, will be considered hereafter. (See section xvi. *Tube Chemistry.*) Such substances as are of moderate volatility, like naphthaline, iodine, camphor, chloride of carbon, gallic acid, &c. may be sublimed in glass retorts; the vessel being heated by a lamp or sand-bath, or small furnace, and the neck introduced into a large globe or flask, for the condensation of the vapours. The flask may either be cooled or not, according to the circumstances of the case, the means being those before described, (414, &c.) Florence flasks are frequently superior to retorts for these purposes, and being placed in an inclined position, their necks may be introduced into receivers, as has been directed with respect to the beak of the retort (414).

460. The alembic is frequently used with advantage in the sublimation of substances of moderate volatility. Its convenience consists in the facility with which the products and residue of the sublimation may be removed. There is nothing peculiar in its use requiring notice.

461. Florence flasks are useful in sublimations, which require a higher temperature than the substances just referred to, such, for instance, as calomel, cinnabar, &c. Being charged with the proper materials, they may then be bedded in the sand-pot (156), and surrounded by the sand to a height more or less above the level of the materials within, according to the volatility of the substance. A red heat may then be applied, and the products condensed in the upper part of the flask; or received into another flask, having a wide neck; or with the neck cut short and placed over the first. Sometimes a large tube with its end bent, so as to pass over the neck of the flask, is a



very convenient condensing vessel. The joint may be wrapt with dry paper and tied with twine, the other end of the tube should be drawn out and contracted (sect. xix.), so as to enter a globe, in which vapours, not condensed in the tube, may be caught and finally rendered solid.

462. When Florence flasks can be heated in a sand-pot, they do not require luting, but if they are exposed to a naked fire, must then be strengthened by an exterior coat of clay (996).

463. Some sublimations are most conveniently performed by putting the substance into a basin (344), which is then to be covered with another containing water; the application of heat to the lower causes the evolution of vapours, which are condensed against the bottom of the upper. Such sublimations as can be effected by the heat of an oil lamp are well conducted in this manner. Sometimes small platina capsules (345) are more advantageous. Indigo is best sublimed, after it is bruised, by being put in small quantities into a platina capsule covered by a larger one, and the lower heated strongly by a spirit lamp. The upper should be kept at about 212°; or a little below, by moistening it with a piece of wetted bibulous paper. After some time the sublimed indigo will be found forming a layer of crystals upon the under surface of the upper capsule.

464. Iron and earthen crucibles are useful for the sublimation of bodies that have no action upon them. The crucible may in the first place be charged, and after being covered by a large vessel to condense the vapours, heated in a sand-bath; or, being previously heated, it may be set upon a stone or brick, and after the substance is thrown in, it may be covered. Benzoic acid, naphthaline, and other such bodies, may be sublimed from them into proper vessels.

465. The necks of broken retorts are frequently useful for conducting the vapours which rise during sublimations in crucibles, &c. They are conical, and occasionally so large at the retort end that they easily cover a small crucible standing in the sand-bath. The sand, if heaped, will often serve sufficiently to close the lower end of this vessel, and the upper being introduced into a flask or globe, conducts the

vapours into them, which thus are removed so far from the source of heat as to be easily condensed.

466. Finally, cast-iron pots (156) are sometimes in use for the purpose of effecting sublimation; but they require to be covered with a head and tube, for the purpose of leading the vapours to a receiver sufficiently large to receive and condense them: or the pot being so set as to have a level surface continued from the edges on all sides, a box or large vessel may be inverted over the whole, and the condensation effected in the space within.

467. It is much to be regretted that the chemist cannot obtain glass retorts, and other vessels which have to resist high temperatures, of green bottle-glass, and of all the forms and sizes he requires. Large glass retorts, for the purpose of concentrating sulphuric acid are made of it, but much smaller ones, from two pints to an ounce in capacity, are required in the laboratory of research. Even green glass tubes are rarely to be procured, and are not permitted to be made without the special leave of the Board of Excise.

SECTION VIII.

Precipitation.

468. Precipitation is valuable as a mode of separating substances, and consists in changing them from a soluble into an insoluble state. It always depends upon altering the relation of the solvent to the substance it holds in solution; this being effected sometimes by changing the state of the solvent, as when water is added to a solution of resin in alcohol, or alcohol to a solution of gum in water; and at other times by causing a change in the body dissolved, as when sulphuric acid is added to a solution of baryta to precipitate the earth, or ammonia to a solution of iron to precipitate the oxide. It is often practised to render the presence of a substance visible, and forms an essential part of analytical and other processes, as well in the dis-

covery of bodies as in their separation and estimation. Any substance added to a solution to cause a separation of matters present in the solid form, has received the general name of *precipitant*, and the substance so separated is called a *precipitate*.

469. Many of the vessels useful in the processes of precipitation have been already described, as glasses (343), basins (344), flint-glass and Florence flasks (346, 347); but there are two kinds which particularly deserve mention here. The one is a small cylindrical glass standing on a foot, about one inch in diameter and $2\frac{1}{2}$ in height; it is very useful in testing mineral waters and solutions by precipitation, for which reason, two or three dozen of them should be in the laboratory stock. The other is of the kind called Phillips's precipitating glasses. They are of a truncated conical shape, as represented in the wood cut, and are peculiarly useful in the management of precipitates, in consequence of the facility with which they allow the solid matter to fall to the bottom of the liquid. The precipitate, as it descends, meets with no obstruction from the sides of the glass, tending indeed rather to shrink from it; the fluid, on the contrary, tends to rise in the space left, and thus in numerous cases great facility of separation is obtained. They should be provided of three or four different sizes, having about the capacity, for instance, of two, four, and eight ounces. Jars of this form have already been described (343).



470. When in the progress of investigation it is required to know whether a substance in solution will be precipitated by certain tests, the latter are to be added and mixed; if immediate separation take place, the question is answered; but if otherwise, the results are not to be thrown away, and the inquiry decided in the negative; but the mixture is to be allowed to stand for some hours, and then again examined. If no appearances of precipitation be produced, a heat is to be applied, approaching to 212°; perhaps precipitation may occur during the application of this temperature, and if so, the point is ascertained; but if not, the operator must still persist, by allowing the mixture to cool to common tempera-

ture, and then observe it for the last time. For want of perseverance of this kind, possible precipitations are often considered as impossible. Dr. Wollaston's test of the presence of potash in water is frequently thought to be ineffectual, merely from the hasty manner in which the experiment is made.

471. Precipitations are generally effected by substances with which, from previous experience, they are known to occur; and manipulative instruction merely relates to the best method of obtaining those expected results, and of thus securing the separation of the whole of a substance held in solution, in processes instituted for its purification, or for the analysis of its compounds. It is to be understood that these operations are generally best performed in Phillips's test glasses (469).

472. It is frequently necessary to add a precipitant to a solution, until no further effect is produced. Upon commencing the addition, it is easy to observe the formation of the precipitate; but when the mixture becomes milky or thick, the student is unable to perceive whether the additions he makes actually cause increased separation, or whether they are useless. As soon as this happens, it is better to desist from adding in the precipitant, and after stirring the whole so as to mix it thoroughly, to allow it to stand a few minutes; a separation of the precipitate from the liquid will then take place at the surface, and allow the removal of a small portion of the clean fluid, either by pouring it out into a little glass (369), or by dipping a rod into it and transferring a drop or two to a glass plate (61). This done, a small quantity of the precipitate is to be added to the liquid so separated, and notice taken whether any precipitate is produced; if not, enough has been added to the large portion; but if a further effect takes place, the portion removed is to be restored, the glass or valve being washed by the dropping bottle (372); more of the precipitate is to be added, and the whole again stirred up and examined as before, until it has in this way been ascertained that no further addition will produce any precipitation.

473. If the separation of the precipitate be slow, it is not

necessary at all times to wait till the fluid at the surface be quite clear; for when opalescent, the further effect produced by the precipitant in the trials may often be observed; it is only when approximating to a sufficient addition of the precipitant, that perfect clearness in the portion removed is required. When the precipitate sinks rapidly, it will be unnecessary to remove any portion for trial; for the liquid, being clear, or nearly so, to the depth of an inch or two, may be tested by dipping a glass rod into the precipitant and bringing it to the surface: the small quantity of the test thus conveyed will shew, during its descent through the clear part, whether more is required or not.

474. Sometimes the solution contains so much precipitable matter, that before a sufficiency of the precipitant has been added, the whole is thick and even pasty. In nearly all such cases, the whole ought to be diluted, for not only is the fluid part in such small quantity, when compared with the solid, as to be inseparable by the usual means, but the mixture cannot be made with such facility as to ensure uniformity in every part; without which, uncertainty with respect to the addition of the precipitant will be occasioned. But if from peculiar circumstances it is desirable to avoid dilution, a small portion of the mixture must be diluted in a little glass, and tried as before; the quantity of water thus added to the general mass, when the portion tried is returned, will be no object.

475. The precautions just given with regard to the undue addition of a precipitant, only relate to those cases where either an exact equivalent to the substance to be precipitated is required, or the precipitant itself is valuable, or the superfluous addition of it would complicate and burden the solution so as to embarrass future operations. If a peculiar salt of baryta existed in solution, and it were required to obtain the acid pure by precipitating the earth in combination with sulphuric acid, then any excess of the latter, above the exact quantity necessary to neutralize the baryta, would remain in solution and contaminate the peculiar acid: in such a case, therefore, the precautions above described must be used, and it is better when the precise point required is

nearly attained, to dilute the precipitant (the sulphuric acid in this instance), so that less risk may be incurred of adding too much at once.

476. If the object be merely to save a valuable precipitant, as nitrate of silver, when used for muriatic acid, or to keep the remaining solution as free from extraneous substances as possible, then the trouble of very delicate testing, as before described (472), may be of more consequence than the use of a little excess; and in such cases, when near the point, such a quantity may be added as is known somewhat to surpass it. But when the precipitant is cheap, does no harm if added in excess, and when none of the points above mentioned require attention, it is better not to lose time in minute operations, but to add a considerable excess at once: and indeed in many experiments it will be found that this excess is either necessary for the perfect separation of the substance, or advantageous, as very much facilitating it. The student who is commencing his experimental operations, should in all cases practise the method directed (though without attending to great exactness), until he is so far acquainted with the nature of the ordinary chemical precipitants, such as acids, alkalies and salts, as to form a tolerably correct notion of the sufficiency or insufficiency of the quantity added by the appearances it produces.

477. Solutions to which precipitants have been added are easily mixed in glasses or small jars, by agitating with the rods or stirrers before mentioned (348); but where they are bulky and occupy deep vessels, the mixture is better effected by immersing a small glass tube sufficiently long to reach the bottom of the jar, and then by blowing air down it with the mouth so as to make it pass through the fluid in bubbles. These being made to ascend through different parts of the solution, the whole soon mixes uniformly. The extreme upper end of the tube should be placed quite within the mouth and not in contact with the lips, tongue, or any other part, so that nothing but air or aqueous vapour may pass down it.

478. When rods or tubes are used to stir mixtures which contain weighed or valuable substances, the adhering fluid

should be washed off into the vessel by the dropping-bottle (372), that nothing may be lost; or, if required several times, they may in the intervals be placed with their ends in a small glass, and ultimately both glass and stirrers washed as before (472).

479. Precipitates do not often require heat for their formation or separation, but in particular cases it is very useful; basins (344) and flasks (346) are used for the purpose. If a basin is to be used for the application of heat, the precipitate may be thrown down in it, but if a flask is preferable, the precipitation is generally better effected in a glass or jar, and the mixture afterwards transferred to the flask. More command of the fluid, and easier access to it, is obtained in an open than in a closed vessel. The heat of the sand-bath is generally sufficient for these purposes.

480. A few commonly occurring precipitates are liable to peculiar circumstances, which may be usefully pointed out in this place. Chloride of silver, continually produced in the separation of muriatic acid by nitrate of silver, has, when abundant, its separation facilitated by agitation. When the liquid containing it is stirred, or poured backwards and forwards from one vessel into another, the chloride adheres, forming heavy flocculi, which in a few seconds fall to the bottom, leaving the fluid nearly clear; whereas, without such agitation, it would require from half an hour to two or three hours to produce an equal effect. It falls also more readily when an excess of the nitrate of silver, or of nitric acid, is present; for which reason these substances may occasionally be added with advantage Heat assists its separation.

481. The separation of sulphate of baryta from the fluid containing it, is very much facilitated by the addition of a little nitric acid in excess where it can be permitted, and also by heat. The two together are highly useful in many analytical processes.

482. Prussian blue, constantly produced in testing for iron, falls much more readily in solutions containing a considerable proportion of salts or uncombined acids than in such as are nearly free from them, and for this reason the addition of a little muriatic acid is often advantageous.

483. Carbonate of lime, when thrown down from a solution by an alkaline carbonate, has a loose bulky form, which in the course of a short time alters, and the substance becomes a fine gritty powder, rapidly settling to the bottom of the supernatant fluid. This change, which is advantageous to the separation of the precipitate, is facilitated by the application of heat. The solution from which the lime is to be precipitated as a carbonate, should not have much acid in excess, for then much carbonic acid is evolved upon adding the precipitant, and if cold, much carbonate of lime at first remains in solution. The application of heat causes the separation of this portion, but then a large portion of it adheres as a crust to the vessel, and occasions trouble in its accurate separation. For this reason it is generally better to add alkali in the first place to neutralize the excess of acid, and then to add the carbonate. Ammonia and the carbonate of ammonia are the substances generally preferred for the purpose.

484. Some of the metals are now and then precipitated from their solutions in the metallic state by other metals. Thus silver is thrown down by copper, copper by iron, lead by zinc, &c. In these cases it is best to retain the solution in an acid state by the addition of a little excess of the same acid as that with which the metal is combined. Silver is generally precipitated from its solution in nitric acid. The excess of nitric acid increases the rapidity of action in consequence of the electrical effect which occurs as soon as any silver is precipitated, and at the same time tends to prevent any precipitation of copper on the silver, or any separation of oxide of copper. Copper is best precipitated by iron from its solution in sulphuric acid. The excess of that acid has scarcely any action on the copper once precipitated, and very effectually retains all the iron in solution. Lead is readily precipitated by zinc from any of its soluble salts; the excess of acid is not so necessary in this case, but if the solution be weak, nitric or acetic acid is still advantageous.

485. Dr. Wollaston has devised a very beautiful method of precipitating one metal by another, or rather by two

others combined into a voltaic circuit. This process will be described in Section xvii. on Electricity (979).

SECTION IX.

Filtration, Decantation, Washing, Separation of fluids.

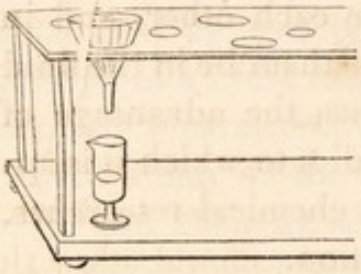
486. Filtration is a process purely mechanical. From its nature it can only be effected where the substances to be separated are such as will not dissolve each other, and in almost all cases it is requisite that one of them be in the fluid and the other in the solid state. It has the advantage of requiring no chemical change in the bodies to which it is applicable. It is of extensive service in chemical researches, and is often supplementary to precipitation.

487. Filtration is a process analogous in its nature to sifting, and is performed by putting the mixed substances into a vessel sufficiently porous to admit the passage of one substance, but close enough to retain the other. As before mentioned, the substances to be separated are usually fluids and solids; hence bodies permeable to fluids are those required for the filter. Unsized paper, cloth, flannel, tow, sponge, sand, pulverized glass, flints, porous stones, and earthenware, with many other substances, are used on different occasions, but the first is almost exclusively resorted to in the laboratory, a few of the others now and then being resorted to only on particular occasions.

488. Funnels are continually necessary to support the paper through which filtration is to take place. The ordinary funnels required in the laboratory for the passage of fluids answer the purpose very well, but they are of use for supporting filters when, from their necks being broken off, they are otherwise unserviceable. They may be either of glass or good Wedgewood or other earthenware; those of glass are to be preferred, because the progress of the filtration and the state of the filter can be better ascertained in them. Metal funnels should not be allowed in the laboratory.

489. No other glass vessels than the precipitating and test glasses (469), and the jars (343), already described, are required. Stirrers will be necessary, and the platina spatula, the platina-bladed pocket-knife (54), and sometimes other spatulas, are very useful in moving precipitates.

500. The funnels containing filters may frequently be supported by the glass or jar intended to receive the filtered fluid, and at other times by the rings of retort stands. But notwithstanding these facilities, so frequently is the operation required, a laboratory should be supplied with at least one filtering stand of considerable size (9). The end of



such a stand is represented in the wood cut. It should be 15 inches wide, 3 or 4 feet long, and have an interval between the bottom and top of 12 inches. The top should have a number of round holes made in it at intervals of 6 inches, differing in diameter from 1½ to 3 inches; two or three small ones of half an inch or an inch in diameter being intermixed. The whole should be well made and firm, so as to support considerable weights, the top having frequently to answer the purpose of a table, and to sustain jars full of solutions, as well as to bear funnels and filters.

501. It is no easy matter for the chemist to obtain unobjectionable filtering paper, and yet it is of such importance in reference to the duties it has to perform, that he should not spare pains to procure the best possible. It should be so porous as to admit the free and ready passage of fluids; so close as to retain the finest solid particles; so strong as to bear the weight of a considerable quantity of fluid, and so pure as to give nothing to the solution, or if heated with the substance retained upon it, to occasion no mixture of ashes. Some chemists use plate paper, i.e. the paper of copper-plate printers. It is very porous, and yet there are few precipitates that will pass through it; at the same time it is often tender, generally yields a considerable quantity of ashes when burnt, and is inapplicable for minute filters, when very small quantities of fluid only are to be worked upon,

because of its thickness and consequent waste of the portion of solution imbibed by it.

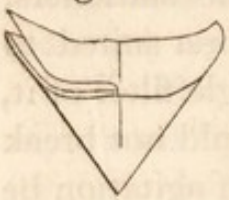
502. It is amongst the thinner varieties of unsized paper, or white blotting paper, kept by some of the stationers, that the chemist will probably find the kind best suited to his purpose. It should be so strong, that a single filter of it, capacious enough to hold a pint of water, should not break with that quantity, even though some degree of agitation be given to the funnel containing it. Its porosity, that is to say, its comparative freedom from size, for it is mostly sized in a slight degree, may be judged of by holding it to the tongue, and observing how it absorbs moisture; and by a cautious pull its strength may be ascertained whilst in such moistened state. The student who is unused to the examination of papers, will however better judge of its capability of allowing fluid to pass, by actual trial with water; a pint filter filled with clean water, should allow the fluid to run in a considerable stream.

503. The best method of judging of the purity of paper is to burn it and examine its ashes: the fewer it yields the better is it adapted for filters. A demy sheet should not yield more than one and a half or two grains of ashes altogether. If it contains more, their solubility or insolubility should be observed, that the student may be aware of the impurities, that may probably be imparted to solutions in very delicate experiments. In minute cases of investigation, sulphuric acid may frequently be traced to the sulphate of lime existing in the filtering paper.

504. Filtering paper should be cut ready for use into different sizes: a demy paper furnishes useful sizes for filters, when the sheet is separated into four, or six, or nine parts; and parcels of each of these sizes being prepared they should have a string passed through the corners, and be preserved for use in a clean place. The previous cutting of the paper in this way is very convenient, as readily supplying the sizes that will be wanted, and in preventing the waste that would occur by carelessly tearing up a sheet each time a filter is required.

505. On preparing a filter, the piece of paper should be

first examined, by looking through it against the light to ascertain that it is free from holes. The simplest filter is made by folding the paper twice in opposite directions, so as to bring the four corners together, and by opening one corner



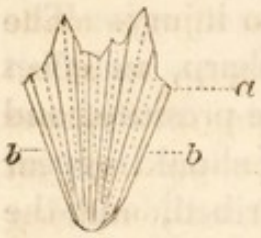
from the other three, so as to produce an irregular conical cavity. Such a filter being put into a funnel and then filled with liquid, will immediately permit its passage: but from the similarity of form between the filter and the funnel, and the close adhesion of the former to the latter, over by far the greater part of its surface, considerable obstruction is opposed to the passage of the fluid and the operation is retarded. For this reason different contrivances have been recommended, to separate the filter here and there from the funnel and allow passages for the fluid. Lavoisier recommended small glass rods inclined along the funnel before the filter is put in. Straws are used in a similar way, and they certainly open channels in their immediate neighbourhood, by which the fluid may flow down. By other chemists ribbed funnels are recommended; but it is difficult to find a funnel so deeply ribbed, as to support the paper in such a manner, that it shall not touch the glass in every part, and if they do not perform this they are of no use.

506. The best expedient by far, is, so to fold the filter that ribs may exist in the paper itself; and this may be done, so as not only to allow numerous free passages for the fluid between the filter and the glass, but also to allow of ready transmission through its whole surface, and not of one half only, and even that imperfectly, as in the former case. For this purpose, the paper is first to be doubled, and in this state, is again to be folded in half, each half folded into quarters, and each quarter into eighths, the folds being all on the same side, and radiating at equal distances from the middle of the folded edge to the other edges.



The wood cut represents the doubled paper thus divided into eight parts. Each eighth is now to be divided into half by folds in the opposite direction, but in lines still originating at the same centre, which makes the doubled piece resemble a

child's paper fan, both when closed and when a little open: it is represented by the accompanying figure.



Whilst in this state, the projecting corners should be taken off by a knife; folding the whole up tight like a closed fan, and making the section at about *a*. Being now allowed to expand a little, the originally doubled sides are to be separated from each other for the first time, but without disturbing the angles or bending the ridges or ribs which they form. Having opened it sufficiently to separate the cut edges from each other, it will be found that the paper is equally divided into parts forming alternate external and re-entering angles, except at the two edges *b b*, where two external angles come together. Here the intervening portion of paper between the two contiguous external angles should be folded, by bringing the latter together and creasing the paper down, so as to form a re-entering angle between them: this should be done at both places. Then opening the paper sufficiently to bring the bottom into proper shape, by thrusting out the part which is convex within, so as to make it project externally, the filter is completed, and being put into a funnel is ready for use. Its appearance, when perfectly formed, is represented by the accompanying wood cut.



507. It is necessary in making these filters, that the folds be not continued to the point, but that they shonld stop about half an inch short of it (see the last figure), for if completed to the bottom, the frequent action of the fingers in folding, will so far break down and destroy the texture of that part, that a hole probably will appear before the filter is finished; or if not, it will be so weakened, as to be unable to bear a quantity of fluid without breaking. Hence that part of the filter will, during the folding, assume a concave form; and the regularity of the folds, which by practice may be easily attained, must be strictly attended to in the upper part, but may be dispensed with at the lower. When opened out therefore for the completion of that part, before the filter is put into the funnel, all that will be required is

to push that side of the bottom outwards which is convex inwards, doing it so carefully as to cause no injury. The folds of the filter should be distinct and sharp, an effect which should be obtained by a single decisive pressure, and not by much fingering. No wrinkle or mark should appear in a well made filter, except the folds described, and the portion of paper between the folds should be as stiff as when first taken up. The filter should be handled lightly during the whole of the operation, and never be opened out more than is represented in the last figure. It is best to keep the folds as close, and the whole filter as compact, as possible, dropping it loosely into the funnel, and permitting the fluid poured in to do the office of opening it out. It should be so regularly made, that when thus expanded by the fluid, the external angles of the folds should touch the glass at equal distances from each other, except at two opposite places where smaller divisions exist, and unless a large quantity of fluid be present, the angles at the upper part should remain nearly as sharp when the liquid is introduced as they were before. Below they gradually pass into the rounded surface, forming the centre or bottom of the filter, which will be about the size of a sixpence or shilling, according to the dimension of the funnel in that part. These filters leave such free space between themselves and the glass as to admit of the passage of a far greater quantity of fluid than is necessary, and no obstruction being placed against the external surface of the paper the whole acts in the filtration, and that in the most favourable manner.

508. Of these two kinds of filters, which may be distinguished as the *plain* and the *folded*, sometimes the one and sometimes the other is preferable. When the object is to cleanse and purify the fluid, that being the valuable part, it is most rapidly and effectually attained by a folded filter; but when the precipitate is the part required to be taken care of, it is generally desirable not to spread it over the irregular and extensive surface of such a filter, but by using a plain one, to retain it on a surface of only half the extent. It is then likewise of such uniform thickness in every part,

as best to admit of the operation of washing, by having successive portions of water passed through it, and when the filter is opened out, the precipitate is delivered in one continuous portion, and not divided into many parts as happens with the folded filter.

509. When a single filter is judged too weak to hold the mass of fluid it is required to sustain, a double one should be used. If the filter is to be a folded one, then a double thickness of paper is to be taken, but if plain filters are used, the two should be made separately and put one into the other, in such a manner that the three thicknesses of the one may come against the single thickness of the other. Occasionally it is proper to strengthen the bottom of the filter, which, not being supported by the glass, has to support the greatest column of fluid, but not so as to obstruct the upper part, where a filtration as free as possible is required. In such a case a smaller filter is to be added to the exterior of the large one, so that it may not interfere with the precipitate within, when it is necessary to remove it from the paper.

510. The filter and funnel being ready, and placed on the stand in one of the holes before mentioned (500), over a glass ready to receive the liquid, the mixture to be filtered is to be poured in. It should not be poured from a great height, nor upon the middle of the filter, but down the side, the force of its descent being diminished as much as possible by good management, lest it break a hole through the paper: for the same reason it is better to pour it down the rod (369). If the first portions of fluid which pass be not clear, they should be returned into the filter, and a second glass is to be placed beneath. The solid matter in the liquid to be filtered will soon, by adhering against the paper, cause clear filtration, except perhaps in one or two particular cases, as with precipitated oxide of tin, &c. on which occasions a double thickness of paper must be used. On changing the vessels beneath the filter for the removal of the clear solution, it should be done so that no drop be lost. By inclining the empty vessel, its edge may be brought under the funnel before the full one is removed; and in no case should a vessel be left under the filter, in which there is

not sufficient room for the contents of the latter if it should break. Such an accident ought not to occur, but ought always to be provided against.

511. Supposing a precipitated substance is to be filtered from the solution containing it, and then washed, the mixture may be poured in all at once, or added successively. In the former case, as the fluid passes through, the precipitate forms a soft mass lying upon the paper, but hollow in the middle; in the latter, this hollow nearly disappears, from the successive portions of solid matter added. The first state is the most advantageous, for the operation of washing, when it is necessary for the removal of the portion of solution retained by the mass on the filter. For this purpose the vacant space should be filled with water, that it may pass through and displace the solution, and this should be done before the part within has drained to the utmost, and whilst it is still soft and bulky, for the water then finds easier access to all its parts. This water having passed, a second and third portion should be added, and the washing thus repeated, until by testing the liquid which passes, it is found to be perfectly pure, or to contain so little matter as to render the rest unimportant.

512. Sometimes the mass, though light, is adhesive: it may then very advantageously be stirred up with the added water, but great care must be taken that the paper of the filter be not broken in the operation. The top of a quill feather may be used for the purpose. At other times as much fluid as possible having passed through, the filter with its contents may be put into a fresh portion of water, the paper removed, and the precipitate being stirred up with the water, the whole may be put upon a new filter. These processes are applicable when a quantity either of the substance in solution or of the precipitate, being required in a pure state, it is desirable to avoid loss as much as possible, without being particularly accurate. The student should understand, that when a precipitate in its moist state occupies a large portion of the space within a filter, it is impossible, except in very long periods of time, to wash it perfectly, merely by passing water through it; because of the

greater facility of passage which the water will find, in one direction rather than another. When the precipitate forms but a thin layer, or when it can be completely stirred up from the bottom by a jet of water, it may be well and perfectly washed.

513. It is advisable in all cases of washing in filters, where accuracy is necessary, to make the filter of such a size as to drop entirely within the funnel; and to cover the latter with a clean basin. This protects the upper moistened parts of the filter from evaporation, which would cause the slow but continual ascent of portions of the fluid from below; and consequently a deposit of the substance there. In slow filtrations a considerable quantity of the substance in solution would be accumulated in the upper part of the filter, instead of being washed away.

514. It is necessary in certain cases first to moisten the filter with water. When aqueous solutions of vegetable matter, which are thick and adhesive, are to be cleansed by this process, the filter should be thus prepared. The advantage will be found very considerable with solutions of sugar. In the filtration of alcoholic vegetable solutions, the filter should always be previously moistened with pure alcohol. Fixed or essential oils, or naphtha, and similar bodies, in mixture with water or aqueous solutions, in which they are not soluble, may be separated from the latter by a paper filter, previously moistened with pure water. In some few cases the other substance may be made to separate by passing through the paper, the filter having been previously imbued with a portion of it in a state of purity.

515. Sometimes hot filtrations are to be performed. Oils filter better hot than cold: tallow and cocoa nut oil may be passed through paper when hot; and many solutions must be filtered at high temperatures, because of the greater solubility of the ingredients under those circumstances. In these cases the fluids should be heated in a flask or basin before they are poured into the filters, and the filter funnels being placed in the glasses or jars, and, after the fluid is poured in, covered over with a basin or glass plate, the whole

should be enveloped in a piece of flannel or a dry cloth. If from the length of the operation or other causes the flannel or cloth be not sufficient, it may be dispensed with; and the glass and filter being placed on a warm part of the sand-bath, should be covered with a box or vessel large enough to rest on the sand, and thus form a hot air-chamber for the process. When the operations are upon a small scale, a paper cone (1229) is sufficient to cover the vessels on the sand-bath and keep them hot.

516. In filtrations of alcohol, or alcoholic solutions, the funnel should be put into the glass, and covered as before mentioned (513), that evaporation may be prevented as much as possible. In all filtrations for analysis the filter should be covered in the same manner, to prevent accumulation of substances in the upper part of the paper. These covers should in no case touch the filter, but merely rest upon the edges of the funnels.

517. When working upon minute quantities, filters as small as possible are used, that but little of the fluid may be absorbed. When of such size as will result from a piece of paper three inches square or less, they are better not folded but plain (505—508) and may then be supported without a funnel in the aperture of a small test glass (469). When a lipped Phillips' test glass is to be used, nothing more is required than to select one having a diameter at the mouth of about one inch and a quarter or less, according to the size of the filter; from one half to a third of which, when in its place, is to be left above the edge of the glass. In arranging the filter, the triple or stronger side should be placed opposite the lip, that the form may be retained, and the space at the lip left open for the passage of air outwards, as the fluid passes into the vessel. These filters should never be filled to a height much above the edge of the glass, otherwise the weight will sometimes bend the paper over the outside, and derange the whole. If the glass used has no lip, then a double fold must be made in the single side of the filter, so as to make a portion from the top to nearly the bottom project inwards,





and appear like a sharp ridge. When put into the jar, this will form a notch as it were in the side of the filter, by which the air may find a passage outwards. It is necessary in these small filtrations that the air-passage be attended to and kept open: should it be badly formed, or from the quantity of fluid within be pressed against the glass, or stopped up by the abundance of liquid which passes through the filter, either filtration will cease, or the fluid, not being able to enter the glass, will flow over and down the outside, and be lost.

518. The dropping-bottles (372) will be very useful in all these filtrations, especially those on a minute scale, and there is another bottle recommended by Berzelius, which is also useful. It is formed much like the dropping-bottle, but the cork has no notch in the side of it, but is inserted air-tight, and the glass tube has a small aperture. Being about half or two-thirds filled with water, it is to be inverted, and then by applying the mouth to the aperture, air is to be forced in through the tube and water, and condensed as much as possible in the upper part; when the mouth is removed, this compressed air forces out the water in a small stream, which continues for some time; and which, directed against the sides of the filter, washes the precipitate from the paper, and accumulates it at the bottom. It is necessary in many cases to collect the precipitate at the bottom of the filter as much as possible, and, for this purpose, besides the dropping-bottle and Berzelius's bottle, a syringe (533) may also be employed. This instrument is easily made from a piece of glass-tube at the blow-pipe table, and is very effectual in cleansing the sides of the filter.

519. When a filter is required so large that paper alone has not strength sufficient, a piece of cloth should be fastened by the edges to a slight square frame of wood, so that it may hang loosely; a sheet of filtering paper should be laid over it, and the fluid to be filtered conveyed upon it.

520. When the object is hastily to filter a fluid for the purpose of removing pieces of dirt, then a little loose tow at the bottom of a funnel, or a piece of sponge slightly

thrust in, is often sufficient for the purpose. Upon some few occasions filters for acids are required. These are generally recommended of powdered glass, being arranged somewhat in the manner described for lixiviation (387). Pieces of glass are put into the neck of the funnel; upon these smaller fragments, then again other layers of particles diminishing in size, until a moderately fine powder has been used, the top being finished with a layer of small fragments, to prevent disturbance by pouring. The pieces of glass should be well cleaned before pulverization, and when arranged, some water should be passed through the filter, to remove alkali or other matters that may be separable from the glass; which should be that of wine bottles, and not flint glass.

521. Another mode of separating a fluid from the finely-divided solid matter it may contain, is to allow the latter to deposit, and then to remove the former. This is called *decantation*, and is a process much superior to filtration in many analytical experiments, and recommended in preference both by Lavoisier and Berzelius.

522. If the fluid be poured off, it should be done from a lipped jar (343. 369.), and with a very steady hand, that as much may be removed as possible, before the deposit at the bottom be disturbed. But a better method by far is, to use a syphon. Let a piece of glass tube, about 0.3 of an inch internal diameter, 22 inches in length, and of sufficient thickness to bear ordinary laboratory work, be bent at the blow-pipe table, so that one limb shall be about two inches longer than the other; the extremities should be contracted at the lamp (sect. xix.), until about 0.2 of an inch in diameter. So formed, when filled with fluid and held as in the figure, but with one aperture closed by a finger, the fluid will not fall out at the other, because of the smallness of its diameter; and yet the larger diameter of the body of the syphon will permit a more rapid passage of fluid than would otherwise take place. When this instrument is to be used to separate the liquid in a jar from the deposit lying at the bottom, the syphon is to be inverted and in-



clined, so that the orifice of the shorter leg shall be higher than the other: it is then to be filled with water from the dropping-bottle, taking care that no bubbles of air are included, which is easily done by holding the beak of the bottle against the side of the aperture; and when the water has filled the longer leg it is to be closed by a finger, and more water added till the other leg also is full. Keeping the finger tight upon the orifice that no air may enter it, the syphon is to be inverted, so as to bring it into its acting position; the shorter leg is to be introduced into the fluid; and then, by withdrawing the finger, the fluid is to be suffered to run out into a vessel placed to receive it.

523. The current may at any time be diminished, or prevented altogether, by applying the finger partly, or closely, against the exterior aperture, and thus complete command in that respect is obtained. As the surface of the fluid descends in the jar and approaches the sediment, care must be taken that the immersed end of the syphon be not brought so near the deposit as to cause any disturbance of it; and towards the last, by diminishing the current and inclining the jar very steadily, the endeavour should be to remove as much clear fluid as possible, without drawing away any of the precipitate. This may be done with care, so that not above a cubic inch of clear fluid need be left behind. The syphon is best held in the right hand during the operation, at about the middle of the exterior leg. A degree of government over the current may be obtained by inclining the syphon, so as to bring the aperture of the external leg nearly to a level with the surface of the fluid in the jar, but in all cases it should be kept somewhat below the latter. The jar should be placed in a steady position during the operation, and is best raised up till nearly on a level with the eye. The top of the filtering stand (500. 9.) answers very well for these occasions.

524. When a very deeply-coloured solution is to be drawn off, so deep indeed as to hide the end of the syphon when in the middle of the fluid, that end should be brought close to the side of the glass within, and a lighted candle held near it, without; in this way the precipitate, the depth

of the clear part, and the orifice of the syphon may be seen, when they cannot be observed by any other means.

525. Washing by decantation is much more easily and effectually performed than by filtration, but it requires more water, and hence one great use of a plentiful supply of distilled water (22.) in the laboratory. After having drawn off the clear solution, it is merely necessary that the jar be filled up with water, the whole mixed either by a stirrer or by blowing (477.), the mixture left to settle, the clear fluid decanted, and fresh water added; and the operation is to be repeated until what is removed contains no soluble matter. Phillips's test glasses (469) and jars (343) are very useful in these washings, from the ease with which the precipitate falls to the bottom in them. Some solid substances contract into a smaller space than others, but even the most bulky should have so much water added to them, as to enable five-sixths to be drawn off after twelve hours standing. During the time that the deposition is taking place, the glasses or jars should be covered to keep out the dirt. The bottoms of glasses having feet (343) answer this and many other useful purposes; when therefore such glasses are broken, the upper part should be chipped away, and the bottoms reserved in a drawer.

526. When the substance has been sufficiently washed, and is left with as little fluid upon it as possible, it may, according to the requisite circumstances of the case, be poured into a basin and evaporated, (as will be described in Section xi.) or poured into a filter to remove more of the fluid, or the water may be removed by means of bibulous paper. There are many bodies, such as chloride of silver, oxide of copper, carbonate of lime, sulphate of baryta, and several others, which readily fall in water and occupy but a small space; and which, having been thus washed, are best removed into a Wedgewood basin, and freed from water in the latter method. For this purpose they should be allowed to settle to the bottom, an effect which is accelerated by moderate warmth; then folding up a piece of filtering paper two or three times, its end should be applied cautiously to the surface and suffered to imbibe part of the water; this

done, it must be taken out, the wet end pulled off, and the edge again introduced as in a process formerly described (60), observing that no solid matter be disturbed during the operation. By taking the precautions formerly given (60); by inclining the basin a little, and by similar attentions, which will suggest themselves at the moment, nearly the whole of the water may in this way be removed without disturbing the substance.

527. The formation of a syphon by a few threads of moistened cotton, or by a piece of folded and bent filtering paper, is now and then very convenient for the gradual separation of a fluid. If a basin contain a mixture of fluid and solid matter, and the cotton or the piece of paper be bent over the edge, so that the inner end is in contact with the fluid, and the outer end lower than the inner, the fluid will gradually be abstracted by a syphon action, and the solid matter left nearly dry. A little temporary syphon of this kind is often very useful when connected with a vessel of water, in constantly supplying a small quantity of that fluid during a long period of time.

528. The precautions given to ensure an easy separation of a precipitate (480—483), must be attended to in washing particular bodies. Prussian blue should always be washed with dilute muriatic acid (482), and sulphate of baryta with weak nitric acid, and, if possible, with warm water (481).

529. It will be observed that the process of lixiviation already described (387), is in fact a washing process. What has been said relative to it, will be abundantly sufficient to direct its application to other substances when necessary.

530. There are numerous cases in chemistry where immiscible fluids are to be separated from each other. Many of these are not difficult, especially where the substances are unimportant or valueless: but sometimes great care is required, because of the value of the substances, and sometimes because of their dangerous nature. A case of separation by filtration has already been pointed out (514). In other circumstances the two fluids may be poured into a wet funnel (if at least one of the two be water or an aqueous solution), closed by a good cork beneath, and left to remain on the

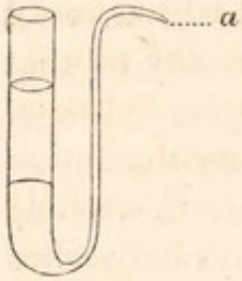
filtering stand until separated: by partly withdrawing the cork, the lowermost may be almost entirely removed from the upper. Glass vessels, furnished with a stop-cock beneath, are made for this purpose. Their use is evident, and requires no description.

531. Another serviceable instrument is a glass tube with a



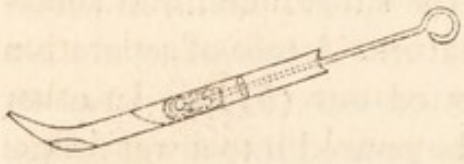
bulb an inch in diameter blown in it, and drawn out below to a moderately fine aperture. The aperture being immersed in either the upper or under liquid, the mouth is to be applied above, and the air withdrawn, when the liquid consequently will enter. The finger being then placed on the upper end of the tube, so as to close it, the instrument may be removed, and the fluid within transferred to any convenient vessel.

532. A useful vessel for the separation of a small quantity of valuable fluid may be made of a piece of glass tube from the third to a quarter of an inch in diameter, by draw-



ing it out in one part until it becomes capillary, and turning it up as in the figure. The point *a* must be closed in the flame of the spirit lamp, the mixed fluids poured into the tube, and suffered to remain till separated. The point *a* is to be broken so as to open an aperture, and then by inclining the instrument, first one fluid, and afterwards the other, may be decanted. The fluids will issue drop by drop into the vessels placed to receive them, and the surface of contact of the two in the fine tube is so small, that scarcely an appreciable portion of the valuable one need be wasted. The pouring, or transferrence rather, is more steady and regular when the beak *a* is placed against the side of the receiving vessel, so that no drop is formed, but a continuous minute stream.

533. Finally, glass syringes, such as have already been



mentioned (518), are very advantageous in the removal and separation of fluids. Such an one as that figured in the wood cut may be used for instance in the management of azotane.*

* Brande, Manual of Chemistry, i. 358.

The tow wrapped round the wire which forms the piston, is made sufficiently tight by being moistened with water, and when not inconvenient, a little water may be retained both above and below it. The beak of the syringe being brought near the globules of azotane, and the piston moved upward, the substance enters, and may be collected by holding the instrument in the position in which it is figured. It may then be transferred to other situations, and, if required, be made to issue from the jet perfectly free from moisture. This is effected by holding the syringe with its beak downward against a piece of filtering paper, then depressing the piston, till the water which may be before the azotane, is expelled, and, when the latter is on the point of issuing, by removing the instrument from the damp paper and ejecting the pure substance into the desired place, by a further depression of the piston. Other heavy fluids may in the same way be separated from the liquids in which they lie; and light fluids may in like manner be drawn up and removed, but then excess of water must not be left below the piston, and a bubble of air should be allowed to intervene between it and the substance to be taken into the instrument.

SECTION X.

Crystallization.

534. Crystallization is a very useful and valuable process in the laboratory. It enables us in many cases to purify bodies with great precision; thus by crystallizing the carbonate of soda, a pure salt is obtained, which affords as a very available source of pure soda; by crystallizing the acetate and the nitrate, similarly pure sources of the alkali are furnished. Potash in various states, useful for combinations, and free from other alkalies or earths, is obtained by crystallizing the bi-carbonate of potash, the bi-tartrate or nitre.

Pure magnesia is obtained from a crystallized sulphate; pure baryta from a crystallized nitrate; pure oxide of nickel from its sulphate; and pure nitric and muriatic acids are obtained from nitre and common salt, previously rendered free from other bodies by this process. A second object attained by crystallization, is the very definite and convenient state conferred upon substances by it. A third, the peculiar but precise forms and appearances which it generally imparts to them: these serve as characters, by which known bodies may be recognised, or by which substances before confounded together, may be distinguished and separated from each other.

535. Crystallization is always effected in the laboratory by bringing the particles of solid bodies into a mobile state, either by solution, fusion, or vaporization. It is not to be understood that these are the only methods by which crystalline form or structure can be conferred, for there are sufficient proofs to shew that a body not crystalline may become so without changing its state of solidity. The crystallization of cooling basalt, as in Mr. Watts' experiments,* or of heated glass, or of sugar candy, or even the spontaneous change of brass wire, which in a few years becomes brittle, are all effects of the latter kind.

536. Considering first the most common case, that of crystallization from an aqueous solution, it is generally performed in one of two ways,—by cooling a hot solution, or by slowly evaporating a cold one. For the due application of the first and most useful method, it is necessary that the substance should be more soluble in hot water than in cold; and the first object is to obtain a hot solution of sufficient strength to deposit crystals when of a common temperature. This may be procured as already directed (352), or a weak solution may be evaporated (Sect. xi. *Evaporation*), till of sufficient strength. A very convenient mode of ascertaining when the solution is strong enough to crystallize, is, to transfer a drop of it by a rod (61), upon a cold glass plate, and observing whether it deposits crystals as its temperature falls (353).

* Philosophical Transactions 1804, p. 282.

537. When a proper solution is made, and filtered if necessary, it is to be allowed to cool undisturbed, and the more gradually this is done, the larger will be the deposited crystals. The vessels may be either basins (344), pans, or such other as may be convenient, having regard to the quantity and quality of the fluid. They should resist chemical action, and generally be of glass or earthenware. They should not be shallow, unless a rapid crop of crystals be required, and then they are to be left open. A depth of fluid about one half or one third of its horizontal width, is the most convenient for the quantities usual in the laboratory. The vessel should be covered over, to prevent evaporation at the surface, where otherwise a crust of crystals will frequently form, disturbing the regularity of the rest. When it is required to cool the whole slowly, it should be covered with a flannel, or cloth, or a cone of paper (1229). Generally speaking, when the solution is strong in the first instance, agitated during cooling, and the temperature diminished rapidly, the crystallization is quick, confused, irregular, and the crystals are small: but when the solution is of moderate strength, the cooling allowed to go on slowly, and the whole retained in a quiescent state, the crystallization is regular, and the crystals are large and distinct. The particular proportions and habitudes of each substance can only be gained by experience.

538. Crystallizations to be effected by spontaneous or very slow evaporation, require a solution saturated at common temperatures. This may be obtained as before mentioned, (352) and must have more surface exposed during the process than was required in the former method. Evaporating basins (344) answer this purpose very well. The solution should be put into a dry place, where there is a sufficient access of air to carry off the vapour which will gradually rise from it, and must then be left for a much longer period than in the former case. It is advantageous, if the place be so clean that no dust can fall into the solution to disturb or contaminate it, to leave the vessel uncovered; but if danger be apprehended on that point, it must be covered either with a thin dry cloth, stretched, so

as not to incur any risk of its sinking into the solution, or else by filtering paper. When however an evaporating solution is thus covered, the process is considerably interfered with, and much more time is required.

539. These vessels, as well as glasses, and many others having round apertures, are occasionally very conveniently covered with paper; for which purpose a piece of paper, so large as to overlap the vessel from half an inch to an inch on every side, being placed over the aperture, should be folded down on one side against the vessel. Then a second fold, an inch from the first and partly overlapping it, is to be made; a third upon that, and so on, until the folds have reached round the aperture. These hold each other down, and the last may be fastened by screwing it up tightly, the whole being done somewhat in the manner that a grocer finishes his paper case holding a small quantity of sugar. The temporary cover thus formed fits the mouth of the vessel tightly, is strainel level over its surface, incurs no risk of sinking into the solution beneath, and being held on by the ledge formed from the succession of folds, is not easily displaced or disturbed.

540. It is by the process of slow evaporation that the largest crystals are obtained. A few of perfect forms should in the first place be selected, and these being placed in the solution, increase in size as the evaporation proceeds, and ultimately become very large. They must be turned every day, that all sides may receive increments of solid matter in succession.

541. An advantageous process between the two now described may often be resorted to; it consists in placing a moderate or weak solution on the sand-bath, in the evening when the fire is going out, heaping the sand round the basin, and leaving the whole until the morning. The evaporation is somewhat hastened, and at the same time the temperature falls very slowly; and thus in many cases a fine crop of crystals may be obtained in a short period.

For most substances the first method is preferable; thus acetate of lead, sulphate of soda, nitre, &c. are better so crystallized; but for a few others, the second is most advan-

tageous, and such are common salt, borax, Rochelle salt, sulphate of potash, &c.

542. A very interesting and in some cases useful process, is the gradual conversion of several small crystals into one large one. Dr. Wollaston, who communicated it to me, has permitted me to describe it here. If a small quantity of sulphate of nickel in solution, with a slight excess of acid, be evaporated in a watch-glass, it will probably, on cooling, yield a crop of numerous small crystals; but if set aside for a few weeks in a place subject to the changes of atmospheric temperature, its appearance will gradually alter, the small crystals disappearing, the larger increasing, until ultimately only one or a few large ones are left. This effect depends on the greater extent of surface exposed by the small crystals, as compared to their mass, than by the larger crystals; so that when any increase of solvent power in the surrounding fluid is occasioned by a slight increase of heat in the atmosphere, the small crystals dissolve to a greater extent than the others; but upon the decrease of temperature, the deposition is equal upon all. In this manner the small ones are gradually dissolved, and the large ones become larger. Thus sometimes a separation from impurities, a perfection of form, or a crystal of magnitude is obtained, which cannot be had by other means. The same effect may often be observed in solutions confined in glass bottles, as in oxalic acid, nitrate of mercury, acetate of lead, &c.; the small crystals which were formed when the solutions were first made being gradually converted into others of considerable magnitude.

543. Other solvents than water must be used for substances not soluble in that fluid, and at times even for some that are. Alcohol is applicable to the crystallization of potash, cholesterine, urea, sugar, &c. Alcoholic solutions are generally crystallized by spontaneous evaporation, unless indeed the solution has been introduced into a retort, for the purpose of distilling part of the spirit, and then the remaining fluid is generally best left in the retort to cool and crystallize. Ether, oil of turpentine, and pyroligneous ether, are now and then employed in experiments on unknown substances, for

the purpose of discovering characters by which they may be distinguished.

544. The influence exerted over one substance by the presence of another, and which often materially affects the appearances of crystals and crystallizations, must now be noticed. Nitre, when crystallizing from solutions containing much common salt, is frequently rough upon its surface, or constituted of a number of crystals, forming a friable, instead of a compact, mass. Common salt, when crystallized from a solution containing urea, or in urine, assumes an octohedral form. It has also the same form, though imperfectly, when crystallizing at the surface of a solution during evaporation. The appearances of several salts are altered when crystallized in animal or vegetable infusions. The most remarkable instance of the kind, and one which deserves notice here in consequence of the great apparent difference produced, although not likely often to happen accidentally, is when strong sulphuric acid has acted upon some of the products of distilled or decomposed oil. If one part of the substance obtained by the compression of oil gas, and which always exists as vapour in it, be mixed with eight or ten parts of strong oil of vitriol, a dark liquor is produced: from this, when diluted with water, filtered, and converted by the addition of carbonate of potash, into a sulphate of potash, a salt is obtained, which, upon crystallization, is nacreous, in the form of scales, and has nothing in its appearance common to sulphate of potash. It is however that salt, and is thus affected by a substance which sometimes does not amount to a two hundredth part of the salt present. The same substance has still greater power over the sulphate of copper, and in increased quantities (still comparatively very small) influences the appearances of a great many saline bodies.

545. Sometimes crystallization is *not* effectual for the separation of salts. When the sulphates of iron and copper are in solution together, crystals will be obtained resembling those of sulphate of iron, but with very variable proportions of sulphate of copper in them, the latter salt being at times present in great quantity; on other occasions triple

salts are formed, as frequently occurs with nickel. But these, and a knowledge of many more extraordinary circumstances attending crystallization, must be left for reading and experience.

546. When salts which may be separated from others by crystallization, have been obtained from impure solutions, they always retain a portion of the impurities, and require to be redissolved and recrystallized, before they can be considered as pure. In particular cases even a third crystallization is necessary.

547. When experiments are proceeding upon an unknown substance or a mixture of substances, to ascertain whether it will crystallize or not, they are generally made as distinctly and effectually upon a small scale as a large one, and often indeed with more success. Thin fragments of florence flasks are useful; as are little dishes, capsules, watch-glasses, and the glass valves or plates already briefly mentioned (1234). Sometimes merely by dipping a rod into the hot solution, and allowing the surface thus wetted to dry in the air, it may be observed from the striated, regular, or uniform appearance, whether the substance has crystallized upon it. At other times, a drop of the cold solution may be put upon a flat glass plate, and the latter placed on a warm part of the table furnace, that the liquor may slowly evaporate, and from the observation of the spot of solid matter left, a judgement may be formed. But perhaps the most decisive evidence is to be gained by leaving a drop or a small portion in a piece of florence flask, to evaporate spontaneously at common temperatures; or, if the substances dissolved are deliquescent, by evaporating them under the air-pump receiver, as will be described in Sect. xi. The crusts of solid matter thus produced should be examined with care; as well with a powerful eye-glass as by the naked eye; sometimes by holding the glass plate in the sun's ray whilst it is regarded sideways, or by the light from a candle reflected by it to the eye, or by looking through the crust and glass, not directly at the light, but at a black ground close to it. In all these trials appearances which resemble crystallization should be closely scrutinized, for the manner in which a film cracks or scales, or the mode

in which the surface of a fluid in small quantities is drawn by contraction, is often such as to occasion appearances so deceitful as to make it absolutely necessary to refer to an eye-glass.

548. Mr. Daniell has introduced a process of dissection,* which, though not concerned in the production of crystals, is frequently of great advantage in developing them from amorphous masses, and shewing the relation of forms one to another. It consists in putting a mass of the substance into a fluid capable of dissolving it, which gradually removing the exterior parts, reveals the interior in their symmetric arrangement. When the substance is moderately soluble, like alum, a lump of it should be put into water, equal to about its own bulk in quantity, and in such a vessel that the fluid may rise a little above its surface, and should be left for several days in a quiet place of uniform temperature. It will then be found, upon examination, that crystalline forms have been developed by the solvent action of the water.

549. Bodies but slightly soluble, as sulphate of potash, may have more water put over them. On the contrary, such as are very soluble, in place of being immersed in water, should be put into a solution of the same substance, which having been saturated, has afterwards been slightly diluted to occasion a solvent action. Substances not soluble in water, but soluble in acids, without effervescence, may be successfully examined in the same manner.

550. As before mentioned, the crystallization of some substances may be effected by fusion, when solution is scarcely applicable, and thus, many metals, sulphur, spermaceti, &c. may be made to assume crystalline forms. The process only succeeds well with large quantities, and may be illustrated by reference to lead or bismuth. The metal is to be put into an iron ladle and melted, the ladle removed from the fire and placed on the sand bath, where, though the bottom may be kept warm, the heat is not such as to prevent the top from congealing. When a solid crust has formed, holes

* Quarterly Journal of Science, i. 24.

should be broken through it at two opposite parts near the edge, with a hot iron rod, and the fluid metal rapidly poured out. When that which remains in the ladle is examined, it will be found crystallized in the interior. A crucible may be used in place of an iron ladle for metals; a glass flask or an evaporating basin for sulphur, spermaceti, or similar substances. When the experiment is made with sulphur, the temperature should not be raised too high, or the fluid will thicken and become adhesive.

551. When crystals are to be obtained by vaporization, the general directions given with regard to sublimation (459, &c.) are to be followed; it is to be observed, however, that the more slowly and regularly the crystals are formed, the finer are the forms obtained. It is easy to sublime and crystallize such bodies as camphor, iodine, naphthaline, &c. but with those which demand a higher temperature, as calomel or corrosive sublimate, good crystals can be obtained, only by operating with large quantities. The crystallization of indigo is best effected as already described (463.).

552. In examining crystals, with a view to recognize their general form and appearance, or the existence of any particular plane, it may be observed that the eye should be assisted by an eye-glass, and sometimes by placing the crystals in the sun's light, or in the light of a lamp, or candle, that the reflection from the planes, as they come into particular positions, may render them evident; and it may also be observed, that where small crystals or fragments of substances are to be taken up and examined by the eye, a soft cement, composed of two parts yellow wax and one part turpentine, is very useful (1035). A little piece of this, softened between the fingers, may be fixed on the end of a pencil or a small stick, and formed to a point, or a small roll of the substance itself may be pointed at the end, and the particle being touched by this point immediately adheres to it, and may be examined with perfect ease.

553. With reference to the use of the goniometer, especially the accurate instrument of Dr. Wollaston's invention, and also to the determination of the forms of crystals themselves, these constitute a part of that extensive, important and

mathematical branch of knowledge now known by the name of Crystallography; and for such information as relates to the use of the instruments required in it, the student is referred to the paper by Dr. Wollaston in the Philosophical Transactions for 1809; Phillips' Elementary Introduction to Mineralogy, p. xxv; and Brooke's Introduction to Crystallography.

SECT. XI.

Evaporation—Desiccation.

554. Evaporation is a process so simple in its nature, and common in its performance, as to be comprehended generally by every one. The ordinary vessels required for it, are basins of earthenware (344), one or two of silver and lead (345), a crucible and capsules of platina (345), Florence flasks (347), fragments of flasks, and watch-glasses. The basins and capsules of earthenware should be thin at the bottom, but all these vessels have been sufficiently described in the section upon Solution.

555. Of evaporation, at common temperatures, that which is performed spontaneously has been referred to in treating of crystallization (538.), and the necessity of a clean airy place, or of covering the vessels insisted upon. But the process has been very much assisted and hastened by the use of desiccators, and in the hands of Mr. Leslie*, has been carried to an extent in its power and application, surpassing every previous expectation or thought. Mr. Leslie's process consists in placing the fluid to be evaporated in a basin so as to expose considerable surface, under the receiver of an air pump, accompanied by another basin, containing a substance which has strong attractive powers for water. Sulphuric acid, having a surface of from twice to thrice that of the fluid to be evaporated, may be used. These should be so placed that the first basin may be supported over the

* Supplement to Ency. Britannica. Art. Cold.

second; and both being covered by a receiver as small as can conveniently be used, it is to be exhausted, and the operation to be left to itself. The air being absent from within the receiver, a ready liberation of vapour from the water, equivalent in tension to its temperature, takes place; but this vapour is as rapidly condensed upon coming into contact with the sulphuric acid, and its place supplied by fresh vapour from the water, which in turn is condensed as before. Thus the process goes on, the water travelling in the form of vapour from the basin to the sulphuric acid, where it combines and resumes the liquid state.

556. This process of evaporation and consequently of desiccation, is valuable, not merely as avoiding any necessity for elevation of temperature, but as actually causing considerable depression, and is for this reason useful in numerous cases where delicate organic substances, which might be injured, even by moderate heat, require drying. For its operation, all that is necessary is, to replace the basin of water by the substance to be dried; whether it be fibre, or a filter with a precipitate upon it, or a portion of precipitate in a basin washed by decantation, or a solution. All these or any other substances, may be put into basins, and supported by a little tripod with glass legs, standing in the dish of sulphuric acid.

557. In the general arrangement of this process, it is necessary that the pump be in such order, and the receiver fitted so accurately to the plate, that the vacuum may be retained for days together. It is also necessary that the sulphuric acid be not allowed to become too much diluted by frequent use. It is most powerful when first introduced, should be stirred up now and then when the receiver is opened, and had better be replaced by fresh acid when diluted with a fourth or fifth its weight of water. Care should be taken to prevent all contact between the acid and the bodies to be dried; and the student should be aware, that upon the first exhaustion after the introduction of fresh acid, there is generally the evolution of a little air, which, forming bubbles at its surface, break and throw up minute

drops. Care should be taken that these drops cannot reach the substance to be dried.

558. Although the arrangement described is the most powerful, it may not always be the most convenient. The substance to be dried may be in a glass or bottle; which may stand in the dish containing the acid, or the acid itself may be in a glass by the side of the substance; but in all cases the acid should be in as open a vessel as possible, for if in a close vessel, its small surface soon becomes diluted and rendered ineffectual; and moreover, as there is also a tendency in the process to accumulate the portion of air left in the receiver in the vessel containing the acid, it retards the condensation, and consequently the operation.

559. Mr. Cooper has a method of setting several of these operations, on a small scale, at work at one time. It consists in the use of glass plates, in addition to the receiver and its contents. These plates, like those already referred to (547), are of thick plate glass, but each has a small hole drilled through it at about one fourth the diameter from the edge. These plates, with a little pomatum or oil between them, are perfectly air tight, and two thus prepared, being placed together, with the holes coincident, allow a free passage for the air through them, but by being turned a little way round one upon the other, the holes are separated, and the passage closed. Mr. Cooper places a jar with an open ground top upon the plate of the air pump, on it two of the glass plates with the holes coincident, and the basin of sulphuric acid with its glass and receiver upon the upper plate. The pump is then worked, both receivers are exhausted, and when in that state the plates are moved one upon the other, so as to close the communication, air is let into the lower receiver, and the upper receiver with its contents standing upon the two plates, is set aside for a few days or a longer time, as may be required. Instead of using the lower receiver, the plates may be put directly upon the air pump, the aperture in it coinciding with those in the plates.



560. More imperfect, but yet very useful processes, may be practised without the aid of an air pump. If the acid and the substance to be dried be placed in a proper position upon a glass plate of sufficient size, rubbed with pomatum, and a receiver covering them, accurately closed upon the plate, then, by raising the receiver, introducing the flame of a spirit lamp to the interior of it, and suddenly replacing the receiver accurately upon the glass, as is practised by cuppers, an exhaustion will be obtained, imperfect it is true, but which still will usefully facilitate the evaporation.

561. Even without any process of exhaustion, evaporation at common temperatures may be carried on by the use of desiccators, more rapidly in close vessels than in the open air, unless indeed a current be taken advantage of; and a wide-mouthed stoppered bottle, or a jar placed over, or in a basin, will at times supply the want of better apparatus. In these cases sulphuric acid, chloride of calcium, carbonate of potash, quick lime, and similar absorbents, may be used. A basin of quick lime, with a moist precipitate placed above it, and the whole covered with a jar or receiver, will soon dry the precipitate.

562. When there is no objection to the application of heat, evaporation may be rapidly conducted by its assistance. The heat being supplied in one or other of the numerous methods already referred to in *distillation* and *solution.*

563. If the evaporation is to be performed at temperatures under ebullition, the vessel used should be an open one, as a basin (344), and have free access of air, that the aqueous vapour may be removed from the surface of the liquid by the aid of the atmosphere, as fast as it is produced. When crusts form on the surface, they should be broken down, for they interfere much with the evolution of vapour, acting indeed the same part as a cover, or the film of oil before mentioned (238); the effect which before was advantageous being now injurious.

564. If the evaporation be required to dryness, as is common in cases of analysis, great care is necessary when the

solid matter begins to be in such proportion to the liquid as to form a thick mixture. The circulation which took place throughout the liquid is now interrupted, and the heat will frequently rise at the bottom of the basin above the boiling point of the solution, before it can pass by conduction through the crust above it. The sudden evolution of small portions of steam, then cause sputtering and petty explosions, and these throw the substance about. In such cases it is necessary to stir the substance continually, that by mixing the whole together, the one part may be prevented from rising to too high a temperature, and the other be more readily evaporated to dryness. It assists also in making way for the steam from the lower part, and materially facilitates the desiccation. It is even necessary, when part of the matter has become so dry as to harden into lumps, to use a pestle in place of the glass rod, and by rubbing the lumps down and mixing them with the moist parts, to bring the whole gradually into the state of an uniform dry powder. When this is done for analysis, great care must be taken not to lose any portion of that which adheres to the rod or the pestle: it must be scraped off with the platina spatula, and the rod and pestle being washed with a little water, the liquid must be reserved to be added to the rest in due time.

565. Sometimes when substances which dry hard, as a solution of common salt, are left to evaporate without stirring, they form a cake, between which and the bottom of the basin, portions of steam are generated, with a force not merely sufficient to throw out a part of the contents, but actually to cause a violent explosion, breaking the basin to pieces, and dispersing the substance in all directions. This is entirely prevented by frequent stirring. When, from the habits of the salt, no fear is entertained of such an occurrence, stirring may be dispensed with in operations not requiring exactness, the evaporating basin being then covered by another to prevent the loss of any particles thrown up. The upper must then be kept hot, which may be done by filling it with sand, or the desiccation will not proceed, the

vapour condensing upon it, and returning to the substance below in drops.

566. If the fluid is to be evaporated at a boiling temperature, there is no necessity for its being done in an open vessel, though it is always most rapidly so performed. It may then be effected either in basins or flasks. In the latter case the dry results are not so easily removed, but that is often of no consequence, and occasionally flasks present decided advantages. The analysis of a mineral water often requires that large quantities of fluid be evaporated: these being too great for introduction at one time, are introduced by successive portions; and as much time is required, the evaporation should be performed so as to avoid the dispersion of any part, and prevent the introduction of fumes or other extraneous matter. The quart Florence flasks are then very useful; the boiling, and consequently the evaporation, may proceed rapidly in them on the sand bath, fresh portions of water being added as that in the flask diminishes, until all is reduced to a small quantity, which may then be decanted, the flask washed out, and this last and concentrated portion treated as the analysis may require.

567. The entrance of dirt at the small aperture of the flask may be prevented by rolling up a piece of paper into a conical form, and putting it loosely into the mouth as a stopper, or covering it in the manner of an extinguisher. Either method will allow free passage for the vapour.

568. When evaporations are going on at the boiling temperature in a basin, it is still more requisite that the vessel be covered, inasmuch as the ebullition will more probably throw a small portion of fluid out, and dirt and vapours are more likely to find their way in. The best cover is a second basin put over the first and kept hot (565); or if the evaporating dish be small, one of the bottom covers (525), or a watch-glass may be used. It is necessary in all these evaporations, as M. Berzelius has observed, that the cover dip downwards, so that any fluid condensed on it may return to that below, and not run to the outside of the vessel: for the particles of matter in solution being thrown up and caught by the cover, are thus returned to the portion from whence

they came; whereas in the other case, they would be carried to the outside and lost. The necessity during these close evaporations of keeping up the heat, will be evident from the observations already made (392).

569. With a view to particular substances in a mineral water, which it is feared may be confounded with any thing that by possibility could be separated from the glass of a Florence flask by long boiling, it is sometimes required to carry on the evaporation in a metallic vessel. A deep silver crucible, or vessel, is probably the best apparatus that will present itself, though one of platina would be better. The vessel must be perfectly clean, and covered with a silver or platina dish as a cover in the manner just described (568). The water must be added in successive portions.

570. When heat is applied by a sand-bath to a basin during evaporation, the precautions pointed out (355) are to be observed. When the temporary hood (364) is in use, care must be taken that the inside be clean, that nothing may fall from it to contaminate the substance in the basin beneath.

571. Solutions of animal and vegetable substances are frequently to be evaporated and dried, until they become free from water or retain but a small portion of it. In these cases, if the heat be that of a sand-bath or lamp, the temperature is ultimately apt to rise so high at the bottom of the basin, as to cause injury to the substance. The solution, or extract, should be constantly stirred as it thickens, and as a thermometer cannot be applied so as to indicate the heat at the bottom, another method must be adopted for that purpose. Sir Humphrey Davy recommends that a chip of wood be retained in contact with the exterior of the basin at the bottom. When the temperature rises so high as to char the wood, it is sufficient to cause injury to the contents of the vessel, and upon the first indication, the latter should be removed. A few slips of paper laid between the basin and the sand, when a sand-bath is used, answer the purpose very well, and indicate by their changes the power of the temperature to which the basin is subject. As some substances decompose by heat before others, it is advantageous

to have corresponding indications; and if slips of worn calico be used, they will undergo a change at temperatures much below those which affect paper. In cases therefore where more care is required, the former substance should be used instead of the latter.

Similar care is required in the desiccation of organic substances in a pulverulent or divided state, and they should be continually stirred, if the bottom of the vessel containing them be liable to an injurious elevation of temperature.

572. When substances in powder, not liable to injury from an occasional high temperature, are placed upon the sand-bath to dry, they should be covered with paper (539) to keep out dust. Or if loose covers be more convenient, a glass bottom, or another basin will answer the purpose; but in these cases the cover is to be removed now and then, to allow the escape of vapour, and should be dried before it is replaced.

573. In cases of desiccation, it is frequently required to know whether all the water that can be dissipated has risen, or whether vapour be still passing away. A very excellent and delicate mode of determining the point is to cover the dish with a cold glass plate or basin; if dimness appear, it shews that vapour is rising. The test-glass must sometimes remain nearly a minute, or until it is warm, before a conclusion may be drawn, such an interval being necessary to make the presence of vapour visible when it is in small quantity. Powders, supposed to be hygrometric, or to have absorbed moisture from the air, may be heated in a small basin, and tested by this method, and the dryness of extracts, and many other bodies, may be ascertained in a similar manner.

574. Evaporations are frequently performed on a small scale, and will occasionally be carried on in capsules or on small plates (1234), or in fragments of Florence flasks, and the spirit-lamp (176), the sand-bath (155), and the hot plate of the table-furnace (153), will be in constant requisition as sources of heat.

575. A warm air-chamber, when it can be obtained, is highly useful for desiccation, evaporation, and similar pur-

poses. It should not consist merely of a cavity or closet, but should admit of a thorough draught of air. One that has been constructed by Mr. Cooper, is the best in its principle, and most convenient in its application, in the laboratory of research, with which I am acquainted. It consists of an inclosed space placed near the furnace, so as to receive some warmth from it, but rendered fully efficacious in the operations for which it is intended, by a current of hot air traversing it. This air is heated by passing round an iron plate at the back of the furnace, and enters the air-chamber at the top; another passage for its exit commences at the bottom, in a situation as far as possible from the former opening, and is continued until it joins the flue of the furnace at a convenient place. Thus the hot air is made to *descend*, and spread through the chamber by the draught of the flue. A damper is inserted for the convenience of opening or closing the communication at pleasure, and entrance is gained to the chamber by a door which closes accurately and is fastened by a button.

A warm air-chamber may be made of brick-work, metal, or even wood, and may be placed in any convenient part near the furnace. An excellent situation for it in the table-furnace (152) exists within the walls and beneath the flue, where the arrangements necessary for heating the current of air will be ready and obvious. Projecting spikes should be fastened into one or two sides of these chambers, to hold a tin plate or a board, to form a temporary shelf when required.

Precipitates, filters, and other moist substances put into such a chamber, are readily and safely dried. The hot air causes evaporation of the water, whilst the current removes the rising vapour. The chamber is very useful in effecting the slow evaporation of liquids (538, 541), and also for hot filtrations (515), when the entering current of air is of a temperature sufficient for the purpose.

576. In cases of necessity, a similar chamber may be made by passing the stream of heated gaseous products from a small crucible furnace (246) into one side of a box, and allowing an aperture on the other side, or at the bottom, for

its exit: but as dust may pass with the air, it is necessary that the substances to be evaporated or dried be covered with bibulous paper. An Argand lamp (247) may be applied in the same manner as the furnace; and in this case even a band-box may be used for the chamber, the hot air entering by a two-inch tube with a funnel termination at the one side, and passing out by an opening at the other side, or in the bottom. The chamber should not be too large in proportion to the lamp, but of such dimensions as to be retained at a considerable temperature, and then the water formed during the combustion of the oil will not be deposited: and though it will diminish the drying power of the air, in cases of evaporation, it will still leave it in a very useful state.

577. Where filters with precipitates upon them are to by dried, one useful method is to put them upon a clean tin plate, with a piece of filtering paper intervening or not, according to circumstances, and then placing the plate over the sand-bath at a part where its temperature may be sufficiently raised. The sand may be removed from, or arranged over the bottom of the bath at this part, so as to regulate the heat communicated to the tin plate, which should never be such as to char paper; and at other times, when no furnace or sand-bath is in action, the plate may be heated by an oil-lamp placed beneath (189). These arrangements will often be found very useful.

578. Precipitates which have been separated or washed in a filter may have a considerable quantity of the fluid removed from them by being placed upon an absorbent body. A large mass of chalk with a flat surface is exceedingly useful for this purpose, when the fluid to be removed is water; and a sheet or two of filtering paper folded up into several thicknesses may be used when the fluid is acid, alkaline, or saline. When the filter with its contents is to be transferred, it should first be loosened at the sides, by inclining the funnel, and then either lifted out by the edges and laid upon the absorbent body, or if too heavy to admit safely of such a method, it should be slipped out of the funnel by inclining the latter, its motion being assisted at the same time by a slight pull. If the filter be a simple one (505), the

side thus laid on the absorbent surface should be that which is single, and then the folds are easily opened, and the filter with its contents laid out. If the chalk be used, it should be separated from the filter by an intervening piece of bibulous paper.

579. After a time proportionate to the nature and quantity of the precipitate, the latter will be found dried to a certain degree. Many precipitates admit of the operation being hastened by folding the filter over them, laying several folds of bibulous paper upon it, and applying pressure with the hand. When the paper has become wetted, dry paper is to replace it, and the operation renewed. This expedient must not be adopted unless the precipitate have so much consistency as to bear the pressure without being forced out at the edge of the filter. After an operation of this kind, the filter with its contents may be removed to the warm air chamber (575), or the hot plate (577), and dried in the usual manner.

580. The solid contents of small filters (517), are frequently dried with advantage in this manner between folds of paper. It often happens that the substance, though in small quantity, is rare or valuable; in which case the following method may be adopted for the prevention of loss. After being pressed once or twice, it will form a layer within a fold of the filter, the paper being above and beneath, and adhering slightly. Fold one edge of the paper quite back, and then pull it, stripping as it were the paper off the precipitate; this may be done without disturbing the moist cake of solid matter: then double the filter with its contents, making the fold pass through the middle of the precipitate, by which it will also be doubled up, and being pressed a little, will so far adhere that the paper may be bent back and stripped off as before, without disturbing the substance; in this way the cake is reduced to half its original extent, but doubled in thickness, and by repeating the operation, the precipitate, however small in quantity, may be collected from the different parts of the filter into one compact portion.

581. Before quitting the subject of desiccation, it may be remarked, that moistened crystals or other substances in small fragments, are frequently put into funnels to drain, and that the required effect is hastened, and also carried to a greater extent, than it otherwise would be, by inserting a folded slip of filtering paper into the neck of the funnel, so that its upper end may touch the bottom of the collection of crystals, and its lower project a little beyond the funnel. Thus situated, it enables the liquor to drain away to a greater extent than would otherwise take place.

M. Robinet * has very much improved this process of draining crystals, by passing a current of air through them. If the crystals be put into a funnel with its neck obstructed by a ball of cotton wool, and the funnel be then fixed in one aperture of a double mouthed bottle, whilst a tube is attached to the other, air may be drawn by the tube through the funnel and its contents, into the bottle, and will carry with it the mother-water, or adhering moisture, in such an effectual manner as perfectly to cleanse the most silky crystals.

SECTION XII.

Coloured tests—Neutralization.

582. Those very important chemical substances Acids and Alkalies, in a free state, possess the power, even in very small quantity, of effecting certain general and regular changes in the tints of some vegetable colours. The distinctness of the change and facility with which it is produced, have occasioned the colours to be used as tests of the presence of these bodies when in excess or uncombined, and are now of such constant service, as to be indispensible in the laboratory. They are prepared for use in a state of solution, or else are fixed upon paper. These preparations being called *test solutions*, or *test papers*.

* Annals of Philosophy, New Series, xii. 460.

583. The only substance of the kind perhaps worth keeping in solution is an acid infusion of red cabbage. For its preparation, one or more red cabbages should be cut into strips, and boiling water poured upon the pieces; a little dilute sulphuric acid is to be added, and the whole well stirred: it is then to be covered and kept hot as long as possible, or if convenient, should be heated nearly to boiling for an hour or two in a copper or earthen vessel. The quantity of water to be added at first should be sufficient to cover the cabbage, and the sulphuric acid should be in the proportion of about half an ounce of strong oil of vitriol by measure to each good sized plant. This being done the fluid should be separated and drained off, and as much more hot water poured on as will cover the solid residue, adding a very little sulphuric acid. The whole is to be closed up, and suffered to stand until cold, and then the liquid poured off and added to the former infusion. The cabbage may now be thrown away. The infusion is to be evaporated to one half or one third its first bulk, poured into a jar, allowed to settle, and the clear red fluid decanted and preserved in bottles. The residue may have water added to it, the solid part be allowed to subside, the clear liquor drawn off, evaporated, and added to the former, or it may be dismissed altogether. This solution will keep for a year. When required for use, the acid of a small portion of it should be neutralized by caustic potash or soda (not by ammonia) when it will assume an intensely deep blue colour, and will in most cases, require dilution with twelve or fourteen parts of water. The red liquor of pickle cabbage, will, occasionally, answer the uses of the solution, and is when required for service, to be neutralized in a similar manner.

584. Test papers are far more advantageous for use than liquids: two of them in general application and delicacy surpass the rest, these are litmus and turmeric papers. For the preparation of the former, some good litmus is to be rubbed to powder with hot water in a mortar, the mixture poured into an evaporating basin or a flask, and water added until the proportion is about half a pint for each ounce of litmus. It is to be covered up so as to remain warm for

an hour, after which the clear liquor is to be decanted, and fresh hot water poured on to the residue. This is to be covered up as before, suffered to stand, and the liquid evaporated. The operation is to be repeated a second time, and if much colour appears to be removed, even a third. The first solution is to be kept apart from the second and third, which may be mixed. The first portion will not require evaporation, but the others are to be so far reduced in quantity, that when a piece of filtering paper is dipped into them, and dried, they will impart to it a blue colour of sufficient intensity for use.

585. Paper is then to be dipped into the prepared solution. The paper should in all cases be bibulous, and not sized, so that fluid dropped upon it should be instantly absorbed. Sized paper often presents a fairer tint of colour upon the surface, but is by no means so delicate as a test. The paper should be of a good colour, that the tint may not be injured; of sufficient thickness not to become almost transparent when wet, and particular care should be taken that it be free from earthy matter, especially carbonate of lime, and alkalies. It may be examined as to these points in the manner recommended for filtering paper (503).

586. The paper selected should be cut into pieces of a size convenient to be dipped, somewhat less for instance than half a sheet of post paper. The litmus solution should be poured into a dish or soup-plate, and the paper should be drawn through it piece by piece, in such a manner that the fluid may be in contact with both sides, and then having been held to drain a few minutes, it should be hung on lines of thread or twine to dry, in a convenient place. No fumes of acid or burning charcoal should have access to it, for they injure the colour; and as soon as the paper is dry it should be taken down, and laid together. The tint ought to be a full blue, or if light, not faint or undecided: it may be judged of by touching a piece of the paper with a very weak acid, and observing whether the red colour produced is vivid, and a strong contrast to the blue tint of the rest of the paper. If the solution should have been made so dilute as to produce too weak a tint, the paper may be dipped a se-

cond time, but this is be avoided if possible, as it involves a second exposure to the air.

587. It may happen from the suspension of fine particles of litmus in the solution, that the tint is not so clear as was required, but has a dusky appearance. This is unpleasant, but is not injurious; the fine particles of litmus testing the presence of an acid nearly as well as the stained paper.

588. When the paper has acquired its proper colour and is dry, it should immediately be tied up closely in stiff paper, and preserved from the air and light: the latter injures and destroys its colour, and the former, from the carbonic acid and other occasional substances it contains, injures the colour, and consequently the sensibility of the paper.

589. Turmeric paper is to be prepared in a similar manner. A hot infusion of finely bruised or coarsely ground turmeric is to be made, by boiling one ounce of the root with ten or twelve ounces of water, for half an hour, straining through a cloth, and leaving the fluid to settle for a minute or two. The liquid should be of such strength that paper, when dipped into it and dried, should acquire a fine yellow colour. The paper should be of the kind before described (585). No particular care is required during drying, relative to exposure to the air, except that acid and alkaline fumes should not have access to the paper, as they may transfer injurious matter to it, and diminish its delicacy. When dry it should be wrapped up and preserved with care.

590. The stock of test papers should not be left lying about the laboratory for general use, for then much is torn up carelessly and wasted, and much more spoiled by floating fumes. But a piece of each should be cut into slips about six inches in length, and half an inch in width, and either put into a stoppered bottle, with dark paper pasted round it to prevent the entrance of light, or what is more convenient, tied up in a case of cartridge paper, the slips projecting about half an inch at each end, that one, either of litmus or of turmeric may be withdrawn at pleasure.

591. In using these test papers with a fluid suspected to contain free acid or alkali, or knowing that one of these substances is predominant, to ascertain which is so, all that

is necessary is to moisten them with the liquid, and observe the change; if the fluid be acid, the blue colour of the litmus will immediately become red; if alkaline, the yellow colour of the turmeric will be changed to a brown. The moistening may be effected by dipping the paper into the liquid, but a better method is to touch the edge of the slip with a rod dipped in the fluid (348). In the latter case there is no risk of contamination to the fluid from the paper, and only a very minute quantity of the liquid is used at once.

592. These trials must be made by day-light; artificial light not permitting that just estimation of the changes by which the presence of a small excess of acid or alkali is to be determined. As the proportion of free acid or alkali diminishes, the intensity of the new tint produced upon the paper is also diminished, and when in very small quantity it requires considerable attention before a decision can be arrived at. The test paper should occasionally be touched with pure water in the immediate neighbourhood of the part where the solution has been applied, for any change in appearance that may have occurred, not due to mere moistening, is then readily perceived.

593. Although acid is generally tested for by litmus paper, and alkali by tumeric paper, yet the former is sometimes used advantageously for the latter purpose, being first slightly reddened either by exposure to the air, or by momentary contact with muriatic acid fumes. When the paper thus modified is used to detect a free alkali, instead of turmeric paper, that substance is indicated by the restoration of the original blue colour. Litmus paper is best slightly reddened for this use, by putting a drop or two of muriatic acid into a large jar, allowing it to stand a few minutes, and then bringing the paper towards the mouth of the jar, or carefully placing it within; so soon as the blue tint has become slightly reddened, the paper should be removed for use. If too much acid be imparted to the paper, the delicacy of its indications is injured, because of the greater quantity of alkali required to neutralize the acid, and restore the blue colour. For the same reason a paper

free from alkali or carbonate of lime has been recommended for the preparation of these tests (585), for these impurities combining with a minute portion of acid, neutralize it, and thus prevent that delicacy of indication which the test paper ought and may be made to possess.

594. Neutralizations are best effected with the assistance of heat, especially if a carbonate be used, or if precipitation occur during the operation. The carbonic acid in the first case is dissipated, and in the latter the combination is more rapidly and perfectly effected. Evaporating basins (344), are highly useful for these purposes, their contents being easily stirred, and the rod used for that purpose also applied to moisten the test paper when required. The solution to be neutralized should not be very strong, and the substance added should be diluted (474), upon approaching the point of neutralization, if it be accurately required, for the reasons before given. The successive trials on the test paper should be made down one edge, and occasionally contrasted with the effect produced by water (592). On very delicate occasions this comparative trial should be made with hot water, heated in a small basin by the side of the larger one containing the solution. Great care should be taken that the paper be not brought into contact with acid fumes during the trial; or much error may inadvertently be occasioned.

595. Sometimes precipitations are to be effected in neutral solutions, by the addition of an alkali or an alkaline carbonate, it being desirable to have as little excess of the latter as possible. Turmeric paper is then required, and the operation should be performed by heat as before mentioned; but instead of adding the precipitant gradually to the whole of the solution, until slight indications of an alkali in excess appear, it is better to reserve a small portion of the solution, and then rapidly rendering the rest slightly alkaline, afterwards to add the small portion by degrees, testing with the turmeric paper until the point is as nearly attained as required. The small remaining part may then be precipitated, by adding alkali carefully and continuing to test it, and finally adding it to the larger portion.

596. There are many substances which affect the colour of test papers, and especially of turmeric paper, either independently of the free acid or alkali they contain, or with appearances different to those described; which, if unknown, might sometimes lead to error. Solution of boracic acid, whether strong or weak, gradually changes turmeric paper, producing a tint resembling that occasioned by an alkali; and, if previously mixed with the common acids, produces still stronger tints of red and reddish brown. The borates occasion the same effect, especially when mixed with acids, and some of the tints very much resemble those produced by alkalies. Strong oil of vitriol, and muriatic acid gas, redden turmeric paper, but the redness is removed by the addition of water. Ammoniacal gas, on the contrary, does not redden turmeric paper, unless there be sufficient water present in the paper to dissolve the gas. The salts of iron, tin, and uranium, the muriates of zirconia, zinc, antimony, and manganese, and the nitrate of bismuth, when in moderately strong solution, produce tints in turmeric paper, resembling those occasioned by excess of alkali.* It should be remarked, for the instruction of those who, meeting with a difficulty of this kind, may resort to paper stained yellow by rhubarb, that it also is affected in the same way, though not so generally, but that with particular care, it is a very excellent test of the presence of alkalies.

597. *Alkalimetry* at present consists in an estimative process dependant upon neutralization, and the use of the test papers just described; the object being to ascertain the quantity of free alkali or of carbonate, contained in any impure specimen, as for instance, in that produced by the first rough process for their preparation. Descroisilles first resorted to neutralizing power for this purpose, but the extent to which the application has been improved by chemists since his time, may be seen in modern works.†

598. Let a tube, closed at one end and of about three-

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* Quarterly Journal of Science, xiii. 315, xiv. 234.

† Ure's Dictionary of Chemistry, introduction, p. xiii. Henry's Elements of Chemistry, eighth edition, ii. 512.

fourths of an inch internal diameter, and nine inches and a half in length, have 1000 grains of water weighed into it; then let the space it occupies be graduated into 100 equal parts, by the processes formerly described (116, &c.), and every ten divisions numbered from above downwards. At 23.44 parts, or 76.56 parts from the bottom, make an extra line a little on one side, or even on the opposite side to the graduation, and write at it with the scratching diamond (115) *Soda*; lower down at 48.96 parts, make another line, and write *potash*; still lower at 54.63 parts, a third line marked *carb. soda*; and at 65 parts a fourth, marked *carb. potash.* It will be observed that portions are measured off, beneath these marks, in the inverse order of the equivalent numbers of these substances, and consequently directly proportionate to the quantities of any particular acid, which will neutralize equal weights of the alkalies or their carbonates. The tube is now completed, except that it should be observed whether the aperture can be perfectly and securely covered by the thumb of the left hand, and if not, or if there be reason to think it not ultimately secure, then it should be heated and contracted until sufficiently small, (Sect. xix.)

599. Diluted sulphuric acid must now be prepared to be used with the tube. When of a specific gravity of 1.141, it will be very nearly, if not accurately, of the strength required; and this may be obtained by mixing one part of oil of vitriol of specific gravity 1.849, with four parts of water. If, when cold, the specific gravity of this diluted acid be as above mentioned 1.141, it must be nearly, if not exactly, of the strength required; but before being admitted into use, should be examined experimentally. Assuming it however as being absolutely correct, it will be found that a quantity measured into the tube up to any one of the four marks described, is sufficient to neutralize 100 grains of the dry alkali or carbonate set down at the mark; consequently if water be added in the tube, thus filled up to any one of the marks, until the 100 parts are full, and the whole uniformly mixed, one part of such diluted acid will neutralize one grain of the alkali or carbonate named at

the mark, up to which the acid of specific gravity 1.141 was first filled.

600. When a specimen of potash, or barilla, or kelp, is to be examined by this instrument, 100 grains are to be weighed out, dissolved in warm water, filtered, the insoluble portion washed, and the solution added to the rest; by this process the alkali will be separated from carbonate of lime, or other insoluble matters, which otherwise might cause errors in the estimation. The alkaline solution is to be put into a basin on the sand-bath, and then the tube and acid prepared. For this purpose some of the acid, of specific gravity 1.141, is to be poured into the tube until it rises up to the mark indicating the substance to be tested for; potash or carbonate of potash for the potash or pearlash of commerce, and soda or carbonate of soda for barilla or kelp: then water is to be added, until the hundred parts are filled, and closing the tube with the finger, its contents are to be perfectly agitated and mixed.

601. The alkali in the basin is now to be neutralized with the acid in the tube. After having once placed the thumb of the left hand over the aperture of the tube, it is not to be again removed; but inverting the tube by turning the hand so that the thumb and the mouth of the tube are downwards, the acid is to be let out gradually into the alkaline solution, by relaxing the thumb and admitting a succession of small bubbles of air; the hot solution beneath is to be continually stirred, so as to mix the acid instantly with the whole, and the operator must proceed with increased caution as the point of neutralization is approached. Very small quantities of the acid may be added, by slightly relaxing the thumb so as to permit a minute quantity, less than a drop, to flow to its extremity, and touching it with the glass rod; the final adjustment may thus be made more accurately, than by dropping the acid from the lip of the tube. The process must be thus carried on, until the alkali is found by the test papers to have been exactly neutralized: then the tube must be inverted, the thumb removed, drawing its under surface over the edge of the tube, so as to leave as much as possible of the fluid that

otherwise might adhere to it, and having allowed the sides to drain, it must be observed how many parts of acid have been used, the number of which will indicate the number of grains of the alkali or carbonate, contained in the 100 grains of the impure alkali operated with.

602. With respect to the proper strength of the acid (599), it is to be examined in the following manner: crystals of bi-carbonate of potash are to be fused in a platina crucible, the fluid poured out upon a clean, cold metal plate, and a piece of the resulting solid, estimated to be 70, 80, or 100 grains, weighed in water (63); in this way a known weight of pure carbonate of potash will be obtained in solution. The solution is then to be diluted, heated, and neutralized by acid from the tube diluted as before described (599), from the mark of carbonate of potash. If it be found that as many parts of the acid have been used as of grains of the carbonate weighed out, the acid is of proper strength: if more acid has been used, it is too weak, if less has been sufficient, it is too strong. Suppose for instance that 100 grains of the salt (fuzed carbonate of potash) had been used, and that 90 parts of the acid were sufficient; then these 90 parts ought to have occupied the 100, and consequently the 100 parts contain 1-tenth too much acid, in consequence of the experimental acid itself containing 1-tenth more than it ought to do. Hence the latter must be diluted with such a quantity of water as will make nine volumes into ten, or by 1-ninth its volume; for as the 90 parts used are to the 100 parts they ought to have occupied, so is any number of parts by volume of the acid under trial, to the number of parts which it ought to occupy. The difference between the two last numbers will give the quantity of water in volumes, to be added to the acid expressed by the first of them, in order to correct it and make it of proper strength. On the contrary, if it were found that the 100 parts were insufficient, and that 10 parts more of similar acid were required, then there is too much water by 1-eleventh of the whole in bulk, which would be corrected by adding 1-tenth of the 35 parts; hence 0,7 parts by weight of the same oil of vitriol that was used before, must be added for every 35 parts of the mixed

acid. The correction in any other case may be easily made, by considering that the number of parts over a hundred which are necessary to saturate the 100 grains of carbonate of potash, are proportionate to the quantity of oil of vitriol which must be added to bring the experimental acid to proper strength: thus if 136 parts of the diluted acid were used, then 36-hundredths more of the weight of oil of vitriol already used must be added; and the quantity of oil of vitriol that was added at first being known to be 1-5th by weight (599), the additional quantity required is easily ascertained. These corrections are not strictly accurate, but sufficiently so to meet the exaggerated cases put of a difference of 10 parts, and to bring it within the limit of errors of experiment.

603. Sometimes instead of using test papers, a little of the neutralized blue cabbage liquor (583), or of infusion of litmus may be put into the alkaline solution; the former immediately assumes a green tint: and by attending to the change effected by the addition of the acid, and noticing the point when blueness is again restored to the cabbage-colour, or when the litmus becomes reddened, the indication of neutrality is sufficiently evident and accurate for general purposes. The test by papers is however more precise.

604. Some of the impure sources of potash and soda used in the arts, contain amongst other substances sulphuret and sulphite of alkali. Both these occasion errors in the mode of estimation above described, to obviate which M. M. Welter and Gay Lussac * advise, that after the soluble parts have been separated by water, a little chlorate of potash should be added to them, the whole evaporated and heated to redness. This converts the sulphuret and sulphite into neutral sulphate, and then upon redissolving the whole, the caustic and carbonated alkali may be ascertained as before described.

605. A process of neutralization, quite the same in principle, may be adopted for the purpose of estimating the strength of *acids*, but from circumstances it is not often used, and

* Annales de Chimie. xiii. 212.

being easily comprehended from the above directions, claims no further notice here. Acetic acid is at present the substance which most frequently requires some such estimation as the above, both because its specific gravity varies very little with its strength, and because it is much in use in the arts in an impure state. Dr. Paris has pointed out the exact agreement between the equivalents of acetic acid and carbonate of lime, and has proposed to estimate the strength of this acid, by allowing it to act upon a known weight of fragments of carbonate of lime, and ascertaining the quantity dissolved, which will at once express the quantity of pure acid present. Thus let 500 grains of vinegar, or any other solution of acetic acid, be put into a basin or flask with 100 grains of marble in fragments, and after the first effervescence is over, warmed, and the neutrality ascertained; the solution is then to be poured off, and the remaining pieces of marble washed, dried, and weighed; if 60 grains have disappeared, 60 grains of dry acetic acid were present in the 500 of vinegar employed.

606. In the same manner muriatic, nitric, and any other acid, which forms a neutral soluble salt with lime, and has had its equivalent number well ascertained, may be estimated, and its strength become known. The number of grains of carbonate of lime dissolved in muriatic acid multiplied by 0.74, indicate the number of grains of dry acid by which it has been dissolved; and the number dissolved in nitric acid multiplied by 1.08. also represent the equivalent of dry nitric acid, or the quantity present in the solution submitted to experiment.

SECTION XIII.

Crucible operations—fusion—reduction.

607. Open vessels, intended to receive bodies to be subjected to high temperatures, have received the name of crucibles. They are very various in form and material, both for the sake of economy and to fit them for peculiar uses. By

far the greater number are formed of earthen-ware; they are cheap, they resist a high temperature, and also the action of most bodies which, from their fixedness, admit of or require the application of heat. They must however be distinguished from each other.

608. *English crucibles* are easily scratched by a knife or glass, and break with a granular crumbling fracture. They are useful for many common purposes, may be had of a triangular or circular form, with covers of the same material, and are cheaper than any others. They will bear a bright red heat, but will not resist a very high temperature; for in it they soften and froth, occasioning the loss of their contents. In consequence of their approach to fusibility when hot, fluxes render them quite fusible, for which reason they will not retain these agents long; their penetration by fluxes being favoured by their softness and porosity, the fluid consequently finds rapid entrance and access to the interior. After being heated for a short time with a coloured flux, the extent to which the flux penetrates them may be readily observed when cooled, and broken.

609. *Hessian crucibles* very far surpass the common English vessels, in the resistance of high temperatures and the action of fluxes. When powerfully heated and even softened, they do not become vesicular. They are triangular, but are not accompanied with covers, a want very often felt in the laboratory. They are usually of a brown colour, are harder than English crucibles since they scarcely yield to a knife or to glass; the fracture is sharper, and they are more compact, and interspersed with black particles. The price is about 7d. for the nest of five or six crucibles.

610. *Cornish crucibles.* Round crucibles of different sizes are made in Cornwall, for the use of the assay masters, and are plentiful there, but not common in London. They may be bought of Mr. Beauchamp, 22, Grafton-street, Soho. They are equally good with the Hessian crucibles. They resist a very high temperature, and on softening do not become vesicular and frothy. They agree with the Hessian crucibles in hardness, fracture, and in all points except

colour, being white or nearly so; covers of the same material may be obtained.

611. *Wedgwood's crucibles* are made of a close white ware, and hence though thin it is difficult to dissolve them, and they retain fluxes at moderate temperatures longer than other crucibles. They are round, well formed and finished, and their covers fit with considerable accuracy. They are liable to crack when heated, or if this be prevented by care, they frequently do so in cooling, which renders it necessary to use much caution during their change of temperature. They bear a moderately high heat, surpassing in that respect the common English crucible, but not equalling the Hessian or Cornish.

612. *Blue pots or black-lead crucibles*, are made of a mixture of coarse plumbago and clay, and are generally of large size, being intended principally for use in the arts. They bear a higher temperature than the English crucible, are not so liable to crack when suddenly heated or cooled, and resist the action of fluxes better than most others at moderate furnace temperatures; but as they contain abundance both of iron and charcoal, they cannot be used in experiments where either the one or the other would be injurious. Covers to these crucibles of the same material may be obtained.

613. Attempts have lately been made to improve earthenware crucibles, but as yet none equal the Hessian and Cornish in the power of sustaining a high temperature unchanged. Those made by Marshall * and Anstey † are said to approach in some properties to the blue pots. They are made of Stourbridge clay and pulverized coke; Anstey's are not baked previous to use. These vessels bear temperatures equal almost to those which are sustained by a Cornish or Hessian crucible, and with care are but little subject to crack in the fire. They are principally in use as melting pots.

614. Of all these varieties the Hessian and Cornish crucibles are the most valuable in the laboratory. They are

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* Trans. Soc. Arts, xli. 52. † Trans. Soc. Arts, xliii. p. 32.

generally used singly, and uncoated, but on particular occasions it is advantageous to place one in another, and by taking two successive ones from a nest, a double crucible may thus be obtained, which is not very clumsy. They should not be put simply one into the other and then used, but Stourbridge clay (Sect. xviii) mixed with water into a smooth and rather soft paste, should be put at the bottom and about the inside of the larger, in such quantity that on introducing the smaller, and pressing it in, it may come in contact with the clay in every part, the excess being thrust out at the edge between the two vessels. It requires some power to force in the smaller crucible and displace the excess of clay. This object is best effected by placing the crucibles with the mouths downward on a table, and pressing on the bottom of the larger, whilst a little twisting or lateral motion is given, until its edge is also in contact or nearly so, with the table. The two crucibles being thus by the intervening clay compacted into one, must be put into a warm place (575) and left for some days to dry. They must not be used in a damp state.

615. A Wedgwood's crucible is sometimes advantageously luted, and is then not so liable to crack by the heat as if not protected. Or, sometimes one may be placed as a lining within a Cornish crucible: but being more delicate, less force must be used than in the case above (614), and the paste of Stourbridge clay is to be made somewhat thinner.

616. Charcoal crucibles are very convenient for certain operations of reduction. Klaproth recommends that they be formed by making a cavity in a piece of well burned charcoal, answering to the size of the substance to be operated with, and with a charcoal stopper to close the mouth. The charcoal vessel is then to be fitted into a common clay crucible, which last is to be well covered and luted.

617. Stoppers or covers may be made out of solid charcoal, and as that of alder wood does not crack or fly to pieces when heated, it is best adapted for the purpose; but it is requisite previously to heat the charcoal to a high degree in consequence of the contraction which that substance undergoes, and which appears to be proportionate to the tem-

perature it is submitted to. Charcoal made as it usually is, by mere ignition, when fitted and then subjected to high heat, will be considerably deranged, from the contraction occasioned by a greater temperature; but if previously ignited strongly this derangement is avoided.

618. For a similar purpose it is often advantageous to line crucibles with charcoal. The charcoal should be pulverized, and the more compact and close the lining is required, the finer should be the powder; for in consequence of the porosity of charcoal its powder lies in a much smaller space than the solid or coarsely pounded substance. It is to be mixed with weak gum water, not putting so much as to make it adhere, but forming with it a moist powder, and with a coat of this the crucible is to be lined from the fourth to the half of an inch or more in thickness. The cavity is to be finished by a smooth mould, or rather core, as the end of a pestle or a properly formed piece of wood; and having pressed the lining as hard as possible with this, it is to be withdrawn carefully, by giving a little rotatory or lateral motion, so as to set it free from the lining without deranging it. The crucible is then to be set in a warm place to dry (575.)

619. Of metallic crucibles, those formed of platina are most generally useful: they should be accompanied by covers of the same metal. They are usually made with a flat bottom meeting the sides at a sharp angle, and then have the advantage of standing steadily; but they are peculiarly liable to injury at this angle, not only because they are often thinner there than elsewhere, but from blows upon the outside, and from endeavours by means of hard instruments to loosen their contents. The substance adhering to it, should, on account of the value of a platina crucible, be loosened as much as possible by solution, and afterwards removed by smooth or blunt bodies, as glass rods, or spatulas. By making the crucible with a round bottom, or egg-shaped, the disadvantages attending the angle are avoided, but the inconvenience of not standing by itself, is incurred. It is however, when hot, easily supported in the sand-bath,

and when cold, either there or on the top of a test-glass (469). The two forms are equally well supported in the furnace.

620. Platina capsules have been before referred to (345). They are useful in heating bodies either in the furnace or by the spirit-lamp, and often supply the place of crucibles. When a cover is wanted, one will serve that purpose to another, or even to the platina crucible itself; and the crucible cover may be useful in conjunction with the capsules.

621. A platina crucible may often be inserted with advantage into a Cornish one, but it is better not to introduce any intervening substance. The metal crucible is thus protected from impurities in the fuel, and from the forcible action of the tongs in moving it into and out of the furnace.

622. A silver crucible and cover is a useful vessel; it may in many cases be used instead of the platina crucible, and being of a cheaper metal, may be formed of larger size. It is of great service in the evaporation of mineral waters, and various solutions. It should be of pure silver. It should be carefully attended to when heated; because silver fuses at a full red, or rather yellow heat; and because in a furnace amongst the fuel, there are frequent air-ways and currents of small extent, by which one part of a crucible is rendered much hotter than another. It should be understood, that as the heat approaches the fusing point, there are certain temperatures at which the crucible will appear quite whole and sound, even when it is so friable and brittle, that if held at one edge, its weight is sufficient to break a piece out. Hence it is best never to trust it in any other than the crucible furnace (143), where it can be most conveniently watched, and where the heat is not so liable to rise unobserved as in a close furnace. It may sometimes be put with advantage into a Cornish or a Wedgwood's crucible.

Klaproth, who has the merit of first applying fixed alkalies to the analysis of minerals by heat, found silver and platina crucibles so much acted upon by them, as to be induced to make, and earnestly to recommend, a vessel of pure gold for this purpose. Such a crucible is by no means liable to the same kind or extent of injury as the former, but is very fusible in the fire.

623. No other furnace fuel than charcoal should ever be used to metallic crucibles. The sulphureous fumes which rise from coke and coal injure them, and iron and other substances present do not merely form slags, which adhere to the vessels and soil them, but actually corrode and destroy them.

624. These crucibles gradually deteriorate and become injured by successive operations: platina frequently rises up into blisters, which are exceedingly inconvenient, not merely as weakening the vessel, but as forming cavities; which, by the retained portions of substances formerly fused in them, contaminate the present. The surface of the metal gradually becomes roughened, and the whole is rendered more or less brittle. The purest platina undergoes these changes in time, partly perhaps from the fumes of the fuel in the furnaces, or the slight, but successive action of the substances heated in it. Silver crucibles change much more rapidly, and after some time acquire a crystalline structure and become very brittle.

625. An iron crucible is occasionally required; though but seldom for experiments of ignition. On the whole, though a more fusible material, it is better of cast than of wrought metal.

626. When in the absence of crucibles, an extemporary vessel of this kind is required, it may either be a tobacco-pipe, or a piece of green glass tube luted, or a china cup, or its fragments.

627. In the appropriation of metallic crucibles to particular uses, it is to be observed that fusible metals, or compounds of metals likely to be reduced, must never be heated in vessels of silver, gold, or platina; otherwise alloys will be formed, the crucible destroyed, and its contents lost. Even several chlorides which are unchanged in and cause no injury to glass, will, when heated in platina, injure it. This is the case with chloride of lead, which being partially reduced, the crucible becomes lined with an alloy of lead, and seriously injured. It is the same with oxide of lead and many compounds containing that metal, such as flint glass. These crucibles should be used, therefore, only with infusible sub-

stances in mass or powder, or with such fluids as will not act upon them. In analyses the chemist is frequently obliged to heat alkalies in them, because no other vessels resist their action so well. Caustic alkalies act at a high temperature upon both platina and silver, though not rapidly: the action is much increased by free access of air, and seems to be dependant in part upon the formation of a portion of the peroxide of the alkaline metal, oxygen being afterwards transferred from it to the crucible. The carbonated alkalies do not act upon either, but they cannot be fused safely in silver, from the high temperature they require. When charcoal is mixed with the carbonated alkalies, action takes place slowly on platina, perhaps in consequence of the formation of a portion of potassium.

628. When the characters exhibited by earthy bodies, upon being heated, are to be ascertained, the earths must not, as Klaproth has shewn, be put into earthen crucibles.* Vitrification frequently takes place, in consequence of an action which occurs at the surface of contact, when it would not happen in crucibles of charcoal or metal.

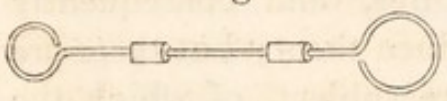
629. Earthen crucibles are best adapted for the retention of metals at high temperatures, and consequently for all experimental attempts to reduce them; but there are certain liabilities to which they are subject, of which the student must be aware. The action of fluxes upon them has been already noticed, and it is such that they will not stand in the fire beyond a certain time, proportionate to the temperature and dissolving power of the flux. They also occasionally yield substances to the bodies heated in them; thus platina heated highly with charcoal in an earthen crucible, will be found to have combined with silicon, i. e. if the temperature has been carried up to the fusing point; and either wrought or cast-iron, in like manner heated intensely in an earthen crucible, will be found to have acquired silicon, and perhaps the basis of alumina.

630. Finally with reference to the selection of these vessels, it is generally best to reject an earthen crucible that

* Klaproth's Analytical Essays, 2. 35, 36.

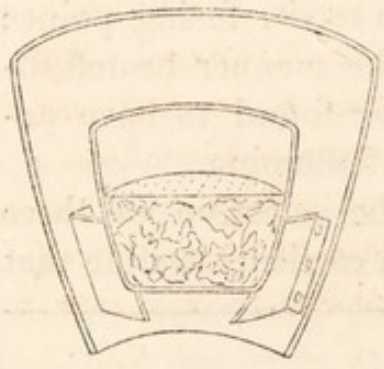
has once been used, except it be large, in good condition, and required for a repetition of a former process. For the numerous small and varied experiments made in the laboratory, it is always advisable to commence with clean vessels, and to throw them away when done with, lest any impurity should be communicated to an important result. The cheapness of crucibles removes the charge of extravagance against such a practice; one failure in an experiment, is of more consequence than the second use of several earthen crucibles.

631. The apparatus for the application of heat requisite for crucible operations, as lamps, furnaces, &c. have been already decribed (sect. iv.); so that now there remains but to notice such circumstances as peculiarly relate to their use with crucibles. The small and the large spirit lamps (176, 182), answer well for platina crucibles and capsules, when the heat they communicate is sufficient; for no fumes arise which can occasion injury to the metal. If the tranquil flame of the lamp be hardly sufficient, the broken flame before described (213) may be used. The crucible may be conveniently supported by a piece of iron-wire, bent so as to from a ring at each end, one about two-thirds of an inch



and the other one and a quarter inch in diameter, separated by a straight line seven inches in length; the wire should be pushed, before being bent, through a couple of phial corks, which, when brought to the middle of the straight part, serve as a handle, and prevent the hot metal from burning the hand.

632. The heating power of the tranquil flame is much economised, and the temperature of the crucible increased, by using a jacket like that represented in the wood cut, partly in section and partly in perspective. It is to be made of sheet copper or iron, open at the top and bottom, and within it, three projecting slips of iron-plate are to be fixed by rivets, intended to support the crucible on



their edges. This jacket is to be sustained on the ring of a retort stand, the crucible placed within it, and the spirit-lamp beneath. The supporting slips should be of such dimensions as to leave a space of about the third of an inch between the crucible and the jacket, in which the flame moving tranquilly, wraps itself around the crucible, and as no flickering motion takes place, every portion is thus effectually applied. The loss of heat from the crucible by radiation and contact of cold air, is very much diminished, and this is still further lessened when the cover is on the crucible. A very important difference in the temperature of the contents of a metallic crucible, depends upon the circumstance of the cover being on or off. The spirit-lamp used to heat the crucible must bear some proportion to the size of the vessel, and the quantity of its contents. The two mentioned (176, 182) are sufficient for most purposes when platina crucibles are used.

The jacket is also of highly advantageous application in the use of an oil (189, 190) or gas-lamp (192), and is often economical in distillations, evaporations, &c. A second on a larger scale, must then be used for the larger sized retorts, and it should not have supporting slips within, but the jacket and retort should be sustained independently of each other; for otherwise the edges, from the rapid manner in which they become heated, would often occasion the fracture of the glass.

633. In considering the relations of furnaces to the crucibles that may be heated in them, it is hardly necessary to notice the table-furnace (152). Any crucible less than six inches in height, and four inches in diameter at the top, may be heated to full redness in it. It may be set on the fuel, and raised now and then when needful by tongs, or be put upon a square piece of soft brick about an inch thick, placed upon the bars. As before mentioned, coke should be the fuel used (170), and a cover (of common English ware or black lead), should be applied, when the highest heat is required; the furnace-door should be shut, the ash-door open, plenty of fuel around and upon the crucible, and all extra flues communicating with the chimney closed.

634. When a crucible is to be heated in a crucible-furnace (143), the grate should be placed in it not less than half way from the top (145). The furnace should be of such a size as to allow at least two inches of space for fuel all round the crucible, when the latter is two inches in diameter or less, and somewhat more if it be so much as three inches in diameter: this will permit the supply of fuel in sufficient quantity to produce a strong heat. When a fire is to be lighted in the furnace, a few pieces of charcoal may be put into a common fire, and when ignited placed in the crucible furnace, and being afterwards covered by charcoal, the combustion will soon become sufficiently vivid. If the crucible to be heated be of platina, it may be placed on the fuel, the cover put on, and charcoal added at the sides. Unless a strong heat be required, it will not be necessary to place fuel over the crucible, but if there be occasion for a high temperature, the fuel is to be piled up, and even the flue (148) used. As the fuel sinks, it must be re-adjusted with the tongs, the crucible raised, and, if the heat has not been continued long enough, fresh fuel is to be added. The crucible should never be allowed to sink to the grate. If it contains a soft or pasty substance, it should be carefully watched, to prevent its position from being deranged, or the cover displaced. It will acquire the highest temperature when about an inch and a quarter from the grate, equally distant from the sides of the furnace, covered with about an inch of fuel, and with the temporary flue over it.

635. If the heat is to be continued longer than during the combustion of one charge of fuel, a stand should be used for the crucible. This may be a small crucible about one inch and a half high, turned upside down, with a little sand or clay between it and the crucible; or an English cylindrical crucible with the mouth upwards, either empty or filled with sand; or a small round pillar of soft brick (1240). It should be put into its place, the furnace lighted, the crucible arranged, the fuel added, and the heat raised. The fuel should not be suffered to burn down very low, nor should much be added at once; but the addition should be gradual and continual, that the crucible may

never be left exposed to the air, if the experiment has in the first instance required it to be covered. Cold fuel suddenly diminishes the temperature of that part of the fire with which it comes in contact, which if it occur where the crucible itself is situated, causes injurious variations in its temperature.

636. The temperature of a furnace should never be allowed to rise and fall suddenly and irregularly, whilst an operation is going on. Such changes are liable to affect the temperature of the crucible, and even to cause its fracture.

637. The utmost heat that can be given to a crucible is to be attained in the laboratory by such a blast-furnace as has been already described (163); the fuel being coke or cŏke and charcoal, (166, 169, 171.) When of the dimensions specified, it will heat a crucible three inches and a half high, and two inches and three quarters in its upper diameter, very highly; and one not more than one inch and three quarters diameter at the top, intensely. To acquire the most powerful heat, the crucible should be raised about one and a half or two inches from the grate, and covered with at least the same depth of fuel. Hence arises a necessity for supports and covers, capable of resisting intense temperatures. The best supports would be crucibles made of the Cornish or Hessian clay, of a cylindrical form, from one and a half to two inches in height, and from half an inch to an inch internal diameter; the closed end being put upon the grate, and the bottom of the crucible on or into the aperture above, where it would be steadily retained. But in the absence of such supports, recourse must be had to Cornish or Hessian crucibles, and one being selected with a flat bottom, it must be placed upside down with the mouth upon the grate. From the irregular form of the bottoms of these crucibles, and the necessity of choosing them as narrow as possible, that the fuel may be close to all parts of the crucible to be heated, the latter is necessarily, when simply placed upon the stand, very tottering; it is therefore generally advisable to lute the crucible and stand together with a little Stourbridge clay, a small portion being put between

the two surfaces, and more at the side, so as in fact to make the two vessels into one, their bases being attached to each other. Such luting must be well dried for a day or two before it is placed in the furnace (996).

638. With respect to covers, the arrangement is more difficult, in consequence of the absence of those necessary accompaniments to Hessian crucibles, and the uncertainty attending the supply of them with the Cornish crucibles. Suppose that iron or steel is to be heated without contact of carbonaceous or extraneous substances of any kind. A common English cover will not answer the purpose, because it will melt and run into the crucible. A larger crucible of the same kind may be turned over it, and luted at the edges; but this inconveniently increases the size of the mass to be heated, which, when the highest temperature is required, should be as small as possible. A smaller crucible of the same kind may be inverted and put *inside* the other, and the interval filled by a luting of Stourbridge clay, but the heat contracts the lute, the fissures of which may receive particles of fuel and slag. This is the more probable because in all cases of a blast in the furnace from below upwards, there is an eddy in the stream of air above the crucible, which stands as a fixed obstacle in the current, and which causes the return and accumulation of numerous small particles upon the top.

639. The method that has been found to answer best, is to beat up some Stourbridge clay with water into a stiff paste, to make it into a cake the fourth of an inch thick, to put it over the top of the crucible, to press it down with a common English cover of proper size, so as to force a cake of the damp clay into the crucible and cut off the excess by its edge, and then to finish by luting the edge of the cover and the side of the crucible together. This is to be done before the crucible is luted upon its stand, and the whole is to be well dried before being used. When heat is applied, the internal cover of lute becomes baked, and though it diminishes in size, yet from the form of the crucible, it seldom sinks down to the charge; and if the English external cover

soften and fuse, it is still supported on the former, and generally serves to keep out impurities.

640. When the crucible is of charcoal, or is lined with charcoal, and consequently has a charcoal stopper inside (617), the common cover may be put directly over it and luted; and even in plain crucibles, when charcoal is not injurious, an internal cover of it, formed out of one or several pieces, may be used instead of the plate of lute, and the ordinary cover then put over it.

641. The furnace being clean and in order, and the crucible with its luted cover and stand being dry, the latter is to be placed steadily on the grate of the furnace; a few pieces of lighted charcoal are then to be dropped in, and covered by cold charcoal to the depth of two or three inches, and the whole left until the combustion has spread in the fuel, the air finding a sufficient access through the aperture beneath. When the crucible becomes warm, coke is to be added so as to cover it, and the temporary flue (148) is to be adjusted, to assist the draught. When the fuel is nearly red-hot an inch or two below the surface, more coke is to be added until it rises about two or three inches above the crucible, the flue is then to be replaced, and the combustion is to proceed until the crucible itself is red hot. This will occupy perhaps an hour, and require attention only at the short intervals when coke is to be added. The course described is adapted to the object of raising the heat steadily and gradually to redness; it may be well to explain, that the coke should not be put on until the crucible has been somewhat warmed by the charcoal, to prevent the deposition upon it of the water driven from the coke. Having attained a red heat, the flue must be removed, the bellows applied (164), slowly at first, and more powerfully as the heat rises, until the highest point required, or that is possible, be attained.

642. It is very desirable that the heat should be raised regularly, and sustained steadily. For this reason the blast should not be variable, but uniform. As the combustion goes on the fuel will generally fall freely, but it should be touched now and then by the tongs or an iron rod, in order that, if hollow places should occur, they may be

filled up without delay. The fuel should never be allowed to burn away very low, and then a large quantity of cold fuel piled on, but it should be supplied at small intervals, the top of the crucible never being left uncovered, except purposely, to observe that it has not melted down. Cold fuel should not be allowed to come in contact with it; even bright red-hot fuel will cool a white-hot crucible. All these precautions in heating the crucible, are necessary to insure the fullest advantage that may be attained in the short time which an operation in this furnace generally takes. When the crucible is large, or double, or is lined with charcoal, or contains a considerable charge, it is sometime before it acquires a temperature approaching to that of the fuel on the outside; and if the heat has been raised in an intermitting manner, or if the fuel, after being allowed to burn low has been replenished by cold portions, the furnace may have appeared very hot at times, and yet no proportionate effect be obtained within the crucible.

643. When very high temperatures are required, as in the fusion of platina or rhodium, the crucibles become so soft as to sink and fold like leather, and the results are often lost. This is sometimes due in part to the pressure of the fuel upon the crucible, and may be prevented by hanging a shelter over it. A long narrow English pot, having a mouth a little larger than the crucible to be heated, is to be selected, and a hole made through its bottom; by passing an iron rod with a hooked end through this hole, the pot may be suspended in an inverted position over the crucible and within half an inch of it, thus preventing the contact of the fuel with its top. Care will be requisite that the expansion of the rod and vessel, as the heat rises, should not cause the latter to press upon the crucible. A great depth of fuel is, on these occasions, to be preserved in the furnace round the shelter, to compensate as much as possible for its effect in diminishing the temperature; and this with a little more than common application of the bellows, is always sufficient for the purpose. In this way many crucibles and their contents have been saved, which, from the average of experiments without the shelter, there is reason to believe would have been lost.

644. When an operation in this furnace is considered as concluded, it is best to withdraw the bellows, and to let the temperature sink a little before the crucible is disturbed, otherwise the heat will be unbearable, and the vessel from its softness will be liable to injury. If allowed to cool entirely in the furnace no harm results, and occasionally much advantage.

645. Whether this or any other furnace be used, care is necessary in handling the crucibles with the tongs when in the fire, or in putting them in and taking them out. If heavily laden, and nipped by the tongs at one edge, they should not be held too upright, lest the weight break them. Attention should also be paid that no impurity be communicated to their contents, from the tongs or from the fuel, by aukward handling. If the charge is fluid as in analytical processes, the tongs should never touch any part of the inner surface where the fused matter has adhered, lest it not only convey impurity, but remove a part of the charge.

646. The following general remarks upon the objects of these operations may be useful. If the object be the ignition of a mixture for analysis, or the desiccation of analytical products, then a platina crucible with its cover on, and raised either by the lamp or the charcoal furnace to a moderate red heat, is sufficient. When the substance is to be weighed, or the loss of weight ascertained, the crucible is first to be counterpoised, then weighed with the substance in it, afterwards heated and weighed again, to ascertain if there be loss. The remaining substance is then to be removed, and the crucible weighed for the last time, to see that the counterpoise continues correct. Or if it be a substance to be dried, as silica, it is to be heated carefully, and weighed with the crucible after it has been heated; the substance is then to be removed, the crucible wiped, and the diminution of weight ascertained. In that way the quantity of dry matter it contained may be estimated better than by transferring the substance itself to the pan and weighing it; or if the latter be done, the weight may be verified by the former method: for it is easier to remove and clean *all* the substance out of the crucible, than to put it *all* into the balance pan. If a substance to be fused or dried decrepitate by heat, it should first be

pulverized, or in less precise cases the crucible should be covered. If the object be to observe the changes that may take place in bodies by heat, attention must be paid to the precaution pointed out by Klaproth (628) and others, as to the mutual action of the crucible and the substance.

647. When the end to be obtained is the mutual action of bodies, then the crucible, being charged, is to be heated gradually, fluxes being used as seldom as possible; for although they are very advantageous in cleansing the reduced metal, and assisting its separation from embarrassing impurities, they corrode and weaken the crucible as before mentioned (608). In making alloys, the metals are to be well agitated together; for in some cases, even when apparently miscible and well mixed, there is, as Mr. Hatchett has shewn, a remarkable tendency to separation. * In the preparation of alloys, and the fusion of some metals, it is advantageous to cover the surface of the metal with pieces of charcoal, to prevent oxidation. In these cases a loose cover should be put on after the charcoal, to hinder the access of air, and prevent combustion as much as possible.

648. Fluxes are very frequently required in cases of chemical action amongst metallic compounds at high temperatures, and often cannot be dispensed with. Their use is to protect the substance from the air; to dissolve impurities which would otherwise be infusible; and to convey active agents, as charcoal, and reducing matter into contact with the substance operated upon.

649. *White flux* is made by deflagrating a mixture of equal parts of nitre and cream of tartar in a large earthen crucible, heated red hot at the bottom. The mixture should be introduced in successive small quantities, the combustion of one portion being allowed to arrive nearly to a termination before another is thrown in, or the substance will be blown out of the crucible. That part of the flux which has been in contact with the sides of the crucible, when removed from it, should be separated from the rest, and be kept apart; a little earthy substance being usually derived from the vessel,

* Philosophical Transactions 1803.

which though ordinarily of no importance, may be of consequence in delicate experiments. The flux should be preserved in a closed jar or bottle. It consists almost entirely of carbonate of potash, the nitric acid of the nitre and the combustible tartaric acid of the tartar having both been destroyed; indeed the process has for its object the preparation of a carbonate of potash from the two salts used. This flux disintegrates ordinary earthy or stony matter, dissolves silica, separates acid and sulphur from metals, assists in the oxygenation of many metals, and dissolves many metallic oxides. When charcoal is present it decomposes portions of the flux and yields potassium, which sometimes combines with the metals beneath. Antimony, bismuth, and some other metallic bodies thus become highly alloyed with potassium.†

650. *Black flux* is made from a mixture of one part nitre and two parts crude tartar, deflagrated as before in a crucible, but just hot enough to cause feeble combustion; the result should not be raised to so high a temperature as to fuse. From the quantity of tartar used, this flux contains an excess of charcoal resulting from the tartaric acid, hence it differs from the white flux, with which it would otherwise agree, in containing a reducing agent; the charcoal frequently assists in converting metallic oxides into metals by abstracting the oxygen. The flux yields potassium in the manner before mentioned.

651. *Crude tartar, argol, or cream of tartar*, when decomposed by heat, yields a carbonaceous carbonate of potash. It is used sometimes with advantage as a flux, from the accuracy with which it may be mixed with the pulverized substance whilst in the state of tartar. The intimate manner in which the charcoal and potash of this flux are mixed, causes the evolution of much potassium. The action of these carbonaceous potash fluxes is influenced by the potassium evolved, the reductions frequently depending to a considerable extent upon it.

652. *Nitre* is a salt frequently added to the contents of a crucible for the purpose of communicating oxygen to some

† Serullas Journal de Physique, xci. 123. 170. xcii. 115.

of the metals, and converting them into oxides. Potash is left, which operates as a solvent of the oxides produced, and acts, generally, as the fluxes already described. If the substances present be such as easily combine with oxygen, the nitre should be added carefully and gradually, lest a violeut and sudden action be occasioned.

653. *Sal Enixum* is an acid sulphate of potash formed in the manufacture of nitric acid. It is powerfully corrosive and cleansing in the crucible, and acts at first as an acid from the excess which it contains. This excess is soon either neutralized or driven off, and when charcoal is present, often occasions the production of a sulphuret, which, being injurious in certain experiments, is then to be avoided.

654. *Borax* being an expensive salt, is a flux but seldom used, and only for the cleansing or melting of the most valuable metals, such as gold, rhodium, &c. It is a ready solvent of metallic oxides generally, and yet does not act so rapidly upon earthenware crucibles as potash, or alkaline fluxes containing carbonate of potash. It has little or no action on silver, gold, or platina crucibles.

All these fluxes act upon earthen crucibles, some more than others. They are not used with metallic crucibles except to dissolve adhering impurity, and to cleanse them.

655. *Common flint glass* is a very good flux in many cases, and exerts but little action on earthen crucibles. But it contains much oxide of lead, which is reduced if any charcoal or combustible substance be present, and even by the access of smoke. Many metals, as iron, zinc, &c. and several ores, also reduce portions of the lead, and thus the button beneath becomes contaminated.

656. *Green bottle glass* is a very serviceable flux at high temperatures, but when charcoal is present, it yields iron; even traces of silicium and alumium have been observed in iron, previously pure, after being heated with it.

657. These fluxes are sometimes pulverized and mixed with the ores or other substances to be acted upon before being introduced into the crucible, and sometimes are gradually thrown into the crucible afterwards. The method to be adopted must depend upon the different circumstances

of the substance to be operated with, the flux, and their mutual action. It is necessary that care be taken upon first introducing the crucible into the fire that the heat and action be moderate, lest from the ebullition which always takes place in consequence of the liberation of either gas or moisture, a part of the flux should flow out, and thus a portion, even of the valuable part of the contents, be lost. As the ebullition diminishes, more of the mixture (if any remain) may be added, and when all is in, and the charge is less agitated, the heat may be raised until the metal be fused; or if an action is going on, until the flux itself become quiet and tranquil; a result which generally indicates that the chemical action has ceased.

658. In consequence of the very common occurrence of metals in the state of oxide, their deoxygenation is most frequently the object of a crucible operation, and carbon in one form or another is the agent generally resorted to. It is for this reason that tartar and black flux are so valuable as fluxes. Charcoal is frequently added to the oxide to be reduced, in quantity greater than that contained in the flux; sometimes indeed no flux at all is used, it being actually injurious from its affinity for oxides, and from being in opposition to those affinities which assist in reducing the metal. A charcoal crucible, or a crucible lined with charcoal, is useful for the reduction of some oxides, as that of iron for instance,* and also for the deoxygenation of sulphates and their conversion into sulphurets;† but in other instances, when the oxides are infusible, and yet cannot be thus reduced by cementation as it were, the charcoal may be pulverized and mixed with the oxide, and the mixture introduced into the crucible. In these cases it is generally best to use a crucible lined with a thin coat of charcoal.

659. There are several substances which occasionally surpass charcoal as reducing agents; sometimes because they mix more intimately with the oxide in powder, and at others because they either are fluid, or melt when heated; and being absorbed, are present every where in the mass, and when de-

* Berthier. Annales de Chimie, xxvii. 24. † Journal des Mines. vii. 421.

composed leave charcoal wherever they have had access: but they should be such substances as bear a high heat without being dissipated, or when decomposed leave much carbon. Of this kind are starch, gum, sugar, wax, spermaceti, oil, fat, tar, and pitch.

SECTION XIV.

Furnace tube operations.

660. The operations to be described in this chapter are such as require a high temperature, like those just referred to, but being performed with substances in either the gaseous or vaporous state, require another description of apparatus, for their confinement and subjection to the necessary heat. The vessel now adopted is a tube, and by its means either gases or vapours may be simply subjected to great heat, or they may be passed over solid or fluid bodies previously raised to a high temperature. On both these accounts the methods about to be described are very common and useful.

661. Different tubes are required for different occasions. They are frequently made of earthen-ware; these resist a high heat, except that they are liable to crack in the fire; but this fault may in part be guarded against by previously luting them, for the reasons and in the manner directed with respect to stone retorts (455, 996). In addition to the directions there given for luting, it may be observed, that with respect to tubes, the lute, after being put on as stiff and as tightly as possible, may be surrounded by a long slip of sampler or open canvas, running round it in a spiral manner, so that each fold may overlap the last (1005): this will retain the lute in its place during desiccation, and prevent the occurrence of cracks.* The porosity of earthen-ware has been before mentioned (453, 455), and if necessary must be guarded against as much as possible by washing the tube with borax, &c. as already directed (455). But when the loss

* Mr. Cooper's Practice and Suggestions.

of a part of the gas is of little importance, when passed into the tube to operate upon the substance within, without reference to quantity, then the porosity of the tube does not much interfere. Wedgwood's tubes are of pure ware, but very liable to crack. Tubes of the same material as that used in the manufacture of common English crucibles are not so subject to this failure, but are more porous. Black lead tubes, or such as are made of a mixture of clay and plumbago, are least liable to crack of any, but sometimes communicate iron, and are very porous. These tubes are frequently bent into the form of a narrow U, when they may be readily introduced into the mouth of a common furnace, the two ends and apertures being outwards, and close together. When straight it is advantageous to guard them in the furnace by a semi-cylinder of tin-plate, and at times they are conveniently strengthened by being passed through a cylinder of plate-iron, roughly turned into a form which may serve as a casing.

662. *Iron tubes* are constantly useful. A gun-barrel, when convenient as to size, answers the purpose very well. When larger or smaller tubes are necessary they must be forged for the occasion. If required for a long operation, or at a temperature above a red heat, they should be protected from the fire either by luting (661) or by being passed through a black lead tube. Iron tubes are generally adapted for the decomposition of organic substances, as oils, &c. or water, or potash by charcoal or iron, or of gases that have little or no action upon the metal, as ammonia and carburetted hydrogen.

663. A platina tube can scarcely be dispensed with in the laboratory, because of the very high temperature it will bear, and the few instances in which it interferes with the substance passed through it: substances may be heated together in it which cannot be so treated in any other kind of tube. Chlorine, sulphur, and the metals, are almost the only bodies which affect it; oxygen and acid gases have no power of action on it. Those are best which are drawn, and have no joint down the side, but they are the most expensive. Those which are turned or bent, and soldered with gold, will

not bear the high temperature of the former, and it is impossible to make a joint without solder, which will continue tight. The platina tube may often be used with advantage as a retort, by the adaptation of a plug to one end, which may be removed or replaced at pleasure.

664. A bored copper tube is frequently used when a platina tube is not at hand, but it is limited as to the temperature it will sustain, and also as to the substances which may be passed through it.

665. Glass tubes are perhaps the most generally useful of all. They allow operations performed in them to be watched up to a red and even a yellow heat, and some kinds of glass resist the action of most chemical agents likely to be brought into contact with them in this form. The best tubes are those made of green bottle glass, they require care in heating, but resist the action both of heat and chemical agents much better than those of flint glass. The latter include in their composition both alkali and oxide of lead, substances which are liable to be acted upon in many experiments. They soften also, and are easily expanded, and collapsed at a red heat, but to compensate in part for these bad qualities, they may be obtained any where, whereas green glass tubes are very scarce. When of small size they are readily bent into form, and arranged by a spirit-lamp and mouth blow-pipe. Glass tubes may, like those of earthen-ware, be strengthened by luting, but it is generally so desirable to witness the action going on within, that a semi-cylinder of tin-plate, or of earthen-ware, will be found a more advantageous support.

666. The method of connecting these tubes, when in the furnace, with parts of other apparatus by which the gas or vapour is either to be introduced or conveyed away, must vary with the substance of the tubes. They should be of such length as to leave the ends projecting sufficiently far from the furnace, to be either of moderate temperature, or to allow of the application of cooling processes, which however should only be applied to metallic tubes, and then with caution. When the tubes are metallic, terminating pieces with ground joints or screws may be brazed or welded on, and thus junctions are easily effected; and in these cases

if the ends be hot, washers of card should be applied at the screw (778), and not such as are made of oiled leather; for the latter gradually decompose and become unsound. It is often of use in operations with the gun-barrel, to terminate it at each end by a stop-cock, of which the outer extremity has been formed into a ground socket; perforated wooden plugs, formed at one end so as to fit tightly into these sockets, and at the other into a screw, may then be used as adopters; while they complete the junction, they prevent the transmission of heat.

667. If the tube be of earthen-ware or glass, and the extremity be cool, the junction may be effected by fitting on a cap (780), or by a perforated cork, or by caoutchouc connectors (416), or by any of the processes already described, or to be described in the *sections* on gaseous manipulation, and on lutes and cements. If the terminations be hot, the object must be attained by applying some of the methods described in the latter *section.*

668. When vapours are to be passed through a heated tube, it will be necessary to generate them in a little boiler or a retort, connected with one end of the tube. In such a case the joint must be capable of bearing the heat requisite for the existence of the vapour, and the neck of the retort and the associated part of the tube should be wrapped up in flannel or paper (439), that loss of heat and consequent condensation of the vapour there, may be prevented as much as possible.

669. The adaptation of furnaces to the heating of these tubes will be readily understood. When crucible furnaces are used, the tube should be placed in two notches (143) cut in opposite sides, so as to bring the upper part of the tube below the level of the edges, and the grate should be raised to within one inch and a half of the tube itself. If one furnace be scarcely wide enough to heat a sufficient length of tube, a second may be arranged by its sides, the tube passing through the notches and lying over both. It is easy, by piling the charcoal over the edges of the furnaces where they touch, to heat the tube there; and a brick or tile, or

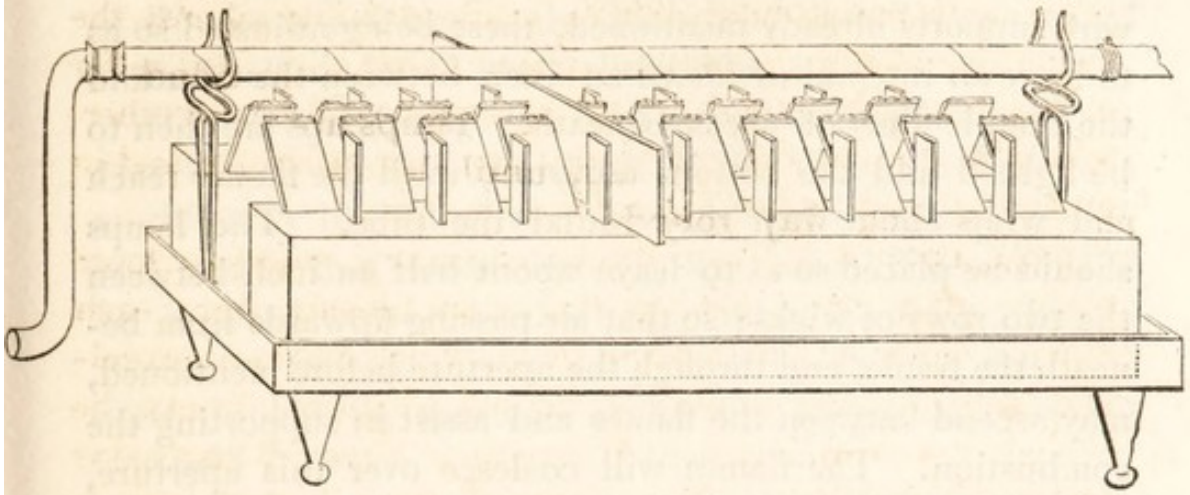
other body should be put on each side, bearing against the two furnaces, for the purpose of interfering with, and as far as may be, preventing the current of air, which will otherwise pass towards the junction of the two crucibles, and in ascending tend to cool the tube at that part.

670. By placing two bricks edgeways, across a loose square grate, four, five, or six inches distant from each other, a space is left between them, which makes an excellent tube-furnace; it may, by the use of several bricks, be arranged to heat any desired length of tube. Charcoal is to be the fuel used. But, when a much higher heat is necessary, and even the application of a blast is required, as in the preparation of potassium, it is better to build up a temporary furnace with bricks and mortar, setting the tube in its proper position in the course of the work; and as the brickwork is not required, nor is likely to be, of much durability, it will be safe, before putting a fire in, to tie it round with iron wire. When the heat is to be raised to a high degree, it will be proper to introduce a stay or two, pieces of black lead tube for instance, as supporters to the lute.

671. A small piece of glass tube may be heated in a spirit-lamp, and a greater portion in the oil-lamp (189). The tube may either go through holes in the sides of the chimney, just above the top of the flame, or it may be bent thus ⌇ so as to pass down the chimney, until the lowest part of the tube is just above the flame. The concentric double-wick oil-lamp (190), or the large spirit-lamp (182. 183) answers for these purposes very well.

672. The lamp which surpasses all others for the ignition of tubes, is that invented by Mr. Cooper,* and figured in the accompanying wood cut. It consist of a frame ten or eleven inches long, which, being raised upon four feet, has an aperture from end to end of 0.8 or 0.9, of an inch in width. It is furnished at each end with a wire support, adjustible

* Transactions of the Society of Arts, xli. p. 56. Quarterly Journal, xvii. p. 232.



in its height, and bent at the top into a convenient form for retaining a tube in a horizontal position. The lamps are two in number, and stand on the frame, one on each side the aperture. They have each ten burners passing obliquely upwards from one edge and inclining towards those of the other lamp, over the aperture before mentioned. Each burner is 0.8 of an inch in length, half an inch wide, and about that distance apart from its neighbours, and the lamps may be put so near to each other as to leave the two sets but little asunder, or they may be removed to a greater distance from each other. Small uprights are fixed on the top of the lamps between the burners: there is also a feed-pipe to each lamp closed by a cork, and each burner is furnished with a cap, to cover it and prevent the evaporation of alcohol when the lamp is not in use. The whole of this apparatus is made of tin-plate and iron-wire.

673. The trimming of the lamps is performed by selecting some straight Argand lamp cottons, and cutting off so much from both edges of the folded cotton as will divide it into two pieces, each of proper width to pass down the burners. The waxed end is introduced first, and the cotton thrust in until it touches the opposite side at the bottom; this is easily done, and then the excess of cotton above is to be cut off with scissors. The caps are then put on, and alcohol introduced at the feeding aperture, until the lamps are two-thirds or three-fourths full, when they are ready for use.

674. A platina tube of half an inch in diameter may be heated to full redness by this lamp-furnace in a few minutes. For this purpose it is to be sustained at the two ends by the

wire supports already mentioned, these being adjusted so as to leave an interval of about an inch between the tube and the double line of wicks beneath. The lamps are then to be lighted and the cottons adjusted, until the flames reach and wrap about half way round the tube. The lamps should be placed so as to leave about half an inch between the two rows of wicks; so that air passing upwards from beneath the frame, and through the aperture before mentioned, may ascend between the flames and assist in supporting the combustion. The flames will coalesce over this aperture, and also from side to side, so as to furnish a powerful and continuous line of intense heat, by the time they have ascended to the tube. By uncovering and using only so many wicks as are beneath, and proportionate to, the part of the tube to be heated, a certain part of its length may be subjected to a high temperature at once.

675. It is desirable in numerous cases to apply the flame successively from one end of the tube to the other. On these occasions the operation must commence with all the wicks uncovered. As many are then to be lighted as may at first be requisite, and to prevent the combustion from spreading to the contiguous uninflamed wicks, a slip of tin-plate, about three-fourths of an inch high, is to be placed across under the tube, and supported by the burners and the upright pieces (672) already mentioned. The heat having been continued sufficiently long on the one part, the temporary tin division is to be removed farther on, more wicks are to be lighted, and if any of those at the opposite end are now unnecessary, a similar plate of tin should be put between them and those which are still to continue in combustion, and the former extinguished by a sudden slight puff of the breath.

676. Mr. Cooper has occasionally constructed the lamps in such a manner, that each burner has its separate receptacle of alcohol, so that in place of one long lamp like that described, it appears to consist of many small lamps, standing side by side, but independent of each other. When only a part of the tube is to be heated at once, a few only of the lamps are lighted, and these, without using the rest, are

easily moved one way or the other, and their flames applied successively under all parts of the tube.

677. The lamps cannot heat a greater length of tube at once than is equal to the length of the frame: but there is no difficulty in putting two or more frames together end to end, and in that manner igniting any extent of tube. If it be required to heat a tube longer than the frame, but in successive portions, it is easily done by shifting the tube itself through the apertures in the wire supporters by which it is held (672).

678. When small metal tubes, or moderately sized tubes of glass are to be heated, a single row of wicks is required, which must be advanced a little nearer to the edge of the aperture, that the flames may rise up just beneath the tube. Green glass tubes are constantly in use with this apparatus, and in some cases, when the advantage of seeing the interior is of no consequence, it is advisable, for many reasons, to inclose them in a tube of copper foil; this supports the glass when so hot as to become soft, confines and prevents it from being expanded into bulbs by the pressure of gas within, and assists in conducting the heat uniformly over the tube. It also conveys heat to those parts of the tube not yet subjected to the flame, and by gradually warming, prepares them for its application; so that no sudden change of temperature is ever occasioned, and the tube is consequently more safely heated. This external case is made of a slip of copper foil, about an inch or an inch and a half wide, and so thick that twenty-five or thirty folds squeezed by pincers may be equal to about the tenth of an inch. The foil, after being flattened, should be rolled up tightly into a small cylinder, bound with a piece of wire, and heated to dull redness for a moment, to destroy the degree of rigidity given to it by pressure between the rollers. Being then cooled and opened out, it is to be wrapped close round the part of the tube to be heated in a spiral, one fold over-lapping another at the edge. When so much of the tube is enveloped as is required, the extra length of foil is to be torn off, and the end kept tight upon the tube by a turn or two of thin wire. The case thus formed is more or less thick, and consequently strong, in proportion

to the degree in which the turns are folded over each other. If a fold overlap the previous one by one half, then the case will be of double thickness; if it overlap two-thirds, of triple thickness; if it overlap but a little at the edges, the case will consist of little more than a single thickness of foil.

679. Glass tubes, whether guarded in this way or not, generally require support in the middle to prevent them from bending. This support is given by a moveable stand, made of a piece of iron wire fixed perpendicularly into a leaden bottom, and terminating above in a loop or ring, or sometimes in a crutch. This wire passes up the aperture between the lamps, and may be moved along the tube between the flames into the most effectual or convenient position. Even short pieces of tube closed at one end may be supported by means of it and heated; it is also useful in the arrangement of other tubes as well as those which are straight.

680. When gases or vapours are to be passed through tubes at high temperatures, for the purpose of effecting their decomposition, it will be advantageous to increase the surface of contact, and also to break the uniformity of current within. Broken rock crystal, or broken flint, answers this purpose very well with glass or earthenware tubes. The crystal or flint should be divided in a mortar into coarse particles, if the tube be large, or if much deposited matter be expected from the decomposition; or into smaller, if the tube be small, or if but a slight action, accompanied with little deposit, be anticipated. A crumpled piece of wire should be thrust into the tube near to one end, a few large pieces of the broken substance dropped in at the other to rest upon the wire, and afterwards, that which is considered of a proper size is to be poured in. If two or three larger pieces, and then more wire be added, they will retain the charge in its place; but the wire should be such as will not injure the experiment, for which reason also, it is better to place it generally out of the heated part. Platina wire answers the purpose for small glass tubes, and will rarely occasion harm.

681. Some substances have singular powers in influencing the decomposition and even combination of gaseous bodies

and vapours, although they have no apparent tendency to combine with either the compounds or their elements; and it is for this reason that tubes of different substances operate differently upon the gases passed through them. If ammoniacal gas be passed into a red hot iron tube, it will be easily decomposed into nitrogen and hydrogen gases; but if it be passed through a glass tube, as Gay Lussac has shewn, it resists an equal and even a much higher temperature, with scarcely any change. This effect, thus produced by different substances, may be taken advantage of without the necessity of having tubes formed of these materials, it being sufficient to introduce them into glass tubes in the manner before described for rock crystal (680), and it will be found that a glass tube charged with broken iron turnings, will as effectually cause the decomposition of ammonia as one of iron.

682. The power of spongy platina is such that it occasions the combination of oxygen and hydrogen, even at common temperatures, producing ignition and explosion. When mixed with earthy bodies, to diminish this action, it is found to be again increased by elevation of temperature. Spongy platina also causes the union of oxygen and oxide of carbon at common temperatures; the decomposition of nitric oxide by hydrogen; and the combination of both the elements of olefiant gas with oxygen, at temperatures above 572°. For further illustrations of this power of the metals, see Dulong and Thenard's paper in the Annales de Chimie, xxiii. 440.

683. The vapour of water passed over iron heated in tubes is decomposed, the metal becomes oxidized, and hydrogen gas is evolved. In this case the higher the temperature, the more rapid is the action. The steam should be raised from a small boiler, and not in too large a quantity, as it tends to cool the tube considerably. If one-third or one-half of what is passed into it be decomposed, it is in sufficient proportion. The iron for small experiments may very conveniently be clean turnings, beaten into small pieces in a mortar. They lie close, expose much surface, and keep open a free passage for air.

684. The vapours of alcohol and ether may be decomposed in a similar manner: iron assists but is not necessary, but rock crystal, or some substance affording surface (680) should be introduced. The results vary with the temperature. Nearly all the vapour that is sent in should be decomposed. It may be generated in a little boiler, or in a flask or retort, and caoutchouc junctions may be used, even with ether.

685. Olefiant gas, nitrous oxide, and some other gases, are decomposed by being passed through heated tubes. If the general facts only are to be observed, the gases may be introduced from the retort evolving them, or forced in from a bladder or an air-tight caoutchouc bag (769, 770), and the contents may even be received in similar vessels at the other end of the tube: but if accurate experiments upon precise quantities are required, then two mercurial gazometers should be connected with the tube, that nothing may be lost.

686. Many oxides may be reduced in part or entirely when heated in tubes, by passing certain gases or vapours over them. Protoxide of manganese is best obtained in this way from a pure peroxide, or from the oxide precipitated from a pure salt; hydrogen passed over it at a red heat reduces every particle to the state of dry protoxide, and the progress of the change from one end of the tube to the other is beautifully exhibited. Oxides of titanium, tungsten, chromium, iron, &c. are often usefully treated in this manner; and besides hydrogen, other reducing agents may be used. Ammonia has equal power with hydrogen, and sometimes, from the nascent state of the hydrogen in it, is superior to the pure gas. The vapours of alcohol, ether, naphthaline, and camphor, may be used, where it is probable that carbonaceous matter will favour the desired effect.

687. Many *combinations* are effected with great advantage in a heated tube. Thus oxygen is easily combined with baryta, and the peroxide of barium formed. The heat should be a dull red; no oxygen will pass till the whole of the earth is peroxidized. In such cases the end of the tube at which the oxygen passes out, does not require to be connected with any apparatus: a glowing match should now and then be applied to it, and when the presence of pure oxygen is evident, the operation is finished.

688. Sulphur may be combined with platina, and phosphorus with lime, in a tube apparatus, with great convenience. The platina in the spongy state, or the quick lime, are to be placed in the tube, and heated to dull redness; the tube should be slightly inclined, and the higher end lengthened so far from the furnace or lamp, as to be only warm. If turned up, it is an advantage, and the aperture there should be fitted by a good cork. When the tube is sufficiently heated a piece of sulphur in the one case, or a piece of phosphorus in the other, is to be dropped or thrust in at this end, and the aperture immediately closed by the cork. A small spirit-lamp flame will melt the substance, and cause it to run down to the warm part, where it will gradually become vapour; and though a part may distil back (which is of no consequence) the greater portion will be sent over the platina or lime within: the progress of the change will easily be observed. When the first portion of substance has combined, a second is to be introduced; the aperture being rapidly opened and closed, so that no current may be allowed to occur in the tube, and this process is to be continued until the substance within is entirely converted into sulphuret or phosphuret. Great care is of course required in handling the phosphorus; pieces not more than one-third or the half of an inch in length, should be introduced at once into tubes half an inch in diameter. They should first be dried, then dropped in rapidly by a pair of forceps, lest the temperature of the tube should be sufficient to inflame them. In wiping phosphorus dry, it should be rolled between two or three folds of cloth or filtering paper, every part of its surface being pressed but not rubbed; and when thus dried, it must not be held in the uncovered hand, but be inclosed in cloth or paper, and be taken out from them by the forceps. This is to be done at some little distance from the furnace or lamp, and when the phosphorus is carried towards the heat, the operation should be conducted quickly though steadily, that no time be allowed for the temperature of the substance to rise so high, as to cause its inflammation before it be in the required situation.

689. Titanium may be combined with chlorine by passing

the gas over the metal in a heated tube.* The alkaline earths may be decomposed by passing chlorine over them in the same manner, oxygen being then evolved, and their bases remaining combined with the chlorine:† numerous other chemical actions of the most important kind may be effected by this mode, in a manner the most convenient possible for observation. When the substance used and the results produced are equally fixed, small platina trays, formed by doubling a piece of foil, may be used for containing them; they are easily introduced into the tube and withdrawn again by a wire bent into a hook at the extremity. Every facility is afforded for conducting away the results, whether solid, fluid, or gaseous; and in by far the great number of cases, those excellent flexible connectors formed of caoutchouc (416), are of perfect and easy application.

SECTION XV.

Pneumatic Manipulation, or Management of Gases.

§ 1. *Pneumatic troughs, jars, &c.*

690. The first apparatus necessary for the experimental practices to which this chapter relates, is the pneumatic trough, with its accompanying jars. We are indebted to Priestley for the invention of this useful vessel, and for much of the apparatus which is used in conjunction with it.

691. The common pneumatic trough is a vessel constructed so as to retain water, and of such dimension that large jars may be filled in it; and it is furnished with shelves or supports beneath the surface of the water, on which jars may firmly stand. The trough is frequently so contrived, that the shelf is of considerable extent, and the deeper part, which may be called the well, made of such dimensions as just to allow the filling of the largest jar

* Mr. George, Annals of Philosophy, N.S. ix. 18.

† Sir H. Davy Phil. Trans 1811, p. 12.

required for use. This is of no consequence as regards the level of the water, and its alteration by filling jars, and raising them upon the shelf; but it is of importance that the well should be sufficiently large. There should be width and breadth enough for two or three jars to be immersed at once, and sufficient depth to permit the inversion of any jar or tube beneath the surface, likely to be in use at the trough. The shelf also of the large trough should be of sufficient size to hold several jars of gas at once. If the surface of water be 19 inches by 28, and a well be formed at one end of 14 inches by 10, and 12 inches in depth, so as to leave a continuation of the shelf surface on three sides of the well, of two inches and a half in width, it will be found sufficiently large for almost every purpose.

Such a trough is best made of japanned copper, and supported in a wooden frame, so as to stand about 39 inches from the ground. Two depressions like small wells, should be made in the shelf, each about seven inches long, two wide, and one and a half deep; they should be placed with one of their narrowest ends about one inch and a half from the end of the shelf which is furthest from the well, and about eight inches apart. These depressions are to receive the beaks of retorts delivering gas into jars placed over them; and it is advantageous to have a flap fixed to this end of the trough frame, which, turned up or down at pleasure, may be used when there is occasion to support a retort stand or other apparatus required in the evolution of gas. This trough should be filled with water until it is one inch and a quarter or one inch and a half above the shelf. A stop-cock should be fitted into the bottom of the well, by which the water may be drawn off when it has become acidified or dirty.

692. These principal troughs are sometimes made of wood, but never with advantage, because of their complexity of form, and the consequent difficulty of keeping the numerous joints tight. They are often on a smaller scale, and when the chemical establishment altogether is small, are then more in proportion to the rest of the apparatus. A very useful and usual table trough is of a circular form,

and about two feet in diameter, internally divided into three parts; the middle part is seven inches deep, and forms the well, the other parts on each side four inches deep, and are the shelves; a moveable shelf with holes in it, extends from side to side across the well, and serves to support such jars as are receiving gas from the beaks of retorts placed under the holes.

693. Besides a principal trough, several smaller ones are required for the preparation of particular gases, as for example, chlorine, when warm water is required, or sulphuretted hydrogen, which contaminates water, and would discolour metallic troughs. These may be either of metal or earthenware, and need not have fixed shelves. An earthenware foot-bath makes an excellent trough; and even a wash-hand basin, or moderately sized evaporating pan, is at times sufficiently large, very portable, and offers advantages.

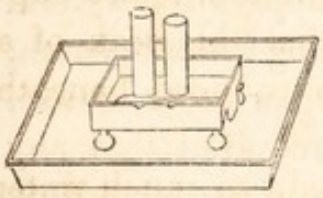
694. Trivets are used with these smaller troughs to support the jars. They are best made of cast-iron, in the form of very open grates, either square or round, and raised by means of three or four feet; they should be of different heights, from half an inch to two inches, and when very dry should be covered with a good coat of black varnish, or made hot almost to visible redness, and then brushed over with oil; the oil is in this way decomposed, and leaves the metal covered with a very permanent varnish. These trivets answer the purpose of shelves when required, and also support the jars when filled with water, so that the beak of a retort, or the end of a tube, may be introduced beneath them.

695. When the small troughs are used, so much water must be present as at all times to cover the trivets an inch or more in depth. Small and narrow jars may be filled in them with water, but larger jars are generally filled more conveniently at the large trough, or in a pail, and then transferred in the manner to be shortly described (712). If during their use the water rise so high in them as to endanger the steadiness of the jars containing gas standing in them, a part must be removed. The facility with which extemporaneous troughs may at any time be contrived, will

be evident from what has been said relative to these smaller arrangements.

696. Water troughs are calculated for the reception and retention of gases not soluble, or alterable by water, but not for the many which are affected by that fluid. Dr. Priestley was the first who, in these cases, recommended the use of mercury; and though its weight and opacity are disadvantageous, that metal is still so superior to any thing else, as to be constantly used in these cases. Being expensive as well as heavy, it is necessary that the troughs in which it is used should be as small as possible, consistently with the performance of experiments, and at the same time of a material that will resist the action of the metal. They have been made of wood and of marble, but varnished cast-iron, which is now generally adopted, is by far the best substance. In principle and in the arrangement of the parts, they resemble water troughs. Newman's large mercurial trough will allow the use of a jar two inches and two-tenths in diameter, and nine inches in length; it has seventy-six square inches of shelf room very well arranged, and has also a mercurial gasometer attached to it at one extremity. It requires from 60 to 70 lbs. of mercury for the free performance of experiments.

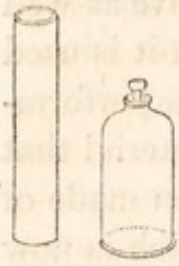
697. Newman has also a much smaller trough for the use of jars 1.5 inches in diameter, and six inches in length, though in a confined manner, and having only thirty square inches of shelf room. It requires 20 lbs. of mercury to fill it, with a jar standing on the shelf. When working with jars of gas over this trough, the metal requires transferring backwards and forwards, because of the difference in level made by the descent or the elevation of a jar-full,—but it is very useful in facilitating operations on small quantities, either in tubes or small jars.



698. A mercurial trough should always stand in a tray, and should likewise have a cover to keep out dust and dirt, when not in use. Its place, as before described, should be upon the table groved round the edge (9), that waste of mercury may be avoided as much as possible. If only occasionally in use, it is better to keep the mercury in stone

bottles, than by constant exposure in the trough to render it liable to accidents and loss.

699. The jars which accompany, or are required with, pneumatic troughs, are of various kinds. *Plain jars* should be from twelve to sixteen inches in length, two and a half or three inches in diameter, and of such thickness as to withstand the general liabilities of use (about one-eighth or one-tenth of an inch), and ground at the edges, so as, when moistened or greased, to be closed accurately by a flat glass plate. Those for the mercurial trough should be from four to eight inches in length, one and a half or two inches in diameter, and as thick as the former, that they may safely bear their weight of metal when filled and in use. They also should be ground at the edges.



700. *Stoppered jars* have an aperture above, fitted with a ground-glass stopper, and resemble stoppered bottles without bottoms. They are required of different sizes, and should be larger in diameter than the plain jars; the proportions may be gathered from the figure in the preceding wood-cut. Such as are less than three inches and a half in diameter, should be ground at the lower edge, and all ought to be ground flat at the top, for the convenience of closing them occasionally by a glass plate, instead of the stopper. It is useful in public laboratories, and often in private ones, to have a second set of stoppers for several of these jars, the stoppers having a projecting knob beneath, to which a deflagrating spoon, or a taper, or other article, may be attached by a wire. When it is required that any one of these should be introduced into the gas already confined in a jar by the first stopper, it is to be attached to the second, and introduced rapidly after the removal of the first stopper, and the jar closed by the stopper to which it is suspended. When these second stoppers are not at hand, corks will often answer the purpose very well, the wire which supports the article introduced, being thrust through them: but being combustible, they will not answer for deflagrations in oxygen gas, unless their lower surfaces be previously guarded by a plate of

lead. A good cork will occasionally form a very tight and excellent stopper to an open jar which has not been ground.

701. The stoppers of jars, and indeed all ground-glass stoppers, should be of considerable thickness where the lower and upper parts are connected; for sometimes considerable strength is required to loosen them from their places, in consequence of difference of temperature, or the desiccation of some substance around them, or other circumstances. For the method of loosening stoppers thus fixed, see Sect. xx. (1156). Stoppers should never be put into pneumatic jars without having been previously touched by a little pomatum or tallow (400), so as to make them fit easily but closely, and this should be renewed whenever from use or cleaning there is occasion for it. Neither should they be put into jars or bottles in a heated state, the latter frequently then contract on the stoppers, and it becomes almost impossible afterwards to move them.

702. *Capped or transfer jars*, are such as being open above, have a cap cemented upon them, the latter being surmounted by a stop-cock. They allow of easy communication by adopters and screws, with other apparatus. They should be of four or five different sizes, and a large and a small one should be graduated. A small capped jar or two should be provided for the mercurial trough, of the dimensions before given (696). These jars should often be examined, to ascertain the tightness of the cap and stop-cock, by which they are closed. This is best done by nearly filling them with water or mercury, according to the trough to which they belong, without moistening the stop-cocks, placing them on a steady part of the trough, observing where the level of the water or mercury stand inside, and leaving them for half an hour or an hour. If at the end of that time the level be unchanged, the jar is tight, and in that respect in order.



703. The lipped glasses before described (343. 469) both large and small, are very useful as jars when operations are carried on at the small troughs, or with small quantities of gas;

and tubes closed at one end will frequently be required for the same purposes. These tubes may be of any length less than 10 or 12 inches, and of any diameter; some may be plain, but several should be graduated (114) for the estimation of small quantities of gas. Those which are too wide to be closed perfectly by the finger, should be ground at the edge so as to be closed, when required, by a glass plate. The others should be level, or nearly so, at the mouth, and not irregular from bad cutting or from fractures.

704. None of these vessels when cracked should ever be used at the mercurial trough, for they are not only rendered very weak and are easily destroyed by a slight blow near the cracked part, but mostly suffer the gas to pass slowly through the fissure. They should rarely be used except in very common experiments, at the water-trough; for, notwithstanding cracks when moistened are frequently air-tight, though not so when dry, yet they as often leak, especially when the water does not adhere to their surface, or when the gas within is subjected to those sudden movements which frequently occur in experiments; besides these risks, the jars are easily broken, and the gas consequently lost.

705. In addition to the vessels already described, small and moderately sized funnels, with narrow necks, will be required to assist in the transferrence of gas into vessels having narrow apertures; and dishes will be necessary for the removal of jars containing gas, from one place to another. These dishes may be of glass or earthenware, as evaporating dishes (344), or of metal, being then best made of sheet copper, with a flat bottom and upright edge. Even common soup plates and tea saucers will answer the purpose extremely well. The glass plates before referred to (700. 1234) are in constant use in closing the mouths of such jars as, not being too large, have ground edges.

§ II. *Production, retention, and transference of gases.*

706. The manner in which gas is evolved is very variable. It is frequently liberated during distillations in iron, earthenware, or glass retorts: these processes have been described, and all that is now necessary to be referred to is the fact,

that such apparatus must terminate in a beak, which may either be directly plunged into the fluid of the pneumatic trough, or lengthened by a tube which may have its extremity placed in a similar situation. Gas is sometimes produced by tube operations (666, 680, &c.), and the manner of leading it away by tubes to the trough will be evident. When the liberation of gas takes place at common temperatures and immediately the materials are in contact, as of hydrogen from diluted sulphuric acid and zinc, or of carbonic acid from muriatic acid and pieces of marble, then glass retorts are sometimes used, and on other occasions gas bottles and flasks. The adaptation of retorts to these purposes is simple and evident. Gas bottles are vessels intermediate in their character between flasks and bottles, being thickened at the neck and having pieces of bent tubes ⁀ fitted to them by ground joints; the bottle therefore represents the body of a retort, and the bent tube the neck. When the materials are introduced, the tube is put into its place, and its open extremity immersed in the water of the pneumatic trough. When a common Florence or white flask has to perform the office of a generator, it must have a piece of bent tube fitted to it by a good cork (448), and this will answer every purpose required.

707. The open neck or tube by which the gas is ultimately delivered, whether it belong to a retort, a tube apparatus, or a complicated arrangement of vessels, is to be immersed in the water of the pneumatic trough. When the vessel is a mere retort or gas bottle, it is easily arranged in a convenient situation, being supported in its place by a stand (359); and moveable apparatus of any kind may generally be arranged on a table near the trough, so as to have the necessary juxta-position. If from circumstances the apparatus disengaging gas is fixed, and cannot be brought to the trough, as may happen for instance in the distillation of oxygen gas in an iron retort, or in complicated experiments of research, then either the neck must be prolonged by connecting tubes of glass, or small pneumatic troughs must be used; these, being portable, may easily be placed in the vicinity of the apparatus. It is often necessary in these cases

to collect large quantities of gas over a small trough; and this is easily effected by transferring the jars (712) as they are filled, to the larger trough, and replacing them by such as are filled with water.

708. A prime object in preparing gases is generally to collect the pure portions only; and it becomes necessary to expel the common air of the retort or gas bottle, before the particular gas is collected. For this reason the first portions may be thrown away; but as a general rule, it is better that these should be collected in a jar, and then rejected, rather than, by leaving the beak of the retort exposed to the air, to allow them to escape at once into the atmosphere. By collecting them, it is known when twice or thrice the contents of the retort has passed out; after that, the gas may be collected for use: by suffering them to escape from the beak, the estimation of the quantity rejected, and the probability of the air being all displaced, is vague and uncertain. When a quantity of gas has been allowed to escape, sufficient to justify the opinion that what is afterwards evolved is nearly or quite free from air, the future portions may be collected in jars for use, as is immediately to be described; but the order of these jars should still be attended to, for which reason it is well to mark them one, two, three, four, &c. as they are filled, and then, in case a portion of gas perfectly free from atmospheric air be required, the third or fourth jar may be resorted to instead of the first or second.

709. On other occasions it is important to collect *all* the gas that may be evolved, that its quantity may be measured. It is then frequently necessary to collect every bubble of gas that comes from the retort, including the common air itself. After having estimated the whole of the gaseous products, the capacity of the retort, and the volume of solid or liquid matter it may have received as a charge, it becomes easy to ascertain the volume of air, and consequently the volume of pure gas evolved. In this case the jars are to be numbered as they are filled; for though the first contains much atmospheric air, and perhaps also the second a little, the others are filled with a pure gas, which may be preserved for use. The operation of collecting and estimating the whole of a

gas is delicate, and requires considerable variation, according to the nature of the gas, and the bodies from which it is to be evolved. These points would be improperly introduced into the description of elementary operations, but will be referred to again in a more advanced part of the volume.

710. The trough being filled with water as before described (691. 695), and the apparatus and arrangement ready for the evolution of gas, a jar is to be selected, which we will consider for the present as a plain one (699), and being immersed in the water of the trough with its mouth inclined a little upwards, so as to allow the air to escape, it is to be filled with water. It is then to be raised upright with its mouth downwards, and it will be found to remain full of the fluid so long as the mouth is retained beneath the surface of the water; it may in that situation be placed upon the shelf of the trough, or upon a trivet. If it be placed over an aperture in the shelf, or with its edge projecting a little way over the well, there will be no difficulty in so conducting the beak of the retort, that the bubbles of gas escaping from it shall ascend into the jar, and, accumulating at the top, gradually displace the water, which will descend and mingle with that in the trough. When the jar is nearly full of gas, a second is to be depressed in the well of the trough, filled with water, placed on the shelf by the side of the first, and when the gas in the first is within half an inch of the mouth, it is to be moved on one side; the second is then to occupy its place, and to be filled in like manner with gas. Or if the retort or vessel be moveable and the jars large, it will be better to place the second jar over another aperture, or projecting conveniently over the edge of the shelf, by the side of the first, and to transfer the beak of the retort from the first to the second, rather than to endeavour suddenly to move them: then after displacing the full jar, the final adjustment of the retort and second jar may be leisurely made. In this way jar is to succeed jar, until the action in the retort has ceased, or until sufficient gas has been collected.

711. The filling of the jars with water in the well of the trough, must be so conducted, that none of the air passing from them shall enter into the jars already filled with gas. For this reason, when a jar is full of gas, it should be put so far upon the shelf, that its mouth may be entirely closed; and in filling the fresh jar with water its mouth is to be turned away from the gas jars already in use. The mouth of a jar is not to be immersed first, so as to cause the air to burst forth in large bubbles; but the closed end should be first depressed, and the water suffered to flow in, and the air to pass out, smoothly.

712. If the trough in use be a small one, there may not be shelf room in it for the jars as they are filled, in which case it will be proper to transfer them to another place. For this purpose an evaporating or glass dish, or a common plate is to be selected, of sufficient size freely to receive the mouth of the jar, and allow water to remain around it; this dish is to be put into the water about an inch beneath the surface, and the jar moved until its mouth is received into it; this being done, the jar and dish are to be raised together out of the trough, and placed safely on one side. The water in the dish will confine the gas, just as well as the water in the trough, the dish in fact being a small trough for the time; and all that is necessary is, to preserve the portion of water which accompanies the jar, always at such a height that the mouth of the latter may never be uncovered. Very little depth of water is required, so that this point be attended to, a common kitchen plate will answer the purpose exceedingly well. The jar of gas thus removed may either be left in that state, or may be transferred into another trough by immersing the dish and mouth of the jar into the water of the second trough, and then removing the dish.

713. Sometimes also it will happen, from the smallness of the trough, that there is not room to fill the jar with water. It may then be filled in a pail, or in the large trough, and transferred in the manner just described, by means of a plate or dish, to the trough at which the gas is to be liberated. The long jars already described (699), which

are ground at the ends, are very advantageously transferred by the help of a glass plate (1234); which, dipped into the water and held tightly against the mouth, is in its moistened state quite secure, and will safely retain the contents of the jar during transference, whether it be water or gas or both.

714. Such is the manipulation with plain jars: it is the same with stoppered and other vessels, except in occasional variations in the mode of filling them with water. A stoppered jar may be filled with water by removing the stopper, depressing the jar in water in an upright position until entirely immersed, and then replacing the stopper: it may be afterwards raised up and used as a plain jar. Transferring jars, or such as, having a cap cemented to their upper aperture, are finally closed by a stop-cock (702), frequently require to be filled with such care as to avoid the introduction of any water into the stop-cock. This may be done by sinking the jar steadily in water, allowing the air to issue out at the cock, until the fluid has risen into the cap, and very nearly as high as the aperture of the cock itself; then by closing the latter the water is retained in the jar. When there is not sufficient depth of water in the trough to admit of this process, another method may be adopted. It is to apply the lips to the upper end of the stop-cock, and to withdraw the air by the force of the lungs and mouth. This may be done at one, or at several times, a clean cloth being placed over the stop-cock to prevent its contact with the lips. As the water approaches the cap, its ascent should be moderated, and when within a very small distance of the cock, it should be arrested altogether by closing the latter.

715. It is evident that these transfer jars cannot be filled with water by inclining them in the trough, without introducing the fluid into the stop-cock, although its entrance may be excluded from the upper half by closing it with the finger. When filled with water they ought to be moved with care, lest any portion should be thrown up into the stop-cock; and when placed to receive gas, the first bubbles should be admitted with equal caution, one by one, or as

they break within they will splash the liquid into the aperture above. When the fluid has descended below the cap, so as to be in sight, there is but little danger of this happening, and the operation may proceed more rapidly. If a pure gas is to be collected in these jars, it is necessary that the first few bubbles should be expelled through the stop-cock, that they may carry away the common air from it; this expulsion is effected by sinking the jar, after opening the cock, up to the neck in water, and refilling it with the fluid. It can only be done in a trough or vessel deep enough to allow of sufficient depression.

716. During the collection of gas in a small trough (707), the jars being filled at another place with water (713), there is of course a rapid alteration at the surface of the water in the trough, from the continual addition of that fluid from each jar. In such cases it is necessary to lade the water out, and to return it to the vessel from whence it was taken, and from which the jars were filled. Considerable care is sometimes required on this point, in order that the level of the water may not rise too far above the surface of the trivet or shelf. If the depth of water be inadvertenly allowed to increase, and at the same time the gas be permitted to collect in the jar until the latter is almost full, it will frequently happen that the jar, becoming buoyant, will fall over and its contents escape. Jars, generally, should not have the water depressed to within less than half an inch of their edges, the level within being then nearly the same as that without.

717. After having succeeded in collecting gases over the trough, the next facility to be acquired is, the decantation of them from one vessel to another, either in large or small portions, or with vessels of different sizes. In decanting gas from jar to jar, which is the simplest case of this kind, the operation is easy, and in reality is only an inverted pouring, the gas or air being poured upwards through water from the one vessel to the other. The jar into which the gas is to be introduced, is to be filled with water, and placed in the usual way with its mouth upon the shelf of the trough, as if it were to receive the gas from a retort; it is then to be brought

forward over the well, removing two-thirds or three-fourths of the mouth from off the shelf, so that though the jar is supported by one edge, another jar may with ease be brought towards it, and turned up beneath its mouth. This done, and the jar retained steadily in the left hand, (that being usually most convenient for the purpose), the second jar (containing the gas to be decanted), and which must previously have been placed on the shelf of the trough, is to be brought forward by the right hand, and being depressed in the well it is to be approximated to the first jar, and inclined so that, while its mouth is elevated, it may be made to pass under the mouth of the first jar, in order that when the gas from the further inclination issues out in bubbles it may ascend into the latter. The top of the jar to be emptied, is then to be depressed until the whole is under and full of water, but this must be done gradually and steadily; the gas not being suffered to pass out suddenly, or in large quantities, for then the magnitude of the bubbles causes them to interfere in their ascent with the descent of the water, and portions are frequently thrown outside. In all practices of this kind, the experimenter should endeavour to obtain a habit of steady and successful manipulation, and even when care may not be required for the particular experiment, he should be anxious to acquire dexterity, that when it is of importance, no chance of failure may be incurred. When the form of the trough is that described (691), it is advantageous to bring the jar full of water over the corner of the well, for its weight is then more safely supported by the two sides of the shelf above, and the mouth of the jar whose gaseous contents are to be transferred, may more readily and certainly be conducted beneath the first jar, by means of the angle existing in the well.

718. When the gas is to be transferred from large into smaller jars, or into bottles, more care is required than in the case just described. A jar with a large mouth delivers bubbles of considerable lateral extent; and when these rise towards an aperture, it is to be remembered they cannot enter it, unless there be space for the passage outwards of an equal bulk of water at the same time; if there be not, they will fre-

quently be broken and part of the gas will be carried outside and lost. In these cases funnels are highly useful, and especially in filling bottles: the funnel being inverted and immersed in the water, is to have its beak introduced into the mouth of the bottle filled with water, and the gas being decanted into the funnel, is readily and safely conducted into its proper place. The difficulty of the operation is at first increased, because attention is to be given to the funnel and the bottle at the same moment; for the former and the mouth of the latter, must both be retained under water, and the edge under which the jar is to be brought is necessarily much deeper in the trough than if no funnel had been used.

719. Instead of a funnel, a lipped jar or glass (343) may be employed in the transfer as an intermediate vessel. These, although they have wide mouths, deliver narrow bubbles of air by the lip, and to that owe their advantages. All that is requisite is, to bring the lip into such a position that, as the jar or glass is inclined, the lip may be the highest part of the mouth, and the gas consequently tend to flow out there.

720. The manipulation with jars and glasses is comparatively easy to that which occurs in transference from them to tubes, or from tubes to each other; and yet this latter practice is continually required in the laboratory, especially in eudiometrical and analytical operations. One circumstance with tubes which occasions difficulty, in addition to the narrowness of their mouths, is, their contracted capacity within, by which the easy passage of a bubble of gas upwards, and water downwards, at the same time, is interfered with; this effect is greatest in tubes of the smallest diameters.

No great difficulty will occur in the transference of gas from a tube to another that is wider. The second tube is to be filled in the usual manner with water, and held in the well of the trough, in a considerably inclined position; the tube containing the gas is to be brought near it, the upper edge of its mouth inserted as it were into the mouth of the first, and then its position slowly altered, until the gas passing towards the mouth be gradually delivered in distinct bubbles into the first tube. During this transfer,



the mouth of the second tube should be retained as much as possible within the first; the latter should not be raised to a perpendicular position, but be considerably inclined, for then the edges of its mouth meet better with, and are adapted to, those of the second tube, so as to confine the gas, and the motion of the bubbles is less sudden and less subject to derangement. Occasionally, it is advantageously placed in almost a horizontal position, its closed extremity being but little raised. One bubble of gas should be allowed to rise to some height in the tube before another is permitted to follow.

721. When the delivering tube is larger than the receiving tube, more care is required in the transfer. The first tube should be inclined as before, and the upper edge of the mouth of the second placed within it, and to assist in uniting as it were the two tubes for the moment, the finger and thumb of the left hand (which holds the receiving tube) should be applied at the sides of the junction, so as to confine the gas and prevent its escape laterally. For this purpose, and generally indeed in tube transference, the tube is best held in the hand, with its open extremity passing out between the thumb and fore finger, so that when sustained in the water in an inclined position the back of the hand may be upwards, the hand being as it were over the vessel; the tube is then easily supported by the two or three last fingers of the hand, and the fore finger and thumb are left at liberty to guide the mouths of the vessels, or to close the lateral opening, as has been just described. At other times it may be held as a pen is retained in the hand, the mouth being confined and guided between the thumb and two fore fingers, but there is then less facility in elevating or depressing it to different angles. The tubes should at all times be retained by a light and easy, though secure hold, and not in a stiff rigid manner, and the arms may often be allowed to rest with advantage on the edge of the trough, whilst the hands are immersed in the water.

722. An intermediate lipped glass should be used for the transference of gas from a large jar to a tube. No difficulty will be found in transferring from a lipped glass to a

tube. The tube being filled with water is to be held under the surface as before described (720); the lip is to be introduced into it, the junction made by the fingers if necessary, as in the former case, and the gas allowed to pass in distinct bubbles. It will be found easier to transfer from a glass that is from a third to five-sixths full of gas, than from one containing more or less. When a glass is nearly empty, it is often exceedingly difficult to transfer from it into a narrow tube. Advantage may therefore occasionally be taken of the circumstance above mentioned, to replenish the glass with gas.

723. Finally, small funnels may, when requisite, be used for the transference of gas into tubes, the procedure being exactly the same as that before described (718). Tubes containing gases are easily transferred from one trough to another, or to other situations, merely by closing their mouths with the finger or thumb, and carrying them to the required situation. The student should very early attain the habit of closing the mouth of a tube by the finger with facility and security. The accurate manipulation of gas in tubes, so that none shall escape and be lost, is often essential in experiments of research, where only small portions of gas are evolved for examination as to many of its properties.

§ 3. *Measurement of Gases.*

724. There are two cases of the measurement of gases. Either a volume of gas is to be accurately ascertained, or the separation of a certain volume from a larger quantity is required. The mode of determining a volume of gas received in a plain jar may be first considered. The jar must stand steadily on the shelf of the trough; three pieces or slips of waxed or oiled paper are then to be attached by a little wax and slight pressure, at equal distances on the outside of the jar, so that they may just adhere and serve to mark the height of the water within, by their upper edges. The jar is then to be removed from the shelf and depressed in the well until the surfaces of the fluid within and without coincide, and the operator should observe how far

this change of position has altered the coincidence of the three pieces of paper with the surface of the water within, taking care that the jar be held upright during the observation, so that any difference may be the same at each mark. The jar should then be replaced upon the shelf, and the situation of the paper marks raised by a quantity equal to that which it was observed they were too low, when the gas was levelled. This may easily be done by the eye, the elevation of the marks being made now just as much above the gas within as they were too low when the jar was depressed in the well. The jar should again be sunk in the well until the inner and outer surfaces of the fluid are level; the correspondence of the marks with the level should be observed, and the process carried on in this manner until the adjustment is perfect: the papers are then to be pressed more forcibly against the glass, that their adhesion may be secured. The gas is now to be transferred into a graduated jar (702), to be depressed also in the well until the inner and outer surfaces of the water being level, the gas within may be subject only to the pressure of the atmosphere; the graduation is then to be observed, and a direct determination immediately made of the quantity of gas contained in the jar.

In this operation the jar should be held perfectly upright, and the use of the double or triple graduation before recommended (105, 135) will be evident, from the facility with which it is now ascertained by inspection, whether the jar is in its right position, and, consequently, whether the determination by the different graduations accord, as ought to be the case; if not, they may easily be made to do so by inclining the jar a little one way or the other, and the volume should not be considered as ascertained until both or all the scales agree.

725. In reading off the height of gas in jars, and also in adjusting the paper marks already referred to, the observation should be taken not from any part of the curved surface of the water close to the glass (108), but from the general and undisturbed level within; and when, in equalizing the pressure within and without the jar, that surface is necessarily

brought low and beneath the level of the eye, the student should not be satisfied with a casual and oblique glance, but should also lower his eye and bring it as nearly as possible to a level with the surface itself. When the jar is thus lowered in the well, without resting any where upon its edge, and sustained only by the hand, great assistance and steadiness may be gained by holding and pressing it as it were into one corner of the well, sustaining it in part by friction against the sides: further assistance may be gained also by supporting the wrist or arm on the edge of the trough.

726. If an accident happen in transferring the gas, or afterwards in the graduated jar, before the volume is ascertained, still a record of the quantity is preserved by the three waxed paper marks (724), and hence their great use: if no accident happen, they still serve to verify the measurement. For the latter purpose the jar is to be removed from the trough, set with its mouth upwards, and then water measured in (107) until it is filled by that fluid to the extent that it before was by gas. If the quantity of fluid thus introduced accord with the measurement of the gas, an assurance is gained of the accuracy of the determination.

727. When the gas is collected in the first instance in a graduated jar, it may of course be measured in it, as has just been described, transference being then avoided; hence an advantage, in many cases, in receiving gas, requiring to be measured, directly in such jars.

728. If the gas to be measured is contained in ungraduated tubes, the process, though a little varied, is the same in principle. The level within and without is to be equalized, and the height of the gas marked with a file (119), or by a slip of waxed paper put round the tube like a ring. The gas is then to be transferred into a graduated tube (703), levelled (725), and its volume determined by the graduation. Both in the marking and observing, particular attention is to be paid to the curve of the water, for the considerations which were formerly insisted upon (122), as important in graduating, are now equally important in observing. The practice there mentioned of always reading in the same manner, should be particularly attended to (108), and by a little

experience the point on the graduation, which may be considered as that which would coincide with the surface, supposing the gas and water to meet by a plane, may be ascertained very accurately from mere inspection. The tube in which the gas was first contained, and which was marked by the file or paper, may afterwards be measured up to the mark by water or mercury from a graduated tube (112, 114); or if very small, the mercury may be weighed, the precautions with regard to convexity of the surface not being forgotten (122).

729. In all estimations of the bulk of gas, the temperature by the thermometer, and the pressure as indicated by the barometer, should be observed and registered in the laboratory note book. No considerable difference should be allowed to exist between the temperature of the air and water at the time of the experiments; if it be more than a degree or two, it should be corrected by altering the temperature of the water. The registered temperature should be that of the water; and great care should be taken in handling the jars, that their temperature be not made to differ from the observed one. For this reason they should be held lightly by the thick part of the neck, and not grasped at the sides, lest a temporary change of temperature and consequently of volume should be induced, which in certain cases might occur just as the volume of the gas was under determination. The barometer should be an accurate one, or if inaccurate, the difference in altitude between it and a perfect instrument should be known, and always allowed for, as a necessary correction. In observing this instrument it should be supported perpendicularly, the eye being level with the surface of the mercury; it should be observed whether the mercury be concave or convex, and after having observed its height, the instrument should be slightly tapped to allow free motion to the metal, until tapping produces no change. If the experiments are long, the barometer is to be observed two or three times during their continuance, that no unperceived alteration may occur to vitiate the results.

730. In measuring out a required quantity of gas, no difficulty will occur with large quantities. A graduated jar is

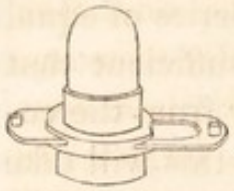
to be filled with water, and the gas passed into it (717) until there be nearly enough. The additional portions are then to be added more carefully, at first from a lipped glass (722), and when the quantity is almost sufficient, from a tube. The water within and without the jar is to be brought to the same level at every examination of the bulk on the scale. Many depressions of the jar in the water, for the equalization of pressure, will not be required, a facility of adjustment being obtained, by attending to the quantity apparently necessary when the level is so equalized. Thus, if it is found when the jar is depressed that the level of the water within is one division higher on the scale or graduation than it ought to be, then on raising it to the shelf, gas is to be added until the level is depressed by one division, without respect to the particular part of the division with which it may happen in that state to coincide; upon restoring the equality of level, the quantity will be found very nearly accurate, and the portion that is necessary to make it quite so, may now very well be estimated, and accurately added at the next trial.

731. The advantage of using the tube for the addition of the last portions is, that much smaller bubbles may be delivered into the jar, and the final adjustment be thus more accurately made. If the aperture of a tube at the trough containing gas be closed by the fore finger (of the right hand), whilst it is held by the thumb and other fingers, and inclined under the water, with the mouth upwards, so that the gas within would escape but for the finger, then if the finger be relaxed a very little at the lower edge, so that a small quantity of water may flow in, and the mouth be immediately closed as before, it will be found, that at each operation, a bubble of air will be expelled from the tube, the dimension of which will depend on the degree in which the finger was withdrawn, and on the quantity of water consequently admitted. In this manner bubbles smaller than a pin's head may be obtained, and consequently a very minute quantity of gas may be added, whereas much risk of adding too much in one large bubble is incurred, if the gas be let out from a tube not thus guarded by the finger, or from a glass or jar.

732. In measuring quantities in tubes, as for eudiometrical experiments, more care is required than is usually necessary with large quantities, because general proportions and results are frequently deduced from very small volumes. In these cases standard or unit measures are often useful, and being equally filled again and again, afford a series of equal volumes. In filling them however it is not sufficient that gas be passed into them until they overflow, for from the cohesion of the water and other circumstances, this will take place when the measure contains very different quantities, and it will in almost all cases be rather more than full, the gas projecting beyond the edge of the tube. When therefore such measures are made out of tubes (129), it is usual to close them when full of gas by the finger, the excess being thus thrown off; but, inasmuch, as the skin when dry or soaked, or when slightly or forcibly pressed, enters more or less into the opening of the tube, an inaccuracy is occasioned unless the operator be careful always to make the applied part of the finger assume the same convexity, and the measure used be of small diameter. With these precautions this is a very good mode of measuring. These tubes are sometimes closed by stoppers so adjusted, as to leave a capacity of the proper measurement, and occasionally larger measures, amounting to the half or the whole of a cubic inch, are made of bottles carefully stopped and adjusted for the purpose (112). In using measures of this sort a surplus of gas is to be introduced, the stopper put into its place, and the excess thrown out; but in introducing the stopper it must be done in such a manner as to exclude water as much as possible from the measure. It should be introduced at first obliquely, one edge being a little higher than the other, whilst the measure itself is quite perpendicular. It should be observed that the gas descends on all sides of the stopper, or at least that no large quantity of water is carried up on one side; and this being the case it may be thrust into its place, the extra bubble of gas thrown off, and that within the measure used as required. If the measure be inclined, and the stopper put in carelessly, it will be found in most instances that a quantity of water has been carried up into the bottle or measure,

on the bottom of the stopper, notwithstanding the considerable excess of gas that was first introduced.

733. Mr. Cavendish used a measure for these purposes, consisting of a piece of glass tube closed at one end and fitted into a brass collar, with a flat slider passing through it; this, when thrust forwards in a direction at right angles to that of the tube, closed its mouth, and included a space accurately adjusted to half a cubic inch. When used, the slider was opened, and a surplus of gas passed into the tube, the slider was then closed, the excess of gas beneath it thrown away, and the included and accurately measured volume retained for use.



734. When in consequence of the nature of the experiment and of the measure used, the operation does not consist in accurately filling a measure or tube, but in filling it to a certain mark only, as for instance, to the fifth or the tenth division on the graduation (and in general this will be the kind of measurement required in tubes) a little excess of gas above what is wanted should be put into the tube, and the adjustment then effected by closing the mouth with the finger, and letting out minute bubbles in the manner just described (731). The tube is to be returned to an upright position now and then, and the quantity left is to be examined as to its accordance with the graduation in the required place. If by accident too much gas has been thrown out, a little more must be added, and the adjustment proceeded with as before. If the gas be valuable or is in minute quantity, then the small bubbles ejected should not be thrown away, but caught in a little tube held over them, and reserved for other experiments. A very quick and accurate adjustment of a required quantity of gas in a tube may in this way be obtained.

735. In observing the volume of gas in a tube, after having brought the internal and external surfaces of water to a level, the necessity of lowering the eye to the level of the water may be avoided by closing the mouth of the tube with the finger, and then raising it out of the water to the level of the eye; but the act of closing the tube must be so performed that the pressure of the finger does not compress

the gas within, and raise the level above its proper place. If the finger be applied to all parts of the edge at once, and then pressed hard, this effect will almost certainly take place. To avoid it the finger should not be applied directly against the mouth of the tube, but a little obliquely, pressing it hard against the part of the edge it first meets, and then folding it over, so as to cover the mouth gradually from one side to the other: the pressure at last upon the whole edge being less than that with which the operation began. In this manner the tube may be closed without any change of level, and it should be observed during the operation, that this is the case. When the habit is once attained the operation is quick, and in long sets of pneumatic experiments the operator is enabled by it to avoid some degree of fatigue.

The barometer and thermometer should be attended to in all these experiments, unless they are brief, or are such as to require merely relative portions of two gases, their absolute quantities being unimportant.

736. The operations which have been described have all been illustrated by reference to the water trough, and to gases permanent over it. They are the same in principle as those which will be necessary in experiments at the *mercurial trough* (696), with those gases which, being soluble in water, cannot be preserved over that fluid. The first point the student has to remember at the mercurial trough is, the excessive weight of the fluid with which he is working, and its influence in his operations, either as coinciding with or opposing the pressure of the atmosphere. If the extremity of a retort, or the mouth of an apparatus, delivering gas, be immersed, for example, an inch, in the water trough, and another to the same depth in a mercurial trough, the pressure upon the interior of the apparatus, which is so little as to be unimportant in the first case, becomes of consequence in the second, being above fourteen times greater. The latter, if unattended to, might derange and burst open joints made by soft cement or lute; might force the gases evolved through bladder or junctions quite tight to the pressure of water; and might blow out a tube or retort heated to redness, as in

the preparation of oxygen gas from the chlorate of potash, which would have suffered little or no change at the water trough. Hence the beak of such apparatus should be immersed to no greater depth in the mercury than is necessary to insure the safe delivery of the gas into the jar placed to receive it. Hence also the shelf of the troughs should not be covered with mercury to a greater depth than is necessary to secure the mouths of vessels placed upon it; and jars, if supported by other means, as by trivets or stands, in small or temporary troughs, should be so arranged that their mouths may not be too far below the surface whilst receiving gas.

737. The mercurial jars are as before described (699), to be strong, and are to be ground at the edges. If they are lipped, which is very desirable in many cases for the advantage of transferring, the lip should be level with the rest of the edge, so as to bear upon a flat surface at the same time with the other parts; and not, as is usually the case, retiring towards the bottom of the jar, so as to leave a space between the lip and a glass plate applied to the mouth. The jars may be filled, either by inverting them in the mercury of the trough itself (710), or with mercury from another vessel; in the latter case the mouth is to be closed by a glass plate (1234), the jar afterwards inverted, and its mouth immersed in the metal of the trough, and the plate withdrawn. But when jars containing mercury are thus closed either for the purpose described or the transference of gas, a strong hold on the plate must be retained to prevent its displacement by the weight of metal upon it.

738. In moving a jar partly or entirely filled with mercury, from one part of the trough to another, great care should be taken to prevent its receiving any sudden blow or jerk, which though slight in appearance, might, from the weight of the mass moved, suffice to break the jar; upon these occasions sometimes, the whole weight of mercury suddenly descends, deranging every thing in the trough, besides occasioning the loss of the metal and the escape of the gas. The jars are, under these circumstances, most liable to injury by slight blows against each other, or against

the iron of the trough, when they take place upon their edges or sides.

When a mercurial jar contains gas it may be removed from the trough, as already mentioned (699, 737), by a glass plate; but if it contain a considerable quantity of mercury, it is safer to effect the transfer by a little evaporating basin (705, 712).

739. When a capped jar is to be filled by the assistance of the mouth (714), the jar should be inclined as much as possible, to diminish the height of the column of air within it, as well as the labour attending the operation; then, by applying the mouth to the stop-cock, and using it to exhaust, in a manner almost the reverse of that described for blow-pipe practice (202, &c.), the air may be withdrawn, and the mercury gradually raised until it fills the jar. Relief should be afforded to the mouth by closing the stop-cock occasionally during the operation.

740. The transference of gas from vessel to vessel under mercury, is the same in principle with transference under water, but differs from it in consequence of the opacity and weight of the fluid; the first of which prevents the experimenter from watching the motion of the gas, and obliges him to work in the dark, whilst the second causes the bubbles of air which leave the decanting jar to be thrown up through the fluid with considerable force. Great care is therefore required in these operations, and especially with tubes. The relative and desired positions of the mouths of the vessels, must be judged of principally by feeling with the fingers. The depression of the decanting tube should be very slow and gradual. The escape of the first bubble should be watched; if it ascends into the receiving tube, all is well, and the position of the mouths should be steadily retained; but if it escape into the air, the position should be changed. Generally speaking, the mouth of the decanting vessel ought to be farther under the mouth of the receiving vessel than is required in water. When tubes are the vessels employed, the use of the fingers in closing the sides (721) is often highly advantageous.

741. There is one circumstance in which water and mer-

curial troughs essentially differ, and of which the student should be fully aware, as it will account to him for many accidents that otherwise might occur in the transferring and collecting of gases at the commencement of his experience, and enable him in most cases to avoid them. This consists in the property which water has of wetting and adhering to the surfaces of the jars and apparatus concerned in operations at the pneumatic trough, which is not possessed by mercury. Hence it is that portions of gas expelled from apertures under water, rise in distinct bubbles through the fluid about them, for the adhesion of the water to the solid substances generally in use, is greater than that existing between its own particles. It is not so however with mercury; that metal does not come into such close contact with glass or other substances as to adhere, and hence it often happens that the gas ejected from the aperture, instead of being thrown as a bubble into the fluid metal, suddenly returns round the edge, and passes up in a stream between the vessel and the mercury. It is in this way diffused for a moment in thin films over a large surface, and ultimately escapes at the ring, where the surface of the mercury ought to be in contact with the vessel from which the gas is thrown out. The collection or retention of the gas in such cases is utterly impossible, its passage in the form of *bubbles* being necessary for that purpose.

742. This insidious emission of gas takes place with little or no disturbance of the mercury, and is sometimes quite imperceptible. It can only occur when the vessel delivering the gas proceeds from above downwards, in the manner of a jar, or the beak of a retort, or a descending straight tube; so that when the extremity of a tube is curved, and made to turn up under the surface of the mercury, it is avoided. It is very usual with dirty vessels, and may often be prevented by wiping them clean: this is especially the case with the beaks of retorts delivering gas. It is more likely to occur in dirty than in clean mercury. In such cases it may not take place immediately, but after the lapse of a short time, the agitation of the mercury apparently collecting a film, or diminishing the adhesion between the metal

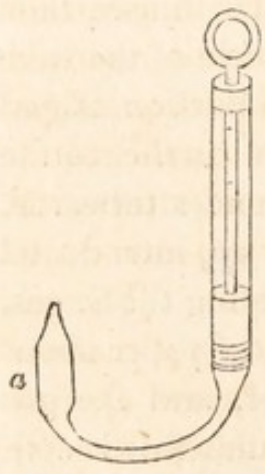
and the glass. Wiping the glass with a clean cloth, even whilst under the metal, is then a remedy. Some gases have a tendency to occasion this effect more than others, and amongst them may be quoted fluoboric and silicated fluoric acid gases, and euchlorine. The necks of retorts delivering these gases should be wiped occasionally. The effect happens more readily when the sides of the vessel or delivering tube approach to perpendicularity, than when they are much inclined, so as to approximate a horizontal position; and finally, it often occurs between the fingers and the mercury, the transpired matter on the surface of the skin apparently facilitating the effect. Hence when the fingers are brought into contact with the gas in transferring operations, they should, when the effect is likely to occur, be bent upwards under the mercury as much as possible.

743. It frequently happens that small quantities of gas are to be taken from larger portions and transferred to other situations. This is constantly the case in analytical and eudiometrical experiments, where small volumes are required in tubes or narrow vessels. Another common case is the transference of a small portion of gas from a jar over water into a vessel over mercury, the transmission of water at the same time being avoided. As these operations are frequent, several useful contrivances have been invented to facilitate them.

744. A common method of transferring a little gas from the water to the mercurial trough in the dry state is, to fill a tube with the gas over water, to close it by the finger, then removing it from the trough, to wipe the outside of the tube and hand dry, taking care that the gas be securely retained during the operation. The tube is then to be carried to the mercurial trough, the finger to be removed, and afterwards, a little piece of bibulous paper, tightly rolled up, introduced through the mercury into the gas. By re-applying the finger, so as to close the tube, and shaking the piece of paper about within, it imbibes a large portion of the water, and the gas may afterwards be decanted into another tube filled with mercury, without any risk of the water passing with it, for the water will be retained by the paper, or by adh sion to

the glass. The gas is thus obtained in a dry state, or at least without the presence of any aqueous fluid. With regard to its hygrometric state, it of course still remains saturated with aqueous vapour.

745. A very useful contrivance for the same purpose, due to Mr. Cavendish, is thus described by Dr. Henry.* "A tube eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at the 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 filled with quicksilver 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 a few inches long, and kept in its place by the finger. The tube is to be removed from the water, and dried by an assistant with a towel or with blotting paper; the point of the bent tube is then to be introduced into the aperture of the tube standing over quicksilver, and 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."



746. Mr. Pepys invented, about five years ago, a very ingenious instrument for the transference of small quantities of gas from one vessel to another over the trough, which he permits me to describe. It is made of a piece of glass tube, about half an inch in diameter and five inches long, attached to a piece of smaller diameter, which after bending as in the figure, terminates in a chamber at *a*, which being cylindrical for the greater part of its length, terminates in a capillary tube and aper-

* Elements of Experimental Chemistry, i. 22.

ture. A small piston rendered air-tight by tow and tallow, is fitted into the cylindrical tube; it is moved by a rod and ring, the rod passing through a box, which closes the upper aperture of the instrument, but which should not be air-tight. A portion of mercury is placed above the piston, the space between it and the capillary opening of the chamber, is filled with the same metal when the piston is in the position depicted. Upon raising the piston, the mercury follows it, and descends into the chamber *a*, the space left by it being immediately filled with the air or gas which has access to the capillary opening. The rod has a graduation upon it, by which it is known when a tenth of a cubical inch of air has entered the chamber.

747. The following is the mode of using this instrument. Suppose the object be to transfer a little gas from a jar to a eudiometer tube, both standing over the same trough: the piston is to be depressed until the mercury entirely fills the chamber *a*, even up to the aperture; that end is to be dipped into the mercury in the trough, and passed under the edge of the jar containing the gas; it is then to be raised above the surface of the mercury within, and the piston lifted: this will cause the descent of the mercury in the chamber *a* within the jar, which consequently will be replaced by the gas surrounding it. As soon as enough has entered, the motion of the piston is to be suspended, the aperture of the instrument depressed into the mercury, the piston raised a very little for the purpose of drawing a globule of mercury into the capillary part, the chamber *a* again elevated into the jar to ascertain that this has been done, and then the instrument removed through the mercury away from the jar. The portion of gas within it will be confined both above and below by the metal, and when it is to be transferred to the eudiometer tube, all that is necessary is, to introduce the capillary opening into the mouth of the tube, and to depress the piston. The gas is immediately ejected from the chamber, and in a manner so much under command, that it is easy to throw up just that quantity which, by the graduation on the eudiometer tube, or on the stem of the instrument, is known to be required for the experiment. When measuring by the

graduation on the instrument itself, it is necessary to bring the level within and without the jar from which the gas is taken, to the same height, or else the gas measured will not possess the same volume at common pressure.

748. The same instrument is equally useful in removing portions of gas from a jar over water, and conveying them, in a dry state, to a jar or tube over mercury. Being full of mercury, it is to be introduced into the jar as before; water rarely adheres in any quantity to the summit of the capillary termination, or if a drop should, a slight lateral shake throws it off. By raising the piston, the mercury in the chamber falls and the gas enters; to confine it there, the instrument should receive a cautious jerk, so as to throw the mercury up towards the capillary opening; it will be found easy to make a globule adhere there, and when that is the case, by depressing the piston, to cause it to enter into the capillary part so as to close it perfectly. The instrument is then to be removed from the jar and water, wiped dry, and the gas conveyed into the required vessel, as before.

749 The instrument described and figured (136), is used by Dr. Hare in transferring accurately measured portions of gas from one vessel to another over mercury. Its use is easy, and will be understood from the description given of the instrument. When full of mercury, the beak is introduced under the edge of the jar into the gas above, and by withdrawing the rod a certain number of degrees, an equal volume of the gas enters, and is easily transferred to any other vessel at pleasure.

750. The general processes for measuring gas over mercury, are the same with those already directed for similar operations over water (724); the propriety of marking the jar or tube, before any attempt to estimate the volume, is even greater here than on the former occasion, because of the greater risk of the gas escaping in transference, or of the occurrence of other accidents. When regulating the quantity in a tube (731), the finger is not of the service in this as in the former case, for the reasons already stated (741. 742), but to make the utmost use possible of it, with the least risk of accidental escape of the gas, it should be

held in a bent position under the mercury, rising upwards *to* the extremity and not *from* it, that the chances of escape of the gas may be diminished (742). It is in cases where these difficulties with gas over mercury occur, that the instrument of Mr. Pepys just described, is particularly useful.

751. When the gas to be measured is in a tube, the advantage of the process (724, 728) in which the height is marked, the gas transferred and thrown away, and its volume ascertained by the weight of mercury replacing it (113. 118), is much greater over the mercurial than over the water trough, simply because it dispenses with the somewhat uncertain operation of transferring the gas under the mercury. But the experimenter must then remember the cautions already given, with regard to the opposite convexities of the mercury, when it is at first confining the gas, and then replacing it (122); and besides marking the true bulk with care, he should be equally careful in estimating the quantity of mercury which is to replace it.

752. In all measurements and estimations of gas over mercury, particular attention should be given to bring the metal inside and outside the jar or tube to the same level, or if there be not sufficient depth of mercury for the purpose, the height of the surface in the jar or tube above that in the trough, should be accurately measured and noted down. This becomes a deduction necessary to be made from the observed height of the barometer, when the volume of the gas is to be corrected, and its true bulk at mean temperature and pressure ascertained.

753. In experiments requiring the use of a large jar at the mercurial trough, it is frequently useful to possess the means of raising or lowering the surface of the mercury in it without moving the jar. Thus, if such a jar were placed over the trough, and it were required to raise the mercury inside it, an inch or two, as in Lavoisier's experiment on the analysis of air, it is easily done by passing one leg of a glass syphon under the mercury into the jar, applying the mouth to the other and withdrawing air (739). When the mercury is sufficiently raised, the end of the syphon in the mouth is

to be closed by the tongue, which must not be removed before the other end has been withdrawn from the jar, through the mercury, by the same way in which it was introduced. Or if, during an experiment, the gas has been absorbed, and the mercury stands very high in a large jar, so as to require care in letting so heavy a mass down, a syphon may be introduced as before, and air allowed to pass into the jar through it, the mercury falling gradually as the air is allowed to enter. To prevent the mercury entering into the syphon during the transit of its extremity through the metal, that end should be closed by introducing a plug of twisted paper into it, or paper should be wrapped about it; either will be sufficient to keep the metal out, without stopping the passage for the air.

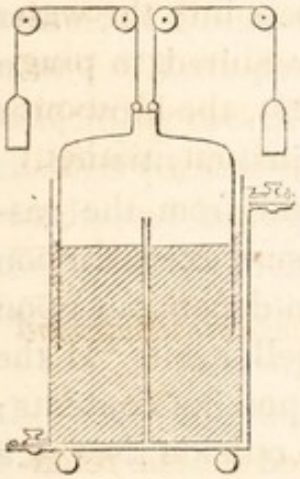
Of larger and independent vessels, for the retaining and storing of Gas.

754. Numerous vessels have been contrived for the retention of gas, independently of the use of jars, or of the water or mercurial trough, and it is necessary that the student be acquainted with the principles and uses of many of them. All have their respective conveniences; some consisting in great capacity, others in facility of operation, and others, again, in their security as to the retention of particular gaseous bodies.

Gasometer.

755. The vessel usually thus designated, may be compared to a large jar suspended in a trough, of size just sufficient to allow its entire immersion in an upright position. The gas-vessel, or bell, instead of resting on a fixed support, is suspended by cords or chains passing over pullies, and having weights at the opposite extremities to counterbalance the vessel. The trough or cistern or tank, as it is called in large instruments, is nearly filled with water, which remains constant in quantity, the aerial capacity within the gas-vessel being increased or diminished by raising or lowering it in the water; it is thus adapted to the quantity of gas it may

contain. The passage of the gas to and from the gasometer is effected along pipes permanently fixed. A single pipe is sufficient in the simplest form of instrument, and this commencing at any convenient place on the exterior of the tank, is conducted through its bottom, and made to rise so high within, that its extremity shall be above the surface of the water. By connecting the external aperture with proper apparatus, gas may be made to pass from it into the gasometer, or from the gasometer into the apparatus. The accompanying wood-cut, presenting a section of this instrument, will illustrate its principle, and assist the comprehension of the annexed directions for its use. The actual construction of the instrument, and its numerous variations in form and adjustments, make no part of our subject. Gasometers were formerly much more used in the laboratory than at present, and great care was paid to their construction, for the purpose of obtaining an uniform pressure. They may be made of a great variety of materials. They have of late years been constructed of enormous size in coal-gas works, and beautifully arranged with regard to their system of pipes.



756. There is nothing difficult or particular in the use of a gasometer. The water in the tank should never rise so high as to endanger its running into the passage pipe, it being necessary that this should be preserved perfectly clear. If water should, perchance, get into the pipe, it may be drawn out at the lower stop-cock. The gas-vessel should be of such depth as to sink entirely into the water when required, and is advantageously contracted above into a small chamber, intended to receive the end of the pipe, and thus to allow of the expulsion of nearly all the air except the small portion the pipes may contain. When it is to be filled with gas, the cocks should be opened, the bell depressed, until it be as empty of air as possible; one of the cocks is to be shut, and the other connected by a tight joint, with the apparatus delivering gas. This may be a retort, or a bladder, or a

funnel placed in the water trough, or in any other vessel. When the operation is over, or the gasometer sufficiently full, the stop-cock is to be closed, and the junction to be disunited.

When the gas within the gasometer is required for use, it may be taken out at that stop-cock which is most convenient. If it be desired to fill a bladder, it should be attached to the end of the stop-cock; or if a jar over the pneumatic trough is to be filled, a piece of tube should replace the bladder, and its open extremity pass into the water of the trough under the jar; or if it be required to pass a stream of the gas through a blow-pipe (229), the blow-pipe should be attached to the end of the tube just mentioned.

757. The entrance or exit of gas to and from the gasometer, is governed principally by the pressure exerted upon the contents of the vessel; this being again dependant upon the pressure exerted by or through the bell itself. If the hand press upon the bell it presses also upon its contents; in consequence of which the water on the outside rises to a higher level than that inside, and the gas tends to issue by any open channel, and with a force proportionate to the pressure. On the contrary, if the bell be forcibly raised by the hand, the previous pressure is diminished, and to such an extent as to make it less than that of the atmosphere on the exterior; the level of the water without falls, and becomes lower than that within, and if any passage be open, the air will enter into the gasometer, being forced inwards by the superior external pressure.

758. These variations and arrangements of the pressure on the contents of a gasometer are very important, but in practice they are effected by the addition of weights either to the bell or to its counterpoise, or the inverse subtraction of them, which has the same effect. Any arrangement of weights which makes the bell preponderate, increases the pressure in proportion to that preponderance; the reverse arrangement diminishes the pressure. Now, on receiving gas into the instrument, care should be taken that the preponderance of the bell should be no more than what is easily overcome by the effort of the gas to pass in, and it

may sometimes be almost entirely removed with advantage. On the contrary, when the gas in the vessel is to be used, a pressure outwards is required, more or less, according to the force which opposes the transfer; thus, but little pressure will enable it to pass from the gasometer into the air, or into a bladder in the air, though more will be necessary, when it has to be thrown out through an aperture at the depth of two or three inches or a foot under water.

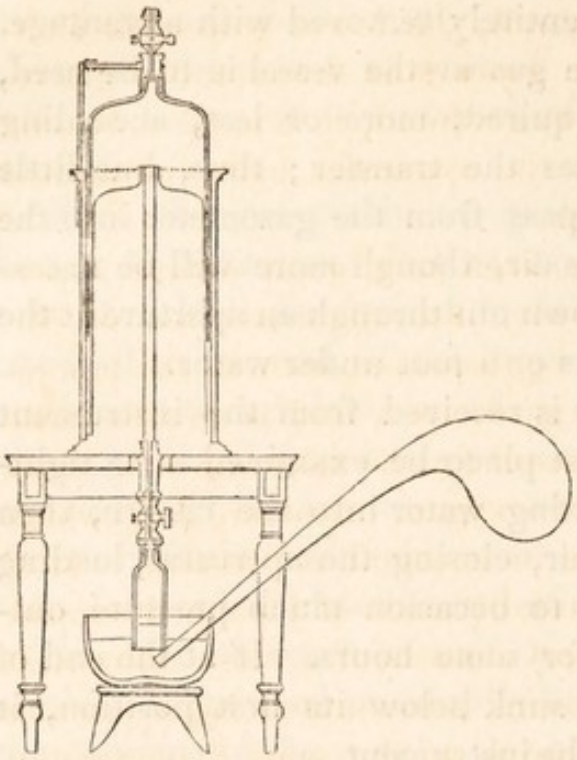
759. When a gasometer is received from the instrument maker, it should in the first place be examined as to tightness. This is done by putting water into the cistern, then half filling the bell with air, closing the apertures, loading the bell considerably so as to occasion much pressure outwards, and leaving it so for some hours. If at the end of that time the bell has not sunk below its first position, it indicates the tightness of the instrument.

760. A mercurial gasometer is the same in principle as those already described, but in order to avoid the weight and expense which would arise from filling the cistern with mercury, its interior is principally occupied by a core, allowing space enough between it and the sides of the cistern for the jar, and for mercury to make it tight. The first instrument of this kind has been described by Mr. Clayfield,* and was constructed of glass. To Mr. Pepys† we are indebted for an excellent instrument of this sort made of iron, and having a very convenient arrangement for the introduction of gases from retorts. This has been connected by Mr. Newman with his large mercurial trough.‡ The accompanying sectional diagram will illustrate the arrangement by which the gasometer is charged: the iron core and the sides of the cistern may be distinguished, and the jar is seen half full of gas, and closed by a stop-cock above. The core is traversed by a perpendicular passage consisting of a glass tube cemented into its place, which being open above into the bell of the gasometer,

* Davy, Researches, Chemical and Philosophical, p. 573.

† Phil. Mag. v. 154.

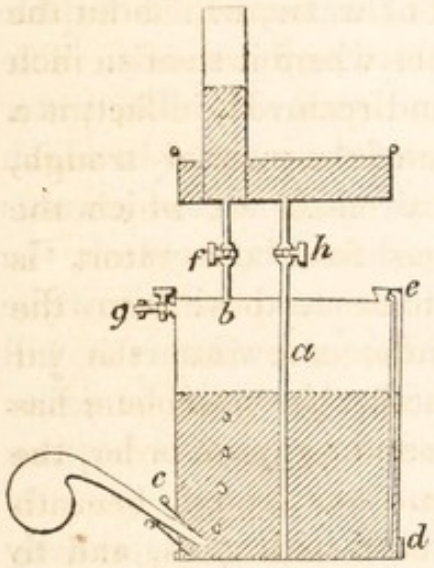
‡ Quar. Jour. of Science, i. 185.



terminates beneath in a stop-cock. To this a small funnel is attached by a screw cap cemented upon it; and beneath the funnel is placed a glass cup or dish containing mercury, and raised so high as to cover the edge of the funnel, about the third or fourth of an inch in depth. It, in fact, is a small mercurial trough, by means of which the gas from the retort is made to pass into the funnel, and from thence through the core into the jar above. On commencing operations after the gasometer has been filled with mercury, the jar found to be in order, the stop-cocks clean and moveable, and the trough beneath arranged, the first step is to open both stop-cocks, and to depress the jar in the mercury until all the air is excluded, then closing the upper cock, to leave the jar to itself. The buoyancy of the glass in the mercury will cause a tendency to rise, and cause also the ascent of the mercury a little way in the funnel beneath, above the surface of that in the dish. If, after leaving it an hour or two in this state, it be found that the jar has not risen higher than at first, the tightness of the instrument is ascertained. The beak of the retort, or the end of the tube delivering gas, is then to be passed beneath the edge of the funnel, the gas allowed to enter the latter, and the jar will be seen to rise at every bubble. When as much as is equal to the contents of the funnel, and the tube of the gasometer has entered, the upper cock is to be opened, and the jar depressed, its contents thrown out, the cock shut, and the gas collected as before. This is to be done once or twice more, to insure the rejection of all common air, and then the future portions of gas are to be collected and preserved for use. When the gasometer is

full, the retort is to be removed, the lower stop-cock shut, the temporary trough taken away, and the included gas reserved until required. When wanted, it is to be drawn off from the upper stop-cock, the apparatus being connected with it in the usual manner.

761. The gasometer has been to a great extent superseded by another instrument, also the invention of Mr. Pepys,* which can hardly be dispensed with in the laboratory. It has been called a gas-holder, and is an admirable vessel for the retention of a stock of oxygen or other gas, which is in constant requisition. It is usually made of japanned copper, and consists of a close cylindrical vessel, surmounted by a circular trough of the same diameter but of comparatively small depth; a pipe *a*, proceeds from the bottom of the trough, and passing through the top of the air-chamber, descends until near the bottom, where it terminates in an open extremity. A second pipe, *b*, also passes downwards from the trough, but merely enters into the top of the air-chamber. Both these are closed by stop-cocks, *f*, *h*, placed between the trough and the chamber. A stop-cock, *g*, is also inserted into the top of the air-chamber on one side, and finally a short piece of wide pipe, *c*, enters through the side of the air-chamber near the bottom, and is placed obliquely, so that the highest part of the edge of the inner aperture shall be lower than the lowest part of the edge of the outer aperture, by at least half or three quarters of an inch. It is closed and made air-tight occasionally by a plug which screws into the aperture. A glass tube is cemented into two sockets at *d* and *e*, which opening into the air-chamber, render the tube in fact a part of that cavity; its use is to indicate the quantity of water, and consequently the quantity of gas, within. All



† Phil. Mag. xiii. 153.

the joints, and seams, should be perfectly air-tight; this point may be ascertained in the following manner. The aperture *c* being closed by its proper plug, the three cocks above are to be opened, and water poured into the trough and allowed to descend into the air-chamber until it is full; the vessel is then to be inclined a little, the lateral stop-cock being raised upwards so that the air may escape by it until water only issue. This and the other stop-cocks are then to be closed, and the guage observed to ascertain whether the vessel be full of water, or if a bubble of air be at the top, to mark the place where it stands. The plug at *c* is then to be unscrewed and removed. The water cannot escape there in consequence of the manner in which the pipe *c* is inserted, unless the air finds access inwards above at the same time, and if there should be any leak, the weight and tendency of the water to descend will draw the air through it: upon standing therefore a few hours it will be easy to ascertain by the guage whether the vessel be tight: i. e. whether any air has gained access, or any water has run out excepting the first small portion.

762. The process of filling this vessel with gas is exactly the same in principle as filling a jar over the pneumatic trough. The stop-cocks are to be closed, the aperture *c* opened, and the beak of the retort or the tube delivering gas is to be introduced at *c*; the gas bubbles up through the water and displaces the fluid. Provision however is to be made to convey away the water. For this purpose the gas-holder may be filled near the sink, and the water allowed to run out; or if it has to be brought towards the furnace, as in the making of oxygen gas, it may be mounted on a stool, and the water received into a pail placed beneath the opening. In such cases it will be found useful to hang a piece of wet tow about the tube conducting the gas, so as to be in contact with the edge *c*; this will lead the water into the pail (434).

763. The descent of the water, and therefore the quantity of gas introduced, is indicated by the guage. When the gas bubbles out at *c*, the vessel can retain no more: the tube or retort is to be withdrawn, the plug screwed up tight, and in

that state the gas is securely confined, and may be preserved for many months provided water is kept in the trough above.

764. No difficulty occurs in transferring the gas out of this vessel into any other that may be required. The lower aperture is, in these cases, of no use, and is to be kept closely shut. Upon opening the stop-cock of the pipe *a*, the water will flow down it to the bottom of the air-chamber until such time as, having accumulated there, the gas above is compressed by a force equal to the weight of the column of water in the tube. No more water will then descend unless the stop-cock *f* or *g* be opened, when the gas will immediately rush out, urged on by the column of water in the tube, and the water above will supply its place. The process therefore of filling a jar or a bladder, or passing the gas through a tube, is very simple. In transferring it to a jar, for instance, the latter must be first filled with water, inverted in the water of the trough (712), and placed over the aperture of the pipe *b*; then having opened *h* as before described for the purpose of causing pressure on the gas within, the stop-cock *f* is to be carefully opened, when the gas will rush up and quickly fill the jar. The water from the jar descends into the trough to supply the place of that which has passed into the air-chamber. The cock *f* is to be closed as soon as enough gas has passed out, then *h* is to be shut, the jar of gas transferred and used as may be required. Or suppose that a bladder is to be filled with gas: the common air is first to be thrown out, the bladder attached to the cock *g*, pressure is to be given by opening *h*, then *g* is to be cautiously opened, and the bladder is to be filled; the water which is necessary being supplied to the trough above from a jug or pail; finally, the cocks *g* and *h* are to be shut, and the bladder removed.

765. It is sometimes necessary to introduce gas from a bladder *into* the gasometer. In that case the full bladder is to be attached to the cock *g*, all the cocks being closed; the plug at *c* is to be opened, and then the cock at *g* cautiously turned to allow the gas to pass in, the water at the same time passing out; the cock is then to be closed, and finally the plug *c*.

766. If the transfer of gas is to be effected through a tube, as for instance, in arranging the oxygen blow-pipe (229), or supplying inflammable air to a jet, the pipe must be attached to the cock *g*; the pressure of water given as before, and the emission of gas regulated by the extent to which the stop-cock *g* is opened.

767. The inventor has provided, even for occasions on which a greater pressure than that of two feet of water may be required, by associating a long tube and funnel with the instrument. This being screwed into the mouth of the pipe *a*, where it enters the trough above, and retained full of water, subjects the gas in the instrument to the pressure of a column four feet in height, and is occasionally very useful.

768. It is essentially necessary that in all the transfers of gas *from* the instrument, an abundance of water be retained in the trough above, to supply the place of that which passes into the air-chamber. It is also necessary to be aware of the possible introduction of common air with the water, even when there is considerable depth in the trough. When the gas is passing rapidly out at the lateral stop-cock, and consequently the water rapidly descending through the tube, it will, if unattended to, frequently acquire a rotary motion, which, from mechanical causes easily explained, will at last produce an aperture commencing at the surface of the water and descending to the very bottom of the tube. Down this, air is rapidly carried by the descending water, which, mixing with the gas in the instrument, deteriorates it, and with inflammable gases may lead to dangerous results. Hence this rotary motion, when observed, should be disturbed. The formation of the central channel for air may easily be prevented by allowing a large bung or a piece of light wood to swim on the surface of the water. If rotation does take place, it will draw the floating mass to the centre, and prevent the air from passing down by hindering the formation of a channel, if water be plentifully supplied.

769. Amongst vessels for the retention of gas may be classed bladders and bags: they are very useful in many receiving or transferring operations, or when subjected to

pressure, in supplying a constant stream of gas for a length of time. Bladders of different sizes are required. The necks should be softened by water, opened, drawn over the lower part of a cap similar to a retort cap (780), and tightly tied with twine. A stop-cock screwed into the cap renders the vessel complete. If the bladders are used in a dry state, the mechanical action to which the membrane is subjected during expansion and contraction, and otherwise, soon breaks the substance, and they become useless. To prevent this, and also to remove their rigidity, which is inconvenient, bladders are commonly moistened before being used. This renders them very conveniently flexible for present purposes, but they become more and more rigid each time they are wetted and dried, and soon break into holes. A bladder may be made to continue tight for a considerable period by pouring a little oil into it at first, and allowing it to become saturated. It is not, then, to be wetted for use, and is at no time so pleasant to work with as a wet bladder. Bladders should be kept in a moderately expanded state, not tightly blown, nor on the contrary compressed together; and this is more particularly necessary with those bladders which are wetted each time they are used, and are laid aside in a moistened state. Bladders are not perfectly tight to gases, and are less so when dry than when moist; consequently gases should not be retained long in them, and never longer than is absolutely necessary. Hydrogen passes through them more rapidly than any other gas.

770. Gas-bags are made of oiled silk, or of two layers of woven material, having between them a layer of caoutchouc, which serves to bind the whole into one impervious substance; they are furnished with a cap and stop-cock, like the bladders just described. Those made of oiled silk are seldom tight, and rapidly increase in porosity. Those manufactured with caoutchouc are superior, and when the substance has been prepared for this purpose with a thick coat of that peculiar body, may be made permanently air-tight. It is however to be understood that the fabrics sold as water-proof, and stated to be made so by caoutchouc, are not sufficiently air-tight for these applications. These bladders and bags are

useful in transferring gases from vessel to vessel, as between jars and air-holders; and when filled and covered with a weighted board, they will supply a constant stream of gas for a length of time.

771. Caoutchouc bottles are useful vessels in particular circumstances, and may be had at the instrument makers; their uniform expansion in all directions having been previously ascertained. It is necessary to introduce the gas by a condensing syringe, in consequence of the force required to dilate the bottle; but being introduced, the spontaneous contraction of the caoutchouc upon it is very useful in forcing it out through the stop-cock, and hence the particular uses of these bottles (230). A bottle, at first not more than three inches in diameter, may be extended till it contains half a cubic foot of gas or more, and upon allowing its contents to escape, will contract to nearly its original size.

772. Those who endeavour to prepare these bottles for themselves, will not succeed with more than one in four or five. They should be selected of uniform thickness, and without external marks or depressions; those which are lightest in colour are generally best. They should be heated in hot water, or in steam, for an hour or two, and then rolled between the hands until they become flexible; when cold they should be tied upon caps, having a stop-cock and a syringe attached; the air is then to be gradually thrown in. The bottle, when fully distended, generally becomes thin at one place first; if upon expansion by air this thinness extends to the neighbouring parts, all is well; but if it increase rapidly and partially, there is little chance of the bottle being made useful. The air should be introduced in successive portions, a lapse of time being allowed after every few strokes of the piston, especially during the first expansion. Caoutchouc bottles thus fully expanded and rendered thin, should not be exposed to heat on one side only or partially, for the heat, diminishing the cohesive attraction, allows the neighbouring parts to contract by distending the heated part; which, becoming gradually thinner, at last burst into a hole.

773. Finally, glass bottles are frequently of great service in the retention and preservation of gases, and more especi-

ally of chlorine gas, which cannot be retained for any length of time over water, in which it dissolves, or over mercury, on which it acts. The bottles should be wide-mouthed and accurately stoppered, their capacities being from four or six ounces to a quart. The necks and the stoppers should in the first place be wiped dry, a little tallow applied to the stopper, and the latter moved round in its situation, so as to disperse the tallow over the ground surfaces, and render the stopper easy in its motion and at the same time air-tight. The bottles should then be filled with gas as if they were jars (710), the stoppers put in under water, and pressed into their places, and then the bottles should be stored away in a dark place of nearly uniform temperature, in an inverted position, and with the stopper and neck immersed in water. This may be done by providing earthenware jellypots, or similar vessels, one for each bottle. When water is put into these, and the bottles inverted in them, the gas is rendered perfectly secure, and may be preserved for months, and even years. These receiving vessels may be conveniently made out of fractured wine bottles, when they remain sound towards the bottom, the upper part being cut off by a hot iron or otherwise (1111).

774. Dry bottles may be filled with such gases as, being either much heavier or lighter than atmospheric air, are at the same time soluble in water, and cannot be collected over that fluid. For light gases, such as ammonia, the bottle to be filled is to have its stopper greased, and is then to be placed in a vertical position, with the mouth downwards over the end of the tube or retort neck delivering the gas, which at the same time is to be directed upwards, until it touches the bottom of the bottle; the light gas occupies the upper part of the vessel at first, and gradually displaces the air: ultimately, from the addition of fresh portions above, it flows out at the mouth of the bottle, and when by applying a slip of moistened turmeric paper to the aperture, it is judged from the change produced that the gas in the bottle is nearly or quite pure, the tube or retort is to be gradually withdrawn, with as little disturbance of the gas within as possible, and the stopper instantly put into its place.

775. Many gases, such as muriatic, sulphuric, or carbonic acid gas, are on the contrary conducted downwards to the bottoms of bottles placed with their mouths upwards, which when they freely overflow with gas at the mouths, are to be withdrawn and quickly stopped. The overflowing of the muriatic acid gas, is known by the fumes which seem to issue from the mouth of the bottle. The fullness of vessels receiving sulphurous or carbonic acid gases, may be ascertained by bringing a lighted taper carefully near the mouth, the rapidity and appearance of its extinction being a sufficient indication. In all these cases it is necessary to allow an excess of gas to pass through the bottles, and to continue the introduction of fresh gas even after the bottle is supposed to be full, a portion being willingly thrown away to ensure the greater purity of that which is retained. The gases above mentioned may readily be collected, especially in small bottles, intermixed with not more than a fiftieth to a hundredth part of common air.

Connexion and Communication.

776. Having already had occasion to mention caps and stop-cocks, it will be necessary more particularly to consider the general uses and arrangement of these and other pieces of apparatus, which are constantly required for the purpose of facilitating the connexion or disjunction of different instruments, or the different parts of a complicated arrangement. Laboratory stop-cocks are usually made of brass, and are terminated by a male screw at each end rising from a flat shoulder, so that the intervention of a washer, or collar of leather (778) renders them, when screwed up into their proper apertures, perfectly air-tight. The plug of the cock should be very accurately ground into its socket, that no air may pass it. It is usually held in its place by a collar and screw, so that the experimenter can take it out, examine it, and apply a little wax or fat, whenever there may be occasion. The passage through the cock should not be more than one-eighth of an inch in diameter, and is even

advantageously smaller where it passes through the plug, for then its section upon the plug and socket is diminished, and the tightness and security of the cock increased.

777. These stop-cocks are necessarily subject to injury during use, many gases, as chlorine and ammonia, having powerful action upon the metal: they should be frequently looked at, examined, and the plug lubricated (776). It is often necessary to cleanse the air-way, and remove such obstructing matter as has either collected or been formed there. This may be done with a stiff wire, but particular care should be taken, in such operations, that the plug itself, or its socket, be not scratched, or the apertures formed by the air-way upon their surfaces injured, which would soon destroy the tightness of the instrument, and render it useless. The plug when turned round in its socket should move easily and steadily, allow of no shake in any direction, and not permit air to pass it. For this purpose, even when new, a little wax or grease should be applied. Tallow is the substance usually resorted to, but a mixture of two parts yellow wax and one part sweet oil is much better, since it preserves the tightness of a stop-cock that is slightly injured, longer than tallow or pomatum. The plug and socket of a foul stop-cock should be cleaned with a cloth, and not with a hard instrument.

If the plug adhere, as though, from chemical action or otherwise it had become so fixed as to be almost immovable, its screw and collar are to be removed, and by tapping the end with wood (not with metal) attempts are to be made to drive it out of its place. If it resist this, and also some degree of force applied to turn it, a little oil is to be dropped in at each end of the stop-cock, and also applied to the end of the plug, and then the whole should be warmed and left for an hour or two, when it may generally be moved. The plug of an old stop-cock commonly requires more wax or tallow than a new one; this should not be allowed to accumulate in the air-way, where it is of no use, but a little piece being put upon each side of the clean dry plug, the latter is to be introduced into the socket, equally clean and dry, and then turned round a few times to effect its

equal and proper distribution. When chlorine or ammonia has passed through the stop-cocks, the sooner they are looked at and aired or washed as occasion may require, the better.

778. *Washers* or *collars* are round pieces of soft substances as leather or paper, which, having holes in the middle, are passed over the male screws of the stop-cocks, so that when the latter are connected with other apparatus, the washers are between their shoulders and the sides of the aperture into which the cocks are screwed, and make the joints impervious to air. They are usually punched out of thin boot or shoe leather, and the pieces being soaked in oil for a day or two and then cleaned, are ready for use. It is best for many purposes to use wax instead of oil on these occasions. Yellow wax should be melted and the washers put into it for five minutes; when taken out, they are to be allowed to drain a moment or two, and suffered to cool. When required for use, they should be rendered flexible by the warmth of the hand, before they are put into their places. Such collars will occasionally remain tight for hours together at a pressure of from 10 to 30 atmospheres, when an oiled washer would inevitably have leaked; and they are more secure and constant even at common pressures.

When the joint has to bear a temperature near to or above 212°, one or more thicknesses of card answer the purpose of a collar better than leather. Sheet caoutchouc, similar to that prepared by Mr. Hancock, may be formed into excellent collars for particular occasions, but it is necessary to be cautious in screwing up the joint. Caoutchouc, from its elasticity, becomes readily adapted to the surfaces immediately upon contact, so that but little pressure renders the joint perfectly tight. On the contrary, were the cock tightly screwed up, the force would be sufficient to press out nearly all the caoutchouc at the edges of the joint; this, although it would not destroy the tightness of the arrangement, would be of no use, but would injure the collar and spoil it for future service. All dirt should be removed from the surface of the shoulders before the collars are put on, or otherwise it will occasion irregular pressure, and interfere with the tightness of the joint.

779. Some variations in the ordinary chemical stop-cock have been recommended, but have not been received into common use. Mr. Griffiths advises that the air-way be lined by a tube of platina, so as to prevent, to a considerable degree, the action of gases and other substances passing through or retained in it.* Sig. Crivelli has combined a conical metallic valve with the stop-cock, for the purpose of rendering it more tight and manageable when employed to retain gases under great pressure.†

780. *Retort caps* are cylinders of thin brass plate, contracted at one extremity by the insertion of a thick ring, in which a female screw is cut, and turned flat at the end so as to screw up tightly against the shoulder of the stop-cock. These caps are of various diameters to fit tubes and necks of retorts of different sizes. The flat extremity at the head of the cap, which screws up against the shoulder of the stop-cock, should have two or three concentric grooves (merely deep lines) turned in it, which will render its bearing against the collar more air-tight and secure. These lines or grooves should be kept free from dirt by having a point run round them occasionally, and the worm of the screw should also be preserved clean and free from obstructing matter.

Caps are fastened upon the ends of tubes or retorts with a particular cement (1033), in the following manner. One is to be selected of such size as to admit the tube and allow a space for cement about the thickness of a card or a little more, but the cap should never be so small as itself to gripe the glass, or any larger than is necessary to allow room for cement to surround the glass. The cement should be heated to fluidity on the sand-bath, but not to a greater degree; the cap should be warmed over a candle or lamp until it is hot enough to melt cement, and then that part of its interior which is intended to come against the glass, namely, the sides of the cylinder, should be covered with the hot cement, applied by a piece of stick. The cap being then laid on its side by the sand-bath to keep it from cooling, the end

* Transactions of the Society of Arts, xlii. p. 29.

† Quarterly Journal of Science, viii. p. 346.

of the tube or retort is next to be warmed, and a coat of cement applied on the exterior, over every part which is to come into juxta-position with the cap, but the other parts are not to be unnecessarily soiled; so much cement is to be left adhering to the glass, that with what there is in the cap, there may be an excess above the quantity that can be retained between the glass and metal when the two are fitted together. When the cap, the glass, and the cement, are all so warm that the latter is fluid, the cap is to be placed upon the tube, thrust into its right position, receiving a little rotary motion at the same time, to distribute the cement equally over all parts, and is afterwards to be set aside to cool. When this is well performed, the retort neck, or tube, should pass along until it be stopped by the inside of the shoulder; no cement should soil its interior, or project within the cap, but it should fill every part between the glass and cap, to make a firm, tight junction, and project in a ring from the edge of the cap over the exterior of the glass. The superabundance is easily removed by the knife, and the annular surface left smooth and made tight, by a hot wire passed rapidly over it. If a piece of cement, pushed on by the edge of the glass, project in the inside of the cap, it should, when nearly cold, be cut off by a knife, and removed, so that no loose fragment may remain in the retort or tube.

781. When there is a deficiency of apparatus, and caps are wanting, their place may be supplied for the time by corks. Thus, if there be no cap large enough for the aperture of a jar or tube, a very good cork may be selected, made to fit tightly into the aperture, a hole pierced through it, and the cock screwed into this hole; care being taken that the cork be not divided or torn to pieces by the force applied. This may be done so as to be quite tight, or if a small leak occur, a little soft cement (1035) will make all secure.

782. Connecters are short perforated pieces of metal, traversed by a female screw, and terminated by flat surfaces at the ends, so as to screw tightly against the shoulders of stop-cocks (776). They have on their extreme surfaces concentric grooves, like those on the ends of retort caps (780) to meet and hold against the collars. Their use is to connect

together stop-cocks or other parts of apparatus terminated by male screws, and hence their name. They are best made square on the exterior, being then more firmly held in the hand, or by a key, when tightly screwed. The clean state of the worm, of the screw, and of the grooves, should be attended to (780). The place of these connecters may at times be supplied by a sound perforated cork (781.1220).

783. The screws of all these stop-cocks, caps, and connecters, should be cut with the same thread, so as readily to fit each other; several of each should be ready for use, and preserved in a drawer appropriated to the purpose (21); those which are old or leaky are to be repaired or rejected, and the rest kept clean and in good order.

784. The tightness of stop-cocks, as well as that of their junctions with connecters and caps, and also of caps when cemented upon retorts, may be determined in several ways. If for instance it be required to ascertain whether a stop-cock is tight, it may be screwed to the plate of an air-pump, and the pump worked until the guage indicates considerable exhaustion. If without further working of the pump this indication continue unaltered for some time, it is a proof that the stop-cock is tight. Or the cock may be screwed into the top of a capped jar (702) standing in the water-trough, the water raised in the jar to near the top, its situation marked whilst the jar stands on the shelf, and then again after several hours: if it remain unchanged the cock is tight. Or a still simpler method, and on the whole a very good one, is, to close the cock, to apply one end to the mouth, to exhaust the air within the small cavity as much as possible by the mouth, and closing the aperture by the lip or tongue, to allow it to be forced against the cock by the pressure of the atmosphere. If after a few minutes the adhesion remains sensibly undiminished, it is a proof that the stop-cock is sufficiently tight to resist the passage of air under considerable pressure.

If it be required to ascertain whether a cap has been fixed upon a retort, so as to be quite air-tight, all that is necessary is to screw in a stop-cock before ascertained to be secure, to attach this to the air-pump, and then to exhaust; if the

guage remain for some time as high as it was raised by the exhaustion, all is tight, or if it fall, air finds admission. The same trial may be made, though not so rigorously, by attaching the retort and stop-cock to a transfer or capped jar, nearly filled with water, and standing on the shelf, and then opening the communication. The level of the water, after the first depression, should be marked, and if it fall not soon afterwards, it is a proof of tightness under pressures equal to that of the column of water in the jar.

785. The apertures of tubes are frequently made to communicate with other apertures very advantageously by connecters of caoutchouc, the formation and application of which have already been described (416). When of a conical shape, they connect apertures of different dimensions, conferring great flexibility and security upon the apparatus.

786. Tubes for the conducting of gas and vapour, though frequently formed of rigid materials, as glass, metal, or porcelain, (661, &c.) are also sometimes advantageously constructed of flexible substances. Tubes of caoutchouc, even three or four feet or more in length, are easily made from Hancock's sheet caoutchouc,* in the manner already described (416), small tubes of six or eight inches long being joined at the extremities, by surfaces freshly cut with a clean sharp knife. Mr. Hancock also makes flexible air-tight tubes of any length, of canvas and other fabrics, imbued with caoutchouc in the liquid state: similar flexible tubes are also made of canvas and oil boiled with litharge, &c. It may be useful for the student to know, that very excellent tubes may be formed of pasted paper, and sufficiently tight to be serviceable on an emergency in numerous experiments upon large quantities of aeriform substances, such as coal-gas, fire-damp, carbonic acid, &c. They should be made by rolling three or four thicknesses of paper round a glass tube, a rod or a wire, one half of the paper being pasted so as to cause at least the two outer folds to adhere throughout. If after they are made they be brushed over with oil, or being first warmed, with melted wax, they be-

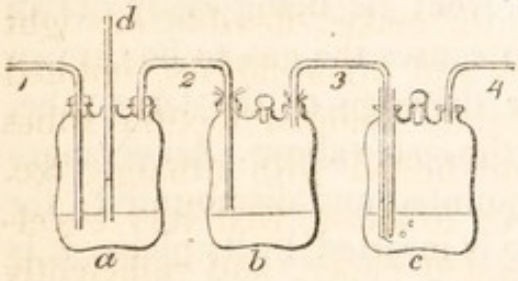
* Mr. Hancock resides in Goswell Mews, Goswell Street Road.

come very tight. A tube very nearly tight enough to hold gas under small pressures may be made simply by rolling up smooth writing paper, and tying it round with thread. When such a tube is wanted for the conveyance of fluids, the paper may be first oiled or waxed, and then rolled into form (1223).

787. When tubes are used for the ready and rapid conveyance of gas, it is desirable that they should be of sufficiently large dimensions. No difficulty occurs in the usual course of laboratory experiments, but in the arts, and sometimes in large experiments upon the transmission of gas, air, or steam, much annoyance has arisen from the contracted dimensions of the tubes employed.

788. In numerous cases of solution or chemical action exerted upon or by gases, there is occasion to pass the gas over successive portions of other substances, and these, when liquid, are best placed for this purpose in an arrangement of vessels first devised by Glauber, but which with some modifications, has since received the name of Woulf's apparatus.

In the general arrangement, a series of close vessels are placed side by side, connected by tubes, which originating from the top of those which precede in the series, descend to the bottom of such as succeed, as in the delineated bottles *a*, *b*, *c*, and the tubes 1, 2, 3. The gas is supposed to be delivered into the bottle *a*, by the tube 1. After having acted upon the water or solution there, it passes out by the tube 2, into the bottle *b*, and from thence by the third tube to the bottle *c*. Now it is necessary in this arrangement that the junctions of the tubes with the bottles be air-tight, or the pressure exerted upon the gas by the fluid through which it is to pass, will cause it to escape. These junctions are made in various ways. The tubes may sometimes pass through corks, and be tied round with bladder, or be luted (432, 440, 1011, &c.), as has already been described; or the joints may be ground air-tight, another mode



of effecting a junction, which has been noticed (440. 706). But these and similar junctions give a stiffness and rigidity to the whole apparatus, which in consequence of the comparative slenderness of the tubes, and the size and weight of the parts connected by them, involves considerable risk of fracture to the former, or at least of derangement at the joints by very slight shaking or motion given to the latter. Hence it is desirable to have flexible or moveable junctions, and this is well effected by the use of such caoutchouc tubes or collars, as they may be called, as, being of a conical form, may be tied at the upper edge round the centre tube, and at the lower round the tubular (418,), as is represented at the tubes 2 and 3, bottle *b*. These may be used with most gases, chlorine being perhaps the only one likely to be passed through a Woulf's apparatus that will act upon them.

789. Another very excellent though more expensive mode of forming a moveable junction, is represented by tube 3, bottle *c*. A wide tube is selected and fixed air-tight, either by grinding or otherwise, into the tubular; it descends nearly to the bottom, and is cut off obliquely, so as to present an oblique aperture. The connecting tube 3, is made to pass down this tube, and having its end turned a little on one side, though not enough to prevent its being easily drawn up and down, that inclination causes the gas to be thrown off laterally, and to pass under the edge of the large tube, and through the solution, into the space above. An arrangement of this kind is rapidly mounted and dismounted; for the instant the conducting tube is inserted in its place, it is air-tight. It is necessary in all such arrangements, that the fluid in the bottle (*c*) should rise above the aperture of the wide tube, and that the extremity of the conducting tube should descend below it.

790. Considering the joints as being properly made in any of these methods, let us illustrate the uses of the arrangement by supposing muriatic acid gas to be thrown into the apparatus by tube 1; it will pass into the water, and be immediately dissolved; but as from the continual additions of fresh gas the liquid becomes saturated, a part of the gas

will pass into the upper part of the bottle, and propelling the air before it, will enter the bottle *b* by tube 2. Here it will operate exactly as in the first bottle *a*, if the arrangement be the same and the gas be conducted into the fluid: but if, as in the figure, this be not the case, it will, after acting upon and saturating the fluid as much as practicable by the surface, pass on in a similar manner to the third bottle, and from that to wherever the fourth tube may lead.

791. Such is the simple operation; but it is liable to frequent variations, which are to be met by particular contrivances. Amongst the most essential of these is the application of safety-tubes, intended to admit air when, from any cause, the pressure within is so far diminished as to be considerably less than that of the atmosphere. Suppose for instance that the currents of gas into the bottles *a* and *b* were stopped whilst solution was still going on: as the water dissolved the gas above it, the atmospheric pressure would force the fluid from the bottle *c* up the third tube into the bottle *b*, and if it reached the aperture of the second tube, even in part into the bottle *a*. If the operation had occasioned the evolution of heat, a mere depression of temperature within the bottle might produce the same effect, and in this manner cause great derangement of the apparatus, and the failure of the experiment.

All this may be avoided by the use of the small safety-tube *d*, first applied by M. Lavoisier from an idea suggested by M. Hassenfratz.* It passes through a tight joint into the bottle, and has its lower extremity immersed in the liquid to the depth of half an inch or more. When the absorption before described takes place, air passes down the tube, enters the bottle, and prevents the recession of the liquid from the other bottles. No air can at any time escape there, but any pressure exerted from within outward, is indicated, and even measured, by the elevation of a column of fluid in the tube: in this way such tubes are highly useful in shewing the state of things within. Another tube of safety called Welter's, has been already described (443), which, being

* Traité Elementaire de Chimie, 453.

fixed into the middle tubular of the bottle, will render that just mentioned needless.

792. When the bottles are connected in the manner described (789, tube 3, bottle *c*,) by a fixed large tube, the latter becomes a tube of safety, permitting the entrance of air whenever the external pressure is much above that within.

793. On first setting an apparatus of this kind to work, the student should be attentive to the quantity of water in the bottles, and the depth to which the extremities of the connecting tubes are immersed. Supposing the immersion to be two inches in each of the bottles *a* and *c*, it makes a pressure of four inches, which has to be overcome by the gas passing into the apparatus through the first tube. From inattention, this pressure may be very considerably increased, and to such an extent as to interfere with the arrangement of the apparatus in which the gas is evolved; in consequence of which, lutings may be deranged, and even the vessels burst. Hence as a general rule, the conducting tubes are not to be immersed more than is needful.

794. Upon numerous occasions it is not necessary to immerse the tubes at all, especially in the large way; consequently, apparatus may then be used for the liberation of the gas, which would be quite inadmissible were any pressure to be exerted upon it. This is particularly the case with muriatic acid, for the solution formed by that gas in water being heavier than either the water or weaker solution beneath it, falls to the bottom. Hence in a muriatic acid gas arrangement, the delivering tube may terminate above the surface of the water as in bottle *b*; the water, as it dissolves the gas, will descend, and this change of place will go on until it be fully saturated. On the contrary, with ammonia the reverse is the case, the solution of that substance being lighter than water; it is essential therefore that this gas be delivered at the bottom of the bottle, that it may always come first into contact with the weakest portions of solution.

795. In several cases the gas is conducted to the bottom of the fluid, that the bubbles in their ascent may cause agitation, and thus favour the solution. This is necessary in

dissolving chlorine in water, and is advantageous with ammoniacal and sulphurous acid gases.

796. Although three bottles are figured in the wood cut, often not more than one is required at a time, and the two or three tubes, in place of being passed each through a separate tubular, may be put through three holes in a cork adapted to the mouth of an ordinary bottle; and the junction may be made good by soft cement or other means. A wide-mouthed jar, or bottle, will occasionally make a very good Woulfe's apparatus; and a large stone bottle often answers the same purpose even in chemical manufactories.

797. An apparatus invented by the late Dr. Nooth, and distinguished by his name, is occasionally used for the purpose of making a solution of carbonic acid. It is rather complicated, is of no general use in the laboratory, and does not require particular description; but it may be prudent to caution those who possess it, against generating gas *afresh* in the lower vessel without first ascertaining that the valve between that and the second is in right order. This is easily done by lifting the upper vessel from the lower, raising it over the head, and applying the mouth to the lower aperture of the valve tube; if the muscles of the cheeks have not power to raise this valve and blow air through it, the apparatus should not be used. The valve is always out of order when it cannot thus be raised; and from inattention to this circumstance, an apparatus of the kind has, in two or three cases, been blown to pieces.

798. Solutions of muriatic acid, ammonia, and sulphurous acid, are generally retained upon the shelves. Solution of chlorine is often wanted, but is not usually preserved. It is readily formed by opening a bottle of chlorine (773) in an inverted position under water, allowing a little of the fluid to enter, replacing the stopper, and then agitating the contents of the vessel; in a second or two it is again to be opened under water, when more of the fluid will enter; it is then to be re-stopped and re-agitated, fresh water admitted, and the process thus continued until the bottle is half full. By further agitation, nearly all the gas may be taken up by this quantity of water, but air should be ad-

mitted now and then to supply the place of the gas dissolved. In opening the bottle, either under water or in the air, the stopper is not to be removed farther than is just sufficient to allow the ingress of the air or water, otherwise the loss of the solution or of the gas is occasioned.

799. Before leaving the description of those operations which relate directly to the transference and removal of gases, it will be proper to observe that, although in making mixtures of gases they will become uniform without agitation if sufficient time be allowed, the period required will be very long, extending even to hours, in narrow vessels. If hydrogen be thrown up into a wide jar half full of oxygen, so as to fill it, and no further agitation be given, the mixture, after a lapse of several minutes, will be of different composition above and below. Hence the propriety in all cases of mixture, of agitating the gases well together. This precaution is more particularly necessary in those eudiometrical or analytical processes, which require the mixture of gases in tubes or narrow vessels.

Air-pumps, Syringes, and the operations performed with them.

800. Air-pumps and syringes are instruments of great service and constant use in the laboratory, but are in their construction and reparation so necessarily the work of the instrument maker, as to render needless here every thing relative to these points. The air-pump is of constant use, not merely in the exhaustion of receivers for experiments with atmospheres of less pressure than those ordinarily occurring, but also for the removal of air from retorts, flasks, globes, &c. that other gaseous bodies may be introduced. A good syringe will answer the same purpose to a very considerable extent, when the air-pump is absent. It has the great advantage of combining the power of condensing air (771) with that of exhausting it, at a very little additional expense. All the screws by which the attachment of other apparatus to the pump or syringe is to be effected,

should be cut with the same thread as that adopted for the stop-cocks (702, 756, 761, 776), that the screws thus used may fit each other without difficulty.

801. The student has to observe that the pistons of these instruments are well oiled, move easily and tightly, and that all the fixed joints are so perfect, as to prevent leakage of air at any of the screws or junctions. The tightness of the pump is easily ascertained by screwing a stop-cock into the air aperture upon the plate, closing it, and then working the pump until the guage indicates considerable exhaustion. When the pistons are in order, the experimenter feels, as he moves the handle, that he withdraws air each time a piston rises, and he can also perceive without difficulty that less and less is removed at each successive stroke. The diminution should proceed until none can be withdrawn by further operations; and this useless condition of the piston when at work, which is judged of by the hand, should coincide with the stationary and highest state of the guage, indicative of the exhaustion within. If after some time the guage continues to indicate the same exhaustion, it is a proof that no air can pass into a receiver fixed tightly upon the plate and similarly exhausted; and if upon working the pistons, the same absence of air is indicated beneath them as when the exhaustion was first effected, it is a proof that no air passes by them into the lower part of the pump cylinders.

802. The plate of an air-pump should be perfectly flat, and ground so smooth that a little pomatum may render a receiver with ground edges quite tight when placed upon it. It should be secured from injury by a tin cover put over it at all times when not required for experiment; for very slight blows with hard substances produce serious injury by the depressions they occasion.

803. The tightness of a syringe piston, when its other parts are accurately fitted, may be judged of by closing either the exhausting or condensing aperture by a stop-cock, drawing the piston as far back as possible, then carrying it forward to the end of the cylinder, if that may be done, and retaining it there a minute or two. This motion condenses the air before the piston, and rarifies that behind it;

and if the piston be not quite tight, the air will pass it, whilst it is forcibly held forward, and consequently when the hand is removed, the piston will not return, as it ought, to the top of the cylinder, or to the place from whence it was displaced. If there be leaks at the joints of the syringe, then the effect above described may be produced, although the piston be tight. In either case the imperfection of the instrument is ascertained, and it should be sent to a workman to be repaired.

804. A syringe has not the advantage of an attached guage like that of the pump, hence exhaustions made by it are necessarily judged of by the feel of the piston when in motion. As soon as the quantity of air removed at each stroke has diminished to nothing, the exhaustion is as complete as possible. This indication is the same as that already described with the air-pump (801), but may be more distinctly explained in consequence of one piston only being in action. It depends, generally, upon the effort made by the air to lift and pass through the valve in the piston, as the latter presses upon it. On first working the syringe, this happens immediately the piston is advanced; but as the air is more and more rarified by exhaustion, the piston has to descend farther and farther, before the portion in the cylinder beneath is sufficiently compressed to lift and pass the valve. It is the particular effect of lifting the valve which, becoming sensible to the hand in ordinary air-pumps and syringes, supplies the indication in question; this is easily to be felt and observed, but difficult clearly to describe.

805. When the instrument is absolutely bad, and cannot be replaced or repaired, the student must compensate for the imperfections as far as he can, by interposing a stop-cock between the instrument and the retort, flask, or other vessel, (which indeed in most experiments of this kind is necessary for other reasons) and close the communication as soon as, by rapidly working the instrument, he has effected the best exhaustion he can attain.

806. Air-pumps and syringes should be preserved from injury, likely to arise from mechanical violence or mechanical action. They are best secured, not in the laboratory, but

in the place appropriated to the balance (25), and other apparatus, liable to injury from acid fumes. And if in cases of emergency any gas has been passed through them, which exerts the slightest action on the metal, leather, or oil, the instrument should be quickly worked in the air as soon as it can be liberated from the experiment, that the injury may, if possible, be prevented by the instant removal of all the gas; or it should be immediately dismounted and cleaned.

807. The pressure upon the exterior of vessels exhausted of air is about 15 lbs. upon every square inch of their surface, and with large vessels it accumulates to an enormous extent. For this reason the form of such as are intended to sustain this pressure, must be particularly attended to, especially when, as in usual laboratory operations, they are of glass. Air-pump receivers are always made of curved forms, and particular directions have already been given with regard to the proper form of retorts (396), which are to be exhausted. A retort is so convenient for the retention of solid or fluid matter during exhaustions, for the reception of sufficient gaseous matter to act upon the substance within, for its allowing the heating of the substances in the gas even whilst on the air-pump, and for the opportunity it affords of viewing all that passes, that it is in constant request in experiments of this kind, where gaseous bodies are acting on each other, or on fluids and solids. Well formed flasks and globes are also in constant use, as bearing exhaustion, and readily allowing the mixture of gases in them; a common Florence flask (347) will, from the general perfection of its form, bear perfect exhaustion, notwithstanding its thinness, and these with globes and retorts, are easily attached to the pump or syringe by means of caps and stopcocks (776).

808. Particular care is necessary with all exhausted glass vessels, that no sudden blow, even though slight, take place on the exterior, especially with sharp edged or hard substances, for the slightest fracture of the surface leads to the destruction of the whole. A retort, flask or globe may be destroyed merely by laying it down hastily upon a table, especially if a particle of sand or any other hard substance

be beneath it; and a slight blow with a glass rod or metal wire, which would do no harm to the apparatus in its usual state, will now shiver it to pieces.

809. On exhausting glass vessels for the first time, they should, after being attached to the pump or syringe, be covered with a cloth, before the exhaustion is effected. If they burst by the mere pressure of the external atmosphere, the fragments are then prevented from flying to any distance. Pieces which may have fallen upon the plate of the pump, or have entered into the stop-cock by which the vessel has been attached, are to be carefully and immediately removed, that no injury may be caused by them to the ground metallic surface, or to other parts.

810. The general process for removing the air from a vessel, and for replacing it by any required gas, is an easy one, and will be readily understood from description. The gas is to be collected in a transfer jar (714), over water or mercury, according to its nature, and a connecter screwed to the upper end of the jar stop-cock. The vessel to be exhausted must have a cap fitted securely to its neck (780), and a stop-cock screwed into the cap, and then, being attached by means of the cock to the air-pump or syringe, it is to be exhausted, and the cock closed. This done, the vessel is to be separated from the pump and attached to the jar by means of the connecter, the stop-cock of the jar being screwed tightly into it; the lower of the two cocks, which now intervenes between the jar and the exhausted vessel, is to be opened, then the upper one gradually, and the gas slowly admitted, until sufficient has passed in, or the vessel be full. If the volume of gas which enters is to be ascertained, it will be necessary to equalize the level within and without the jar (724), but this must not be done until the temperature within the globe is the same as that of the surrounding air. When air first rushes into an exhausted vessel, it occasions a depression of the temperature within, but afterwards an elevation (effects dependant upon well known causes). To prevent therefore the interference of any accidental temperature thus produced, the level within and without is to be equalized, the stop-cock shut, and the

apparatus left for a few minutes; afterwards the level is again to be equalized, the stop-cock to be opened, and at the same time the surface of the water in the jar is to be observed; its motion indicates that the temperature within has changed; again, the vessel must be closed, left for a time, and then examined, and when after the lapse of five minutes no change in the level is produced by opening the stop-cock, it is a proof that the temperature within is the same as that of the atmosphere. This done, the stop-cocks are to be finally closed, and the retort or vessel removed, and used as the experiment may require.

811. It sometimes happens that when the gas to be introduced has been collected over water, a drop or two of that fluid adheres near the upper aperture, and, if the gas be allowed to pass with violence, is carried forward into the exhausted vessel by the current. Care should be taken to prevent this, for which reason, in addition to other precautions, it is useful to introduce a little piece of crumpled filtering paper into the top of the connecter, so that when the second stop-cock is screwed into its place, the paper may lie loosely between the apertures of the two. It will catch any drops of water that may be carried up, and prevent their entrance into or beyond the second stop-cock.

812. This process of introduction is required in the weighing of gases; in the mixing of those which are affected by water or mercury, or afford results so affected; and in the exposure of particular substances to gases or vapours. Where, however, actions of the latter kind are exerted spontaneously, as is often the case with chlorine, it is frequently sufficient to put the substance into a tube closed at one end, and then, having opened a small bottle of chlorine, quickly to introduce the tube and close the bottle. Substances are very often advantageously exposed to gases in tubes (660, &c.), in the manner already described.

813. With regard to those operations in which the compression of gases, instead of their expansion and exhaustion, is required, they are performed by means of the syringe already spoken of (800, &c.); but the vessel is now to be screwed to the end from which the gas is to be forced

out, and the opposite aperture is to be connected by a tube, or otherwise, with a gasometer, or other vessel containing the gas. When the syringe is worked, it draws the air out of the latter vessel, and forces it into the former. Suppose the operation were to condense oxygen to the amount of four or five atmospheres into a brass globe, for the purpose of making a blow-pipe (230); the globe is first to be attached to the syringe, so as to have the air exhausted from it, and then to be detached, and the same aperture of the syringe connected with the vessel, which is to supply oxygen gas. It is now necessary to expel the air contained in the syringe and pipe; one stroke of the piston is sufficient to remove that in the syringe, and a second will generally expel all that was contained in the pipes, if they be of moderate size. The globe is then to be attached to the exit aperture of the syringe, and all the cocks being opened, oxygen will immediately pass into the globe, and fill it to atmospheric pressure; the piston is then to be worked, and as much more oxygen thrown in as may be required; finally, the stop-cocks are to be closed, and the apparatus dismounted. The quantity of gas introduced may be judged of by that which has disappeared from the jar or vessel, if it be visible and can be appreciated.

814. Retorts and flasks will not bear so great a pressure on their interior as on their exterior, and many that will bear exhaustion with perfect safety, will burst long before they have received one additional atmosphere. Even the force of the mouth is adequate to the bursting of thin Florence flasks. Hence the glass vessels intended to retain gases under pressure must be thick, or of small diameter. Small globes are useful in such experiments, and also small tubes carefully closed at one end, and well annealed. According to some experiments of Mr. Brunell, a uniform flint glass tube, its thickness being ten, and its internal diameter eighteen, sustained an internal pressure of 135 atmospheres of 14 lbs. each, when applied in a regular and careful manner. Hence the strength of other glass tubes may easily be calculated by the rule of proportion, for if the glass be but one half this thickness, it will resist only half that number

of atmospheres. No force should be exerted in experiments surpassing one third, or at most one half, of the calculated strength.

815. When small globes or tubes are fitted with caps for the purpose of connecting them with a syringe, in order to subject them to internal pressure, it is necessary that particular care be taken in fastening on the cap that it may remain tight and firm. The outside of the neck should in such cases be roughened by a file, and the junction of it with the inside of the cap made by cement, very carefully and accurately (780). Cement so warm as to be in a state of thick fluidity, should afterwards be put over the outside of the cap and the glass beyond, and tow drawn out, wound round it, so as to pass obliquely backwards and forwards from the glass on to the cap, and back upon the glass again. This should be covered entirely by more cement; it helps much to bind the vessel and cap together. At other times a band of thin open canvass may in the same manner be buried in the cement, passing once or twice round the joint, or cloth or thick muslin may be used for the same purpose; but whatever it is, it should be thoroughly soaked in, and completely covered by, the cement.

Correction of the volume of gases for temperature and pressure.

816. In all the processes relative to volumes of gases, directions have been given that the temperature and the barometric pressure be noted at the time (735). This is for the purpose of making such corrections as shall enable the operator to compare the results obtained at one time with those obtained at another. When the temperatures of gases have been raised whilst the pressure upon them remains the same, they expand in bulk; and when their temperatures are lowered, they contract, but the bulk is *determinate* for every pressure. On the other hand, if the temperature be constant when the pressure is varied, then variations in bulk are also occasioned, the volume increasing as the pressure is diminished, and decreasing as it is increased, whilst it still

remains constant and determinate for every particular degree of force so applied. Now as atmospheric temperature and pressure vary continually, it is evident that experiments made at different times must, occasionally, differ as to the volume of gas they require, and consequently it would be inaccurate to compare these different volumes without ascertaining the influence of temperature and pressure upon them; the latter must therefore be observed and registered. This being done, it is easy to apply corrections by which the volume of gas used at any one time can be truly compared to that used at another; for as the bulk is determinate for any given temperature and pressure, it is only necessary to select two fixed points of this kind, and in every case to reduce the observed volume of gas to what it would be at these points; the results will then be perfectly consistent.

The points usually adopted in this country, and distinguished as mean temperature and pressure, are for temperature 60° of Fahrenheit's scale, and for pressure 30 inches of mercury. Hence when necessary, gas observed at any other temperature and pressure, has to be reduced to the volume it would occupy at these points. This may be done in the following manner:

Correction for temperature.

817. It appears by the experiments of M. M. Gay Lussac and Dalton, that all gases and vapours, of whatever nature, when not in contact with liquids, are affected equally in their volume by changes of temperature, the increase in volume for every additional degree of heat of Fahrenheit's scale being $\frac{1}{480}$ part of the volume at 32° Fahrenheit, and the decrease for every diminution of temperature of one degree being also $\frac{1}{480}$ part of the volume at 32° Fahr. This known, it is easy to calculate how much a volume of gas at a given temperature, 60° Fahr. for instance, would be increased or diminished by a change of one or more degrees. For though it is not, for one degree, a $\frac{1}{480}$ part of the bulk at 60°, the proportion is easily ascer-

tained by adding 28, or the number of degrees of the observed gas above 32° to 480, which producing 508, indicates that $\frac{1}{508}$ part of the bulk at 60° is to be considered as the increase or diminution for every degree of change. For conceive 480 parts of gas at 32°: at 33° they become 481 parts; at 34°, 482 parts; at 60°, 508 parts; the increase at each degree being $\frac{1}{480}$ of the volume at 32°, and consequently such part of the volume at any other temperature, as is indicated by adding the number of degrees above 32° to 480.

818. The rule for correction to be applied to an observed volume of gas, is, therefore, to add to 480 the number of degrees above 32°, to divide the observed volume by this sum, which gives the expansion or contraction for each degree at the observed temperature; to multiply this by the number of degrees between the observed temperature and the temperature to which the gas is to be corrected, which will of course indicate the whole expansion or contraction; and then to subtract this, if the observed be above the corrected temperature, or to add it, if the former be below the latter; thus allowing for the contraction or expansion which would actually take place, if the temperature of the gas were really to be brought to the point to which by calculation it may thus be corrected.

819. As an illustration, suppose 100 cubic inches of gas at 70° Fahr. are to be corrected to mean temperature or 60°. The difference between 70°, the observed temperature, and 32°, is 38, which added to 480 = 518; the 100 inches divided by 518, gives 0.19305 of a cubic inch as the whole expansion for each degree; and this multiplied by 10, the difference between 70° and 60° gives 1.9305 cubic inches as the whole expansion; which subtracted from 100 cubic inches, leaves 98.0690 cubic inches as the volume which would be occupied by the gas at 60° Fahr.

820. Or again, suppose the 100 cubic inches were observed at 50° instead of 70°, then the expansion per degree is obtained by adding 18, or the difference of 32° and 50° to 480: this equals 498, and dividing 100 cubic inches by this, we obtain 0.2008032 of a cubic inch as the expansion per degree at 50°; and this multiplied by 10, the difference

between 50° and 60° = 2.008032 cubic inches, which would be the whole expansion for the 10° from 50° to 60°. Being added to 100, it makes 102.008032 cubic inches as the corrected volume of gas. The decimals have in these instances been calculated much farther than will be necessary except in particular experiments, merely with a view of shewing the difference in the amount of the corrections required at different temperatures.

Correction for Pressure.

821. Boyle and Hooke were perhaps the first to observe that the volumes of gases varied inversely in proportion to the pressure exerted upon them, although the law, having been first distinctly announced and enlarged upon by Marriotte, has received his name. Its truth at high pressure although sometimes doubted, has been confirmed by the recent results of Oersted.* Whatever may be the case at high pressure, the law may be considered as accurately true at such pressures as occur naturally and are indicated by the barometer, and also at the greater variations dependant upon the difference of level of the fluid within and without a jar standing over the mercurial or water trough (724, 736).

822. A pressure of 30 inches of mercury, as observed by an accurate barometer, has been assumed as the *mean height* or *barometric pressure*, and volumes of gas observed at any other pressure (735), frequently require to be corrected to what they would be at this point. For this purpose it is only necessary to compare the observed height with the mean height, or 30 inches, and increase or diminish the observed volume inversely in the same proportion. Thus as the mean height of the barometer is to the observed height, so is the observed volume to the volume required. As an instance, suppose that 100 cubic inches of gas have been observed when the barometer stood at 30.7 inches: then as 30 inches or mean height is to 30.7 inches or observed height, so is 100 or the observed volume to a fourth proportional obtained by mul-
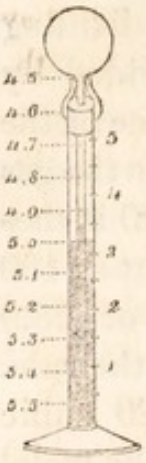
* Phil. Mag. lxviii. 102.

tiplying the second and third terms together and dividing by the first: thus $30.7 \times 100 = 3070$, which divided by $30 = 102.333$ cubic inches; this would be the volume of the gas at 30 inches of barometric pressure. Or consider the gas as observed at 28.9 inches of the barometer: then 30 inches or mean height is to 28.9 inches or observed height as 100 is to 96.333 cubic inches, that being the result of 28.9 multiplied by 100 and divided by 30, according to the rule. Again, suppose a quantity of gas amounting to 20 cubic inches standing over mercury in a jar, the level of the metal within being 3 inches above that without, and the barometer at 29.4 inches. Then the column of 3 inches of mercury within the jar, counterbalancing 3 inches of the barometric pressure, instead of being 29.4, the latter is effectively only 26.4, and the correction will be as 30 inches is to 26.4 inches, so is the 20 cubic inches observed to 17.6 cubic inches, the volume which the gas would really occupy if the mercury were level within and without the jar, and the barometer were at 30 inches.

823. It is constantly necessary to make corrections both for temperature and pressure in the same volume of gas. It matters not which correction is made first, the result being the same in either mode. Thus for instance, 100 cubic inches observed at the temperature of 40° Fahr. the barometer being at 28 inches, if first corrected for pressure, become 93.33 cubical inches: and then for temperature become 97.158469, which is the true volume. Or, if first corrected for temperature, it becomes 104.09836, and then for pressure, it becomes as before 97.158469 cubic inches.

824. Dr. M. Hall has constructed an instrument* which he has called an Aërometer, intended to give at once a correction for changes in the temperature of the atmosphere; in the barometrical pressure; in the external and internal heights of the fluid in the pneumatic trough; and when this trough contains water, for the elevation and precipitation of aqueous vapour. It consists of a bulb of glass $4\frac{1}{2}$ cubic inches in capacity, attached to a long tube whose capacity is 1 cubic

* Quarterly Journal of Science, v. 52.



inch. This tube is inserted into another tube of nearly equal length, and supported on a stand, as in the figure. The first tube may be sustained at any height within the second by means of a spring at the upper part. Five cubic inches of air at mean temperature and pressure are introduced into the bulb and tube, of the latter of which it will occupy one half; the other half, and part of the tube into which it is inserted, are to be occupied by the fluid of the pneumatic trough, either water or mercury. The point of the tube at which the air and fluid meet, is to be marked 5, and the upper and lower half divided into 5 equal parts, indicating tenths of a cubic inch each. The external tube is to be marked by a scale of inches.

When the volume of a gas confined over the pneumatic trough in jars is to be corrected by the indications of this instrument, the difference between the levels of the fluid in the jar and in the trough is to be measured, and the same difference occasioned in the external and internal heights of the fluid in the aërometer. The gas in the instrument, and that in the jar, are then precisely in the same condition, and by observing the volume of the former, the latter may be corrected. Thus if it be 5.2 cubic inches in the aërometer, and 74 cubic inches in the jar, then as 5.2 is to 5, the volume in the instrument at mean temperature and pressure, so is 74 to 71.15, the corrected volume of gas in the jar.

Weighing of Gas or Air.

825. The process of weighing a gas, which of all others is simplest in principle, is, to exhaust a light globe or flask, fitted with a cap and stop-cock for the purpose, then exactly to counterpoise it (55, 56), to attach it to a graduated transfer jar containing the gas to be weighed (714), and after allowing as much as will enter to pass in, permitting the temperature to become that of the atmosphere (810), and equalizing the pressure within and without the jar, to estimate the volume that has entered, by the graduation. Then on weigh-

ing the vessel, it may be ascertained how much it has increased in weight, and the increase will of course be the weight of the observed volume of gas.

826. Globes or flasks of the kind required are sold by the instrument maker. They should be perfectly clean and dry when used, nothing being allowed to adhere to the outside that may alter their weight during the process. The temperature should be noted, and its equality carefully preserved during the experiment; for this reason, the globe should be handled with all the delicacy possible (729). The pressure of the barometer is likewise to be noted. If the gas be in a jar standing over water, it must be let in carefully (811), the little piece of paper before recommended being introduced into the connecter; and it is advisable to let a small quantity of gas pass out there before the parts are closely screwed together, that the common air in them may be removed.

827. Gas when standing over water becomes saturated with aqueous vapour, the quantity being proportional to the temperature. In these cases a part of the volume observed, and also a part of the weight, is due to the vapour, which therefore must be ascertained before the true weight of the gas under examination can be determined. The following table exhibits the proportion by volume of aqueous vapour existing in any gas standing over or in contact with water at the corresponding temperatures, and at mean barometric pressure of 30 inches.

40° — ,00933	54° — ,01533	68° — ,02406
41 — ,00973	55 — ,01586	69 — ,02483
42 — ,01013	56 — ,01640	70 — ,02566
43 — ,01053	57 — ,01693	71 — ,02653
44 — ,01093	58 — ,01753	72 — ,02740
45 — ,01133	59 — ,01810	73 — ,02830
46 — ,01173	60 — ,01866	74 — ,02923
47 — ,01213	61 — ,01923	75 — ,03020
48 — ,01253	62 — ,01980	76 — ,03120
49 — ,01293	63 — ,02050	77 — ,03220
50 — ,01333	64 — ,02120	78 — ,03323
51 — ,01380	65 — ,02190	79 — ,03423
52 — ,01426	66 — ,02260	80 — ,03533
53 — ,01480	67 — ,02330	

828. By reference to this table, which is founded upon the experiments of Mr. Dalton and Dr. Ure, and includes any temperature at which gases are likely to be weighed, the proportions in bulk of vapour present, and consequently of the dry gas, may easily be ascertained. For this purpose the observed temperature of the gas should be looked for, and opposite to it will be found the proportion in bulk of aqueous vapour at a pressure of 30 inches. The volume to which this amounts should be ascertained and corrected to mean temperature. Then the *whole* volume is to be corrected to mean temperature and pressure (816), and the corrected volume of vapour subtracted from it. This will leave the corrected volume of dry gas. It has been ascertained in a manner approaching to perfect accuracy, that a cubic inch of permanent aqueous vapour corrected to the temperature of 60°, and a mean pressure of 30 inches, weighs 0,1929 grains. The weight therefore of the known volume of aqueous vapour is now easily ascertained, and this being subtracted from the weight of the moist gas, will give the weight of the dry gas, the volume of which is also known.

829. As an illustration, suppose a gas standing over water had been thus weighed, and that 220 cubic inches at the temperature of 50° Fahr., and barometric pressure of 29.4 inches had entered into the globe and caused an increase in weight of 101.69 grains. By reference to the table it will be found that at the temperature of 50°, the proportion of aqueous vapour in gas standing over water is ,01333, which in the 220 cubic inches will amount to 2.933 cubic inches, which corrected to the temperature of 60°, becomes 2.942 cubic inches. The whole volume corrected to mean temperature and pressure (817, 822) will be found to equal 219.929 cubic inches, from which, if the 2.942 cubic inches of aqueous vapour present be subtracted, it will leave 216.987 cubic inches as the volume of *dry* gas at mean temperature and pressure: 2.942 cubic inches of aqueous vapour weigh ,5675 grains, for $2.942 \times 0{,}1929 = 0.5675$; this subtracted from 101.69, the whole weight leaves 101.1225 grains, which is the weight of the 216.987

cubic inches of dry gas; and by the simple rule of proportion therefore, it will be found that 100 cubic inches of such gas when dried and at mean temperature and pressure, will weigh 46,603 grains.

830. It is not necessary in this experiment that the globe or flask be perfectly exhausted of air before the gas be admitted, all that is necessary in that respect being, that the quantity of gas which enters, and the corresponding increase of weight, be known. For the same reason it is not necessary that the globe be filled; so that the quantity which does enter is ascertained upon the graduation of the jar when the level is the same inside and outside: and that no alteration of the quantity in the globe be allowed before the weighing is completed. The state and quantity of the gas is estimated *in the jar*, and it is there that the temperature and pressure should be attended to. It is essentially necessary that the temperature of the gas over the water should have been steady for some time before the experiment be made, and that it do not change until the gas has entered the globe and the stop-cock is securely closed. After that, a little variation of temperature is of no consequence, so that nothing passes into or out of the globe until the conclusion of the experiment. The globe, as before said (826), should be clean and dry.

831. Some experimenters prefer drying the gas before it is weighed, and thus in fact weigh a known volume, not of a mixture, but of pure gas. Now gases are dried in various ways. One method is to pass them through a glass tube, containing substances having powerful attractions for water. It is a simple and a useful process, and therefore proper to be described here, though not conveniently applicable to the mode of weighing a gas as above directed, because of the greater difficulty of measuring the quantity of gas which enters. The tube may be about half an inch in diameter, and two feet long, and should have a piece of wire pressed into a loose ball, thrust into one end of it, to prevent fragments falling through. Chloride of lime should be heated and fused in an earthenware crucible, a temperature below that of visible redness being quite sufficient for the purpose, then poured upon a clean metallic or stone surface, and as

soon as it has solidified, broken up and put into stopped bottles. This chloride being divided into a mixture of large and small fragments is to be introduced rapidly into the tube, until the latter is nearly full; the apparatus is then ready for use. The tube may be connected with the jar, gasometer, or other vessel, containing or evolving the gas by caoutchouc connecters (416), or in any other convenient way; and so much gas should be passed through it as effectually to expel all the common air before the globe or vessel to be filled with the dry gas be attached. That being done, the gas should be allowed to pass slowly, 100 cubical inches having about 10 minutes allowed for their passage through such a tube as that described, though if the period be lengthened, no injury is occasioned. If the tube be shorter, or of smaller diameter, more time should be proportionately allowed.

832. Instead of chloride of lime, fused potash, or fused carbonate of potash may be employed, but it is to be remembered that ordinary potassa fusa generally evolves a little oxygen during its solution, and hence may occasionally be exceptionable. Chloride of lime will not answer for ammonia, or for sulphurous and some other acid gases. Potash, or carbonate of potash, answers perfectly well for ammonia, but not for acid gases. Sulphuric acid is a very excellent desiccator for many gases, and may be used in a tube by first curving the tube, then filling it with fragments of glass or rock crystal, and afterwards pouring in so much concentrated oil of vitriol as shall moisten the fragments but not cause obstruction to the passage of the gas. By moving the tube a little from time to time, the acid is made to pass from place to place, it becomes mixed, and it remoistens the fragments, which from the previous quiescent state of the apparatus may have drained considerably. This substance is effectual with almost all gases except ammonia.

833. In any case where tubes like these are to be used for drying the gas to be weighed in the manner already described, and consequently requiring to be measured, the gas must be delivered from a graduated jar, and after the quantity which is to expel the atmospheric air has passed through,

and the exhausted vessel is attached to the end of the drying tube, the level within and without the jar should be equalized and the quantity of gas noted; and again also, when so much gas has passed from the jar as has sufficed to fill the globe, and when its temperature is the same as that of the surrounding air. It will however be evident that in these cases the quantity that has entered the globe is not equal to that which has left the jar, for a certain volume of vapour has been abstracted. This must be ascertained by noticing the temperature of the moist gas, and correcting its volume to the pressure of 30 inches of mercury; then ascertaining by the table (827) the proportion of vapour which was present in the volume which left the jar, and which is to be subtracted from the corrected volume, and the remainder will be the volume of dry gas which has entered the globe.

834. Desiccating tubes, similar to those which have been described, are very convenient for drying gas in numerous cases, without reference to the operations of weighing, and where no account of volume is kept. They may be of various sizes, some indeed not more than five or six inches in length, and the fourth or fifth of an inch in diameter. The tube should be drawn out at one end to a conical form, with a capillary opening; the desiccating substance should be introduced, and the other end drawn out in a similar manner to the former. The capillary apertures are easily sealed hermetically by holding them for a moment in a flame, and the tubes may be preserved in that state until wanted. When required, the ends should be broken off, so as to open small apertures, and the tube should be attached to the gas apparatus by caoutchouc connecters (416), or in any other manner, so as to permit the gas to pass through it. When the operation is finished, and the tube dismounted, the gas within may be blown out by bellows, or drawn out by the mouth, the ends of the tube be sealed as before, and the tube itself reserved for use another time. It will in this way be repeatedly serviceable, until so much water has been abstracted by it as to injure its desiccating power. The drying effect of these tubes is in all cases increased by lowering their temperature, which may very conveniently

be done when the tube is bent, as has been mentioned with respect to sulphuric acid (832), by dipping the bent part into a mixture of ice and salt (421).

835. In other cases, gas confined over mercury, either at the trough or in a gasometer, may be dried by desiccating substances, as chloride of lime, previously placed within the jar: or gas dried by being passed through the desiccating tubes (831), may be conveyed into a graduated jar over mercury, thence transferred into the exhausted globe, and may actually be measured in its dry state.

836. A sulphuric acid bath, or gasometer, may be used with great advantage in the desiccation of particular gases, as chlorine, or in very important experiments. For this purpose a graduated transfer jar should be selected, and a common glass jar for the retention of fluids; the latter of a



size just sufficient to receive the former, and allow it free motion. The latter jar is to be filled with sulphuric acid except about an inch of the top, when if the transfer jar be depressed in it, whilst the air escapes above (714), it will become filled with the acid. The gas to be dried is then to be introduced by the stop-cock, the connection of the apparatus being made by caoutchouc tubes, or otherwise, as may be convenient. As the sulphuric acid must not rise into the cap or stop-cock, and as air will consequently occupy those places, it is needful, after the gas has passed in to the depth of an inch or a little more, to detach the jar and throw out that portion, by which means very little of the common air will remain. The apparatus is now to be re-attached, the gas introduced as before, and allowed to accumulate in the jar. When the jar is nearly full, the stop-cock is to be closed, and the gas left over the sulphuric acid for an hour or two. During this time the jar may rest on the sulphuric acid; or if there be any danger of an overflow, the jar may be blocked up by a cork put between it and the outer jar, or it may be supported in part by a string tied to the stop-cock and made fast to a nail or some other projection. When the gas is dried, it is to be used in any way that may be desired, being transferred through the stop-cock

and its quantity measured upon the graduation, after the level of the sulphuric acid within and without the jar has been equalized.

The original mercurial gasometer of Mr. Clayfield, without tubes (760), is an excellent instrument for the desiccation of gas over sulphuric acid, being altogether of glass.

837. The desiccators mentioned, namely, chloride of calcium, potash, carbonate of potash, and sulphuric acid, are adapted for all gases, one being applicable when another is not. Sometimes dry lime in tubes is used in slow processes, but has no advantage over those bodies, except that it is more economical in large experiments.

838. Returning to the methods of weighing gases; Dr. Thomson has published one * which, being exceedingly simple in principle, relates to the determination of their relative specific gravities, and requires description. The globe or flask (826), with its stop-cock, is to be weighed as accurately as possible, then exhausted and weighed again. The loss of weight sustained is equal to the quantity of common air drawn out, and is less or more according to the size of the flask and the goodness of the exhaustion. The flask is then to be filled with the gas whose specific gravity is wanted (810). All the precaution necessary, according to Dr. Thomson, is, to take care that no particles of water or mercury (supposing the gas to be standing over mercury,) insinuate themselves into the flask. It is obvious that the volume of gas which will enter the flask will be precisely equal to the volume of common air that has been previously drawn out of it by the air-pump. The flask thus filled with the gas, whose specific gravity is to be known, is now to be weighed, and the increase above its weight when exhausted, gives exactly the weight of the gas introduced. This weight divided by the weight of the common air removed by the pump, gives the specific gravity of the gas, that of air being assumed as unity or 1; and this is done without any measurement, or the necessity of any correction for temperature, or the height of the barometer, which remain unchanged during the short time of the experiment.

* Annals of Philosophy, xv. 232.

839. Notwithstanding the simplicity of the principle, however, much caution and even correction is necessary, and without which it would be unsafe to recommend the process to the student. It is especially requisite that no gas of a preceding experiment remain in the globe; for which reason, after one experiment is finished, or before another is commenced, the globe or flask should be exhausted many times, air being admitted after each time; or if access to the interior be easy, much air should be drawn or blown through it.

840. The air which is in the globe is the same as that of the atmosphere at the time it was introduced, and is therefore liable to all the variations to which the atmosphere itself is subject. Now the weight of a given bulk of the atmosphere at the *same temperature and pressure*, varies at different times, because of the variable proportions of water which it contains. It is not often saturated with moisture, and is never quite dry, and would require both hygrometrical experiment and calculation for a knowledge of its true state at any particular period. By reference to Daniell's tables of observation, it will be found that a difference in the dryness of the air, amounting to 20 degrees of the hygrometer when the air was at the temperature of 63°, has been observed within three days, there being at one time 1,053 cubic inches of vapour present in 100 cubic inches of the air, and at another 1.98 cubic inches: a difference of ,927 cubic inches of vapour (uncorrected for temperature) having occurred in that short period.

841. If the air in the globe were dried, it would then be almost constantly the same in weight; for its two important ingredients vary very slightly if at all, and the difference in their weight is so small as to make these variations of no consequence. The carbonic acid in the air is in very small quantity, and though variable can hardly interfere, except under particular circumstances. It may on very important occasions be removed by alkali.

842. No choice can be permitted in this process, as to passing in the gas in a dry or a moist state; it must of necessity be dry. For though if admitted when saturated, the

proportion of the vapour may be deduced from the temperature by reference to the table (827), and its specific gravity may be considered as known, yet as the whole volume of gas introduced is unknown, and the specific gravity is as yet unknown, there is no way of ascertaining the actual weight or volume of the vapour present, without which the correction for moisture cannot be applied; it is therefore necessary that the gas should be dried (831) by some one of the processes already described, and then, if the air in the globe be dried also, without knowing the volumes and without correction for barometer or thermometer (provided they do not change during the experiment), the relative specific gravities of air and the gas may be ascertained, and by similar experiments of air and any other gas. Thus suppose the globe by exhaustion lost 45,28 grains, and by admitting dry oxygen gas gained 50.7 grains, $50.7 \div 45.28 = 1.1197$ the specific gravity of that oxygen gas, common air being 1. Then clearing out the globe, and replacing its contents by pure dry air (839), suppose the experiment repeated with dry sulphurous acid gas, the globe losing this time only 40.25 grains, and gaining by the entrance of the sulphurous acid 90.37 grains, then $90.37 \div 40.25 = 2.245$ the specific gravity of sulphurous acid, air being 1.

843. But if the volume of the gas admitted be measured (825), it may then be saturated with moisture: but now the temperature and pressure must be known. The temperature being known, the volume of the aqueous vapour admitted with the gas may be ascertained by reference to the table (827, 829); and then being corrected for temperature, its weight also may be ascertained; and by subtraction of it from the whole weight gained, the weight of the dry gas admitted is known. Now diminishing the *weight* of the common air taken out by a proportion equal to the volume of the vapour in the gas, the rest is the corresponding weight of air of a bulk equal to that of the dry gas, and dividing the latter by the former, the specific gravities are ascertained. The proportion in bulk between the gas and the vapour mixed with it, required in the latter part of this calculation, is to be obtained by correcting the whole volume of gas to the pressure

of 30 inches, and then subtracting the volume of vapour from it.

844. On the whole, it is better perhaps in this method that both the air and the gas should be saturated with aqueous vapour, the temperature being known, and the same for both. This is easily done by exhausting the globe or flask, and filling it with common air from a receiver over the same water as the gas; then counterpoising it, exhausting it more or less, ascertaining the loss of weight, supplying the place of the air taken out by the gas, observing the quantity admitted and weighing it again. Thus the equal volumes of moist air and gas, their weights and temperature, become known: from the quantity and temperature of either, the volume of aqueous vapour at the pressure of 30 inches may be deduced by the table (827), and is the same for both. The weight of this, when reduced to mean temperature, may easily be ascertained, and that being equally subtracted from the observed weights of the common air and the gas, leaves the actual weights of equal dry volumes of air and of the gas; from which the specific gravity is easily deduced as before by division.

845. As an illustration of this method, suppose the globe to be filled with air from over water, then balanced, afterwards exhausted, and the loss of weight found to be 34.6 grains: on letting in the moist gas, suppose that 112 cubic inches entered, and that the gain of weight was 52 grains, the temperature being 52° Fahr. and the barometer at 29.2 inches. At 52°, the proportion of aqueous vapour in volume is ,01426, which of 112 cubic inches is 1.597 cubic inches; this quantity corrected to mean temperature = 1.623 cubic inches, and this equals ,313 grains of aqueous vapour; the subtraction of this weight equally from the weights of the moist air and gas, leaves 34.287 grains for the weight of dry air, and 51.687 grains for the weight of an equal volume of dry gas. In this way any slight errors in measuring are unimportant, but care is requisite as to the constancy of temperature.

846. In all experiments upon the weight of gases, it will be proper to leave the globe full of pure common air; all re-

mains of the gases which have been in use, having been removed before the apparatus is put away.

SECTION XVI.

Tube Chemistry.

847. Frequent occasion has occurred in the preceding parts of this volume for the description of apparatus formed partly or altogether of glass tube. The object of this section is to shew the important uses of apparatus of that description. The facility with which it supplies the absence of many complicated instruments; the consequent economy and readiness of chemical practice; and the peculiar advantages of it when rare and valuable substances are under examination, are the inducements to collect the information upon this subject into one focus.

848. The material required for the construction of this kind of apparatus is glass tube of half an inch in diameter or less, and of different degrees of thickness. The most useful sort is quill tube, the glass being of the thickness of card or thin pasteboard. Three-square or edge files are required for cutting the tube into lengths. If the table blow-pipe and lamp (221) be not at hand, most and indeed all the apparatus may be made by a spirit-lamp and a mouth blow-pipe (196). To these should be added a drawer full of tubes, closed at one end, of all diameters and all lengths, from one inch to five or six. The fragments of tubes, which are continually occurring, should be worked up into these forms at every opportunity, according to the direction to be given in Section xix. and are then ready for use.

849. These tubes answer all the purposes of test-glasses, and in the small way precipitates are made, preserved, and washed very conveniently in them. They are easily supported in a tumbler or wine-glass, or they may be supplied individually with stands by inserting them in per-

forated corks (58). Those who frequently use them will find a tube-rack very convenient. It may be formed of two boards, one supported two or three inches above the other, and the upper pierced with holes to admit the tubes. Or a very simple one may be made of a board a foot in length and six inches in width, having a piece of coarse wire trellis about three inches above it, supported at the corners by upright pieces of strong wire. The apertures in the trellis serve to receive and retain the tubes. A dropping-bottle (372) is necessary in experiments with these tubes, for the supply of small quantities of water, or for washing precipitates from the sides.

850. When in precipitating or testing, agitation is required, it may be given by closing the tube with the finger, and shaking the contents together from top to bottom. Or if the finger be likely to communicate impurity, and so interfere with the experiment, or be itself liable to injury, then a clean glass rod, about half the diameter of the tube, if raised and lowered in the fluid, will readily and perfectly mix it. Occasionally, with corrosive fluids, the tube may be held rather stifly at the top in one hand, and the fore finger of the other passed rapidly backward and forward by the bottom, so as to strike it each time, and thus give rapid agitation to the contents, if they are not in too great quantity. Such ordinary agitation as would effectually mix fluids in a glass or bottle, is insufficient for the same purpose in these narrow vessels, especially when the depth of fluid is more than an inch.

851. When delicate testing operations are in progress, tubes are exceedingly convenient, owing to the facility with which a little of the fluid to be tested may be compared with the portions to which tests have been added. It is scarcely possible that the slightest change can pass unnoticed when the two are examined by each other.

852. The washing and separation of small quantities of insoluble fluids and fusible solids, is well effected in tubes. An extemporary instrument for the former purpose, made of tube, has been already described (532). In consequence of the facility with which heat may be applied, it is easy

to melt a fusible body in a tube; thus naphthaline may be fused with water or a solution of potash, and if mixed well, and afterwards left to separate and cool, it will be obtained in a cleansed state and a very convenient form. In such cases it is advantageous to let two pieces of wire remain in the tube until all is cold; one is to pass through the naphthaline into the water beneath; the other, bent at the lower end, is to be placed *in* the naphthaline, and retained there by turning the upper part of it over the edge of the tube. If the straight wire be first pulled out, a passage for air is opened, in consequence of which the piece of napthaline may itself be drawn out with facility by the second wire. Wax, camphor, and other equally fusible bodies may be experimented with in the same manner.

853. As already observed, these tubes will bear heat, its application being easy and convenient either by sand-baths, spirit-lamps, or other means. Hence they supply the place of flasks (371) as well as glasses, and many operations (237) both hot and cold, may be performed in them with numerous advantages, amongst which is the important one of easily witnessing what is going forward. Solutions in acids are readily effected, and the action upon a substance, or the changes in the appearance of the solid and fluid may be watched at every moment in the most advantageous manner. The surface of a body which has been partly acted upon, is frequently better seen in a tube when surrounded by fluid, than it can be even in the air; and this is still more particularly the case with such bodies as change in the air, or that cannot be washed or dried without injury. For this reason the crystallizations which are formed from hot solutions as they cool in tubes, are more advantageously examined in that way than in any other (547); and as the cooling can be retarded to almost any degree, either by wrapping the hot tube with its contents in flannel, or else immersing it into a large quantity of hot matter, and enveloping the whole, this method is often superior to any other.

854. Tubes when heated sometimes acquire temperatures which make them untenable in the unguarded hand; this inconvenience is easily obviated by folding a piece of paper

about three inches square three or four times in one direction, so as to form a band of eight or twelve thicknesses, passing this round the tube near the top, and twisting the two ends together into a handle. The conducting power of the paper is so small that such a handle prevents the passage of any heat by which the hand might suffer inconvenience. A very convenient handle may also be made of a sound cork perforated so as to form it into a ring, which is to be cut through with a knife in one place. Half a dozen of these will supply handles to most tubes; they merely require to be slipped upon them, and will clasp the vessel like a spring. Occasionally, a piece of square or angular cork, or the half of a rounded cork, or one that does not fit tightly, being inserted in the mouth of the tube, forms a useful handle; these are more particularly required in sublimations, where the whole of the surface of the tube is to be exposed to view, if possible.

855. In consequence of the small diameter, and therefore small sectional area of tubes, they are much stronger relatively to internal pressure than larger vessels, such as flasks of the same thickness. An advantage is thus gained in some cases of solution or digestion in certain fluids, as alcohol, ether, and even water, because it enables the experimenter to subject the substances to temperatures as high as the boiling points without loss of the fluid (371), or occasionally to temperatures still higher (87), the ebullition going on as it were under pressure. This is easily performed with alcohol, ether, and similarly volatile fluids, in tubes of four, five, or six inches in length, and of such diameter as to be readily and perfectly closed by the finger. Suppose a tube of this kind, one-third filled with alcohol and held tightly between the thumb and second finger of the left hand, its orifice being closed by the fore finger of the same hand. The fore finger is to be relaxed, and the heat of a spirit-lamp applied until the alcohol begins to boil; the fore finger is then to be reapplied closely, and it will be found that the flame of the lamp, applied at intervals, is quite sufficient to keep the temperature up to the boiling point. No alcohol can evaporate, for the finger has power sufficient to retain the vapour even

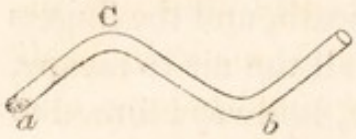
were its force equal to two atmospheres, and the tube itself is also strong enough to resist the same force.

This operation is very advantageous when valuable and volatile solvents are in use, it is therefore worth while to refer to those points which indicate the state and temperature of the fluid, and which make the practice easy. If the fluid be one which, like alcohol, when at or above its boiling point is at a temperature inconvenient to the hand, then, if all the common air were allowed to pass out of the tube before closing it, the whole tube would become heated by the vapour rising from the hot liquid beneath, and the fingers would be injured; but by not allowing all the air to escape, that portion which is retained in the tube, is always forced to the top by the successive formation and condensation of the vapour below, and interfering with the passage of the hot vapour to the part which it occupies, it preserves that portion of the tube at comparatively low and very bearable temperatures. The part thus retained at a low temperature, is proportionate to the quantity of air confined in the tube; this quantity is usually a proper one if the tube be closed just after the alcohol has begun to boil, and before the upper part of the tube has been heated. If too much air has been expelled, and the tube is found to become hot above, the application of the flame must be suspended a moment or two, the whole suffered to cool below the boiling point, the tube opened, the upper part cooled slightly by a piece of moist paper or a cold finger, and then the fore finger is to be re-applied to close it as before.

856. The state of the fluid within is in part indicated by the pressure of the air or vapour on the finger, the latter being urged away from the tube by a force proportionate to the degree of heat above the boiling point, and being drawn inwards when the heat is below that point. Generally therefore, the finger alone will serve to ascertain whether the temperature is above or below the point of ebullition; but as the force required is, after operating for some time at high pressures, such as to diminish the sensibility of the finger to smaller pressures, it sometimes happens that on lowering the temperature, the period at which it attains

that of ebullition in the atmosphere cannot be distinguished. This point is however easily recognized by relieving the pressure of the finger slightly; should the quiescent fluid below then burst into ebullition, it is a proof that its temperature is higher than the boiling point at atmospheric pressure, but should it remain quiescent until the finger is entirely removed, its temperature will be known to be below that point.

857. During long digestions, as in the solution of difficultly soluble bodies, a tube bent into the form represented



in the figure is very advantageous. The acid or other fluid which is volatilized and distilled over into the part at *b*, is easily returned upon the substance at *a*, by elevating the open end of the tube, and is made to re-act upon it; a little piece of moistened paper may be applied at *b*, or that part may be cooled by a refrigerating mixture, or by immersion in water. This arrangement is most frequently useful in the solution of substances but slowly acted upon in acids, as certain metals or metallic ores.

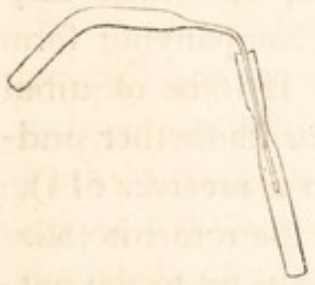
858. The above process also illustrates the use of tube apparatus in distillation, the part *a* answers to the retort, and the part *b* to the receiver of the usual apparatus (414). The fluid to be purified or distilled may be poured into the tube, and the latter being held upright, and the finger placed over the aperture, heat should be applied below and vapour raised; this will condense upon the sides of the tube and flow down, carrying with it that portion of the fluid which, in pouring it in, adhered to the side; this should be done till it is observed that the vapour rises nearly to the top before it condenses, and insures the cleansing of the whole tube. This preliminary operation is intended simply to wash the adhering portion of the introduced fluid to the bottom of the apparatus, that nothing may remain at *b* to contaminate the distilled products. The tube is then to be placed as in the figure, the proportion of the vessel and the charge being such, that the latter should not occupy more than half that part of the tube. Heat being then gradually applied near the top of the fluid, the latter should be distilled

over, into the angle at *b*, which is now to be cooled by wet paper, water, or some other means. If the distillation be unsatisfactory, it is easy to return the product and repeat the operation; if satisfactory, then by applying a file at *c* (1060) the tube is readily divided, and the rectified portion obtained in the closed part, constituting a separate vessel.

859. Distillation is frequently performed in a tube-apparatus, precisely similar to the ordinary retort and receiver. A piece of tube sealed at one end, and then bent as in the

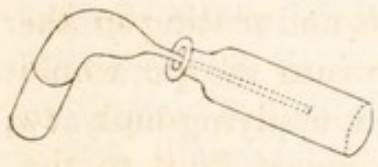


figure, forms what is called a tube-retort. Fluid substances are easily introduced into it through a little tube funnel, made by heating the middle of a piece of tube about two inches long, and half an inch in diameter, by the lamp, and then drawing it out into a capillary tube and separating it of a proper length. A receiver for such a retort is made of a piece of straight tube of larger diameter closed at one end. The beak of the tube-retort is merely inserted an inch or more into the tube-receiver, the junction is left open, and the latter is



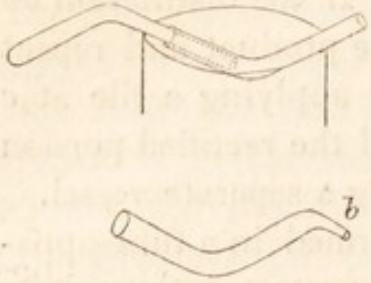
cooled, if required, in any of the usual ways. Occasionally it is advantageous to draw out the beak of the retort into a capillary form, as has been before described (430); it will then enter into vessels having small apertures and necks. Sometimes it is very useful to contract the necks of tube-receivers in a similar manner, as will hereafter be more evident (863).

860. When a larger tube-retort is made use of, it is often



useful to draw out and contract the neck, for the purpose of diminishing its capacity, and consequently the quantity of vapour which it can contain; a common narrow-necked phial then makes an excellent receiver. The tube-receiver is frequently varied in form with advantage, by making it of a bent piece of tube open at both ends, and when one end of it is formed as at *b* in the following figure, it is exceedingly convenient

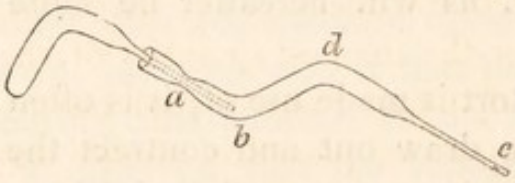
for pouring out minute portions of the liquid contained in it without waste; for by bringing the small extremity *b* against a glass rod or a plate, and inclining the receiver, as little or as much of the fluid may be delivered as is required.



861. These tubular vessels may be supported with facility, sometimes upon the table across two or three pieces of glass tube, or rod, or upon bent rings (59), or in the air upon the edges of glasses placed side by side, or upon retort stands. The arrangements are so simple that no difficulty can occur with respect to them. The receivers may be cooled by wet paper, or by placing them in water in a glass or Wedgwood's dish, or by putting them into a hole in a piece of ice, into which a little salt may be occasionally introduced (421).

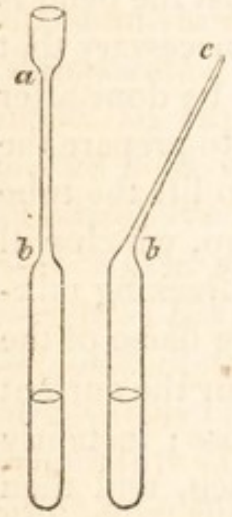
862. In cases of distillation upon a small scale, where, besides a fluid product, a gas is also expected and required to be collected, the tube may have the accompanying form given to it. If it be required to distil the first product a second time for its further purification, it should at first be distilled into a receiver of the second form, and that operation finished, the retort is to be removed, a small flame applied by the blow-pipe to the narrow part of the receiver at *a*, which when soft is to be drawn out and sealed hermetically. The second rectification is to be made either by applying heat to *b*, and placing another receiver at *c*; or by turning the tube into the position it would take if this page were inverted, applying heat at *a*, and distilling into the bend at *d*.





863. A very convenient vessel, answering the purpose both of receiver and bottle, may be made of tube. For this purpose a piece of tube about the third of an inch in diameter, four inches long, and sealed at one end, is to be softened in a flame at about an inch from the open extremity, and when

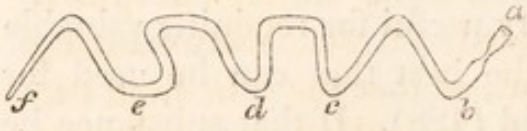
uniformly heated all round, it is to be removed from the flame and drawn out, so as to form a long narrow neck (1079). The substance to be distilled into it, such as sulphurous acid (428. 859), or chloride of phosphorus, is to be conducted by a fine tube, similar to that already described (430. 859), which is to terminate the distillatory apparatus, being either drawn out upon the end of the retort or joined with it by a caoutchouc connecter (416). When sufficient fluid has been distilled into the receiver, the capillary neck of the distillatory apparatus should be withdrawn, the tube softened about *a* by a small flame and drawn off, so as to leave the termination there with a fine aperture; then it is to be softened again at *b*, and bent as in the second figure. The aperture at *c* is easily closed by holding it for a moment in the edge of a flame, and the contents of the vessel, however valuable they may be, are securely retained. When a portion is wanted for experiment, the extreme point should be nipped off so as to make an aperture, and the tube should be inclined until *b* becomes the highest part; so much of the fluid as may be required should be thrown by a little agitation into the neck about *b*, where it will remain in a short column; but by applying the hand to the thicker part of the tube, the air will expand and force out the fluid in the neck, on to any spot to which the aperture at *c* may have been directed. In this manner the smallest quantity of the fluid, or the whole, may be used at once; and enough having been removed, the tube is again to be placed in a more upright position, its extremity sealed, and the whole put aside until again wanted.



864. These receivers are very useful for retaining valuable and volatile fluids, and are the best that can be used for such bodies as sulphurous acid (428). If that substance be confined in ordinary bottles, a great quantity is suddenly volatilized each time the bottles are opened, and from the instantaneous cold produced, the bottoms generally break and fall out: but if it be preserved in vessels like those

described, they may be of sufficient thinness to bear this sudden depression of temperature without fracture, and may even be cooled previously with facility by a piece of ice and a little salt (451. 861). Sulphurous acid may be preserved in such tubes in small portions for single experiments, or if in large quantity, it is easy to distil or transfer it as has been described. When used for sulphurous acid, they must of course be retained in a refrigerating mixture during the distillation (421), they must be continued in this mixture whilst the top piece is withdrawn (863), and also whilst the bend is given to them, if that be required. It is also necessary that they be sealed when thus cooled, for it cannot be done after they are exposed to the air. The best method is to prepare the small aperture by drawing off the extremity, to lift the tube into the air, then to apply the flame of the lamp, which will not as yet seal it, and afterwards to lift up the freezing mixture, or depress the tube in it, still applying the flame of the lamp: as the cold condenses the internal vapour the current outwards will cease, and the extremity will close; instantly withdraw the lamp so that the glass shall harden, and then the receiver may be taken out of the cold mixture, and preserved in a glass or tumbler (849), in a place at ordinary temperature. Should there be a doubt of the sealing being perfect, bring a little ammonia near the extremity; if no fumes are produced all is secure, if there be fumes the same operation of sealing as that just described must be resorted to.

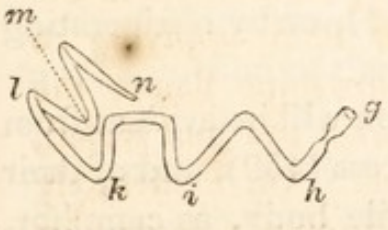
865. Successive rectifications may be made in the same tube, by bending it with several angles as in the annexed figure; such an apparatus was found of great service in experiments upon the fluids obtained by the compression of oil gas. The fluid is to be introduced at the open extremity *a*, so as to lie in the angle *b*, then applying a small blow-pipe flame, the glass should be softened at the neck, drawn out and sealed, the capillary termination at *f* being open. On moderately heating *b* and cooling *c*, a distillation of the more volatile part will take place, the latter collecting at *c*; after a time by keep-



ing *b* and *c* warm and cooling *d*, a rectification of the product at *c* may be effected, and this distillation may be again repeated upon the product at *d* by condensing in *e*. By forming the angles of the tube as in the figure, the results may be returned and redistilled; for upon raising the end *f*, the product in *c* will first return to *b*, then that in *d*, and finally that in *e*; so that if the substance be sufficiently freed from the denser parts only after the third or fourth distillation, the products in *c* and *d* may be returned to *b* and redistilled as before, that in *e* being retained separate: during such experiments *e* should be preserved very cold.

866. In experiments with the oil gas liquor, distillations of this kind were often to be performed in close vessels, that dissipation of the more volatile parts might be prevented. In such cases after having introduced the fluid to *b* and sealed the end *a*, the end *f* was raised till it was the highest point, the fluid in the lower extremity heated until combustible vapour issued at *f*, and then a small flame applied whilst the temperature of the other parts was allowed to fall; the vapour within soon condensed, the extremity was instantly closed by the lamp, the lamp itself removed, and the tube left hermetically sealed. Then collecting all the fluid to the end *b*, the distillations and rectifications were performed, and when fluid had collected in *e*, it was easy by opening the end *f* under mercury, to ascertain whether it was sufficiently volatile to rise as gas at ordinary pressure, and when it did so the gas was easily collected in jars.

867. It will be unnecessary to refer minutely to the capability of transferring backwards afforded by different inclinations of the parts of the tubes: by angles different to those mentioned, the fluid may be first returned from *e* to *d*, then from *d* to *c* and so on. By bending the tube at *l*, as is represented in the accompanying wood cut, so that the tube from *l* to *n* shall be in a plane perpendicular to that which includes the part from *g* to *l*, the power is obtained of returning the products from *k* to *h*, or from *m* to *k* independently of each other; and thus the more fixed and more



volatile parts may both be returned and be re-distilled without mutual interference. The student will easily comprehend these forms of tubes and their advantages by bending a piece of wire into the directed or desired shape, and observing the position of its parts as he inclines it in different directions.

868. Valuable volatile substances are frequently purified with great advantage by distillation in vacuo in tube retorts. A common tube retort (859) is to be softened and drawn out near the open end, like the extremity *a* of the figure, page 399, the fluid is to be introduced, the neck to be drawn off by a small flame, and a minute aperture left ready for sealing (863); the retort being held with this aperture upright, the substance below is to be heated till the tube is full of vapour (866), and the aperture sealed as before described. When the tube is cold, the substance is to be collected to one end, and the distillation effected either by raising its temperature or by cooling the opposite extremity. When the distillation is to be slow, the difference of temperature thus caused between the two ends should be slight, when quick, it must be greater. A very convenient method in slow operations is to pass the end of the tube retort containing the substance through a cork, and to fix



it in the mouth of an open air-jar; this is to be supported by a retort stand or two bricks, or otherwise, and a spirit-lamp with a small flame is to be placed under it: an atmosphere of heated air is thus formed within the jar, which warms the tube more or less according to the arrangement, and effects the distillation. The external or condensing end of the tube may be cooled either by the air, or by water (414. 434), or by refrigerating mixtures (421. 451).

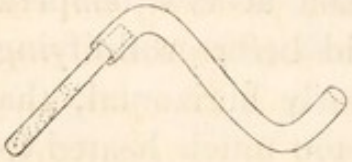
869. The uses of tubes in *sublimation* will be evident from what has been already said of that process (459), and of their application to distillation. Any volatile body, as camphor, calomel, &c. placed at the bottom of a straight tube closed at the lower end and heated, will sublime and condense in

the cooler upper part; after which the tube may be cut with the utmost facility (1060) between the sublimed part and the residuum, and the former obtained in a pure state. In these operations the successful condensation of the vapour is materially influenced by several little circumstances requiring attention: these when the substance is easily condensed, and the upper part of the tube is retained sufficiently cool by mere contact of the air, relate simply to position. The nearer a tube is held to a vertical position, the greater will be the length heated by the ascending flame, and on the contrary, the nearer to a horizontal position, the less will be the extent thus elevated in temperature. Advantage may be taken occasionally of both these circumstances. In subliming cinnabar, arsenic, calomel, or any other body requiring a high heat for the formation of its vapour, the vertical position of the tube is the best, the place of condensation being then farther removed from the place where the crude substance lies, and the crystals themselves being better formed in consequence of the vapour losing its high temperature less rapidly; but with such substances as iodine, naphthaline, camphor, corrosive sublimate, and bodies whose vapours are either formed at low temperatures, or which condense into a liquid before solidifying, the position of the tube should be nearly horizontal, that the place of condensation may not be too much heated for its office, nor so inclined as to occasion the immediate descent of the portion of fluid condensed there.

870. Occasionally it will even be necessary to *cool* the place of condensation: this may be done by a damp finger, or by a piece of tin or copper foil wrapped round it (1242), or by a slip of wet paper folded over it (414) and moistened from time to time. A very convenient and useful method of condensation, when it is required quickly to remove a portion of the substance out of the subliming vessel, is to introduce the end of a smaller tube, closed below, and containing a little water, into the subliming vessel. But this must be done only with such substances as rise at low temperatures and condense readily, for example, iodine, camphor, naphthaline, &c.; for if very hot vapours, as those of

mercury, were to come in contact with such a cooled tube, they would probably break it, and cause inconvenience from the dispersion and mixture of the water. The substance condenses on the exterior of the introduced tube, and may be withdrawn with it. A tube filled with mercury may be used for condensation in a similar way, or even a cold glass or metal rod; but the condensation should in these cases never be continued so long as to heat the rod, or the condensing tube and its contents, very highly, for then their efficacy fails. If they become hot, they should not be withdrawn in that state with the substance upon them, but their temperature should be allowed to fall so low as not to occasion volatilization, or serious loss of the substance, when brought into the open air.

871. Sublimation may frequently be effected very simply and conveniently by condensing the vapours in a tube placed, not within, but over the subliming vessel, a short but larger one being inverted over the mouth of the latter, and the condensation taking place principally in it. In place of this second tube a flask or phial may be used. A very convenient form of condensing tube for heavy vapours, or easily fusible susbtances, as iodine, naphthaline, &c. is that of the annexed figure, the bent tube being of such diameter as easily to pass over the subliming tube, but not larger; the condensation takes place principally in the upper part of the middle portion of the tube, and the refrigeration may be effected in the most convenient manner either by moist paper or immerion in water (414).



872. Berzelius has upon particular occasions used an open tube for sublimation, the length being about six inches, the diameter half an inch or more, and the position an inclined one. When a substance is placed in it and heated, an upward current of air carries the vapours forward into the cooler part of the tube, where, if condensable under the existing temperature and circumstances, they assume the liquid or solid form. The air has access to such a tube, and any combustible body heated in it will consequently burn;



this circumstance occasioned the introduction of the tube into use. A crude mixture containing much sulphur with a little selenium, being put into the lower part and heated, the sulphur inflamed, and forming sulphurous acid, passed away; the selenium sublimed, and condensed in part in the upper portion of the tube, and a fixed impurity remained in the place of the mixture. The portion of selenium might afterwards be sublimed or otherwise examined, and many of its properties ascertained. It is in the continually varying experiments of investigation and research, that such practices and facilities as these are resorted to. They are found of essential advantage where the object is rather to effect the separation of bodies supposed to be present, with a voluntary loss of part, than merely to purify one substance from another in such manner as to preserve the whole. Both objects are important in turn, and both may be attained by one or other of the processes and practices described.

873. Tubes are exceedingly convenient for the heating or even igniting of numerous substances, in the vapours of volatile bodies, which are either solid or fluid, at common temperatures. If a small piece of naphthaline be put into a tube closed at one end, and held in an inclined position, and the bottom be heated, the naphthaline will melt, sublime, condense above, and descend to the lower end in a stream; but as soon as it reaches the hot part it will be re-volatilized, to be re-condensed above, and to flow down as before. In these circumstances the bottom of the tube may be heated red-hot for half an hour or longer, being filled during the whole time with the vapour of naphthaline nearly pure. The same may be effected by a little management, easily to be acquired by practice, with alcohol or ether, or sulphur, or even iodine, and indeed with a numerous set of important chemical agents. It will be evident, that any fixed substance placed in the bottom of the tube, may, under these circumstances, be heated to redness for a long time in the vapour of the volatile body, and thus the facility of acting on metals, metallic oxides, and other substances, by such agents as those mentioned above, is obtained. Nor is it confined to these bodies, for the vapour of sulphur, for instance, may

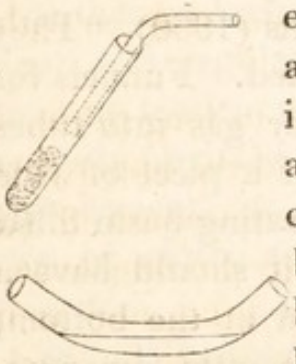
be heated to redness, mixed with the vapour of ether or of naphthaline; or these latter substances may be raised to a red or a white heat, for the purpose of effecting their decomposition; and a great variety of important experiments may be thus performed, to the full satisfaction of the experimenter.

874. Those who work much with tube apparatus, will have frequent occasion to dry precipitates or powders contained in tubes, or even to evaporate fluids in them to dryness. These processes may be performed with more facility than is generally imagined, but require peculiar though simple arrangements and precautions. Suppose, as the simplest case, that a portion of moist powder, a precipitate for instance, contained in a tube, is to be dried: a paper handle should first be adapted to the tube (854), and then heat applied to volatilize the water, the first portions of vapour will condense on the interior of the tube, and forming drops, which descending, may sometimes cause the fracture of the hot glass below. To prevent this the tube is to be held in a position nearly horizontal, so that the drops shall have but little tendency to descend, and a piece of filtering paper is to be folded lengthways and introduced into the tube, as far as the commencement of that part which is too hot to permit of condensation. This piece of paper, lying upon the lower internal surface of the tube, is sufficient to absorb all the liquid that may form, and does not interfere with the passage outwards of that part of the water which is still in the state of vapour. When all the water is driven from the substance, the paper may be withdrawn, bringing away the moisture with it.

875. When the desiccation is performed in long tubes, it is advantageous to wrap paper or tow round the upper part, to keep them hot, and to prevent the condensation of the vapour as much as possible. When from any circumstance a drop has collected in the upper part of a tube, and is in danger of running down and causing injury, either by cracking the glass or by its chemical action, it may readily be removed by bringing the end of a piece of folded or rolled bibulous paper into contact with it.

876. When the contents of tubes have been thus dried, the tubes become filled with aqueous vapour, and their sides are frequently in a damp state. Small portions of water are easily removed whilst the tube is warm, either by blowing or drawing air through it. For this purpose the end of a long narrow tube is to be introduced, the mouth applied to the other end, and air blown through it; this will rapidly take up the warm water, and carry it out into the atmosphere. Still however, the tube remains filled with air from the lungs, which, being in a moist state, would cause a dampness and deposition on the falling of the temperature; to prevent this, and before removing the long narrow tube, a portion of air is to be drawn through it by the mouth, which, as it must previously have entered into the outer tube from the surrounding atmosphere, will effectually remove all portions of that from the mouth which had been left there. This process of drawing the air of the atmosphere through vessels, is a very ready and useful expedient in many cases where vessels are to be dried, but it should never be resorted to if any deleterious vapours or gases are present, as they are then conveyed into the lungs: a pair of bellows should then be used to propel the air.

877 When a comparatively large quantity of water is to be evaporated from tubes upon the sand-bath, at temperatures below ebullition, it is ordinarily a very slow process, in consequence of the limited access of air to the interior, except some expedient be adopted to facilitate its entrance and exit. A very generally convenient one is to insert one end of an open bent tube, as in the figure; a current of air is thus established either in the one direction or the other, and the aqueous vapour readily removed. A more convenient evaporator is a bent tube open at both ends, as in the annexed figure, which being set in the sand-bath, or otherwise heated, so as to have one limb rather hotter than the other, has a current spontaneously established through it. The evaporation proceeds with readiness and facility; the dry results are very easy of access, and yet



little danger of their dispersion during the process is incurred.

878. With reference to *tube pneumatic apparatus*, the advantages which it supplies to those who know how to use them, are equally great with other applications of tubes in the construction of apparatus. It is surprising to observe how many of the ordinary, and even refined experiments of modern pneumatic chemistry, may be repeated satisfactorily with an evaporating basin for a pneumatic trough, and with retorts, receivers, and other vessels, formed of tubes.

879. The tube retort has been already described (859), and the modification produced by drawing out the neck after having introduced the material, has been referred to (859). This variation is often of great service: thus if an oxide of silver or of mercury were to be decomposed by heat, and the gas collected, it would be advisable to put it into a piece of straight tube closed at one end, and then applying heat above the containing part, to draw the tube out into a narrow neck (860) from four to six inches in length; this should be bent near to the body, by holding it over the flame of a small spirit-lamp. Such a retort approaches more closely in its form to the ordinary vessel than the common tube retort, and it will be useful, not merely in the instances mentioned, but in most cases where the materials are solid, and remain so, or do not swell much, during the action of heat upon them.

880. Tube air-jars or receivers, are merely tubes closed at one end, and cut off level at their mouths (1060). They may be long, or short, or plain, or graduated. Funnels for the transference of liquids into retorts, or gas into tubes over water or mercury, are easily made of a piece of wide tube, as before described (859). An evaporating basin filled with water, makes an excellent trough; it should have a slip of heavy metal, such as sheet lead, laid at the bottom, against which the mouths of the tube receivers may rest, whilst they recline above against the side of the basin. The tubes are thus prevented from slipping to the bottom, or

changing their inclined and proper position for a horizontal one, which would endanger the loss of gas.

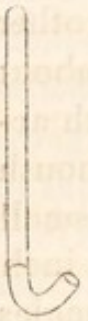
881. Oxygen, a small quantity of which in a pure state is often required, is conveniently and economically made even in the large and well furnished laboratory, from chlorate of potash, in a tube retort. Euchlorine is generally, if not always, best made in a tube retort, but then another variation is advantageous, which is useful also in numerous other cases. The retort itself is to be a piece of plain tube, about half an inch in diameter, two or three inches in length according to circumstances, and closed at one end: the mouth is to be fitted with a good perforated cork, having a small tube fixed into it, which, after proceeding about an inch upwards from the cork, is to turn off nearly at right angles for about three inches, and then return to its first direction for about the eighth of an inch. This piece of tube is the neck of the retort, whilst the wide short piece is the body; and the latter having received its charge, the cork is to be put in and made tight by soft cement, when the distillation may be proceeded with, and the gas evolved and collected.

882. In reference to the distillation of euchlorine, and of all other explosive substances, the student should be aware of the caution required to prevent accidents, in case explosion should occur. Whenever such an effect is probable, the vessel should be surrounded with tow or cloth, that if it break the fragments may be retained; and during distillation the side of the apparatus, or that part which is guarded by the tow, is to be turned towards the eyes, that they at least may be out of danger. It is not easy to wrap tow regularly and tightly round a clean glass tube, from its tendency to slip over the surface; but the difficulty is easily obviated, by rubbing the outside of the tube with soft cement, or a very little turpentine with a piece of tow or cloth, so as to render it slightly adhesive to the fingers.

883. When a mercurial trough is required, it may be made either of a Wedgwood's basin, or an earthenware crucible, or even of a glass or cup, according to circumstances; the first being most convenient for transference, the

latter for collecting gas, delivered from retorts or tubes. The apparatus delivering gas should always be made to turn up at the end, as has been described of the euchlorine retort, that the gas may be fairly thrown off, and into the mouth of the receiving vessel (881).

884. A very convenient mercurial receiver* of the form represented in the annexed figure, may be made of tube



from half to three-quarters of an inch in diameter, and from four to ten inches in length. It is closed above but open at the lower extremity. It is to be filled with mercury when inclined, by pouring in the metal at the mouth, and is then to be suspended or supported in the position represented, with an evaporating basin beneath it. The small tube delivering gas is to be introduced at the mouth, so far as to allow the bubbles to pass into the tube, and the mercury to flow out into the basin below. When the mercury has decended nearly to the flexure, the operation should be stopped.

The gas thus collected may be examined as to a great number of its characters without the help of any other tube, or of any transference but what may be obtained by moving it from one part of the tube to another. For instance, the finger may be placed on the aperture, in contact with the metal, so as to exclude all air and close the mouth of the tube; then inclining the tube, a bubble of the gas may be made to pass round the bend towards the finger; this done, upon restoring the tube towards an upright position, the larger portion of gas will still be in the upright part, but a quantity varying from a quarter to three-quarters of an inch in extent, according to the will of the operator, may be confined between the mercury and the finger, and quite unconnected with the larger portion. This quantity may be tried as to inflammability by bringing a lighted taper near the aperture, and immersing it in the gas the moment the finger is removed. Suppose this trial made and that knowledge acquired, then by pouring in mercury, so as to fill the small space now unoccupied, re-applying

* First suggested I believe by Mr. Cooper.

the finger and re-inclining the tube, another portion of the gas is brought into a situation similar to the former; this may be examined as to smell, and its odorous or inodorous nature ascertained. Again filling the space with mercury, and repeating the operations as before, a third portion of gas is brought to the mouth of the tube, and this may be examined as to whether it is heavier or lighter than the atmosphere, if from the two previous trials it appeared to differ in quality from common air; thus, if after leaving the mouth open a short time, the gas or a part of it still remains in the tube, it must be heavier than air, whereas if all signs of it have disappeared, it is a proof of its lightness as compared with that standard. In a similar manner trial may be made of the solubility of the gas in water, by filling up the space left by the last experiment with water instead of mercury, or at least in part by water, and then bringing a bubble of gas to that part as before: if it instantly disappear, it indicates considerable solubility, if it does not at all diminish, it shews comparative insolubility. If a solution be actually formed, then upon removing the finger it may be examined as to its acid or alkaline nature, or other properties.

In these and similar experiments great care should be taken that no water pass beyond the bend into the tube, for which reason but little water should be put in at once; there should be sufficient mercury between it and the angle to replace the bubble of gas which is to be brought to the mouth, and the inclination of the tube should be carefully attended to, that no water inadvertently pass backward into the higher part. When the trial of solubility is over, the water should be taken from the mouth of the tube, first by a folded piece of bibulous paper, and afterwards with tow upon a wire. Trials may be made with lime-water or alkaline solutions, their action upon a part or the whole of the gas being in this way easily observed.

Thus the gas may be divided into many successive portions, and submitted to numerous examinations; and should it so happen that a part is absorbed by water and a gas left which could not be properly examined whilst in a state of

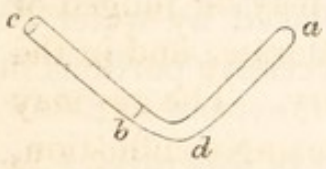
mixture, then, after having made the proper experiments upon the mixture, a little water may be let into the body of the receiver, and shaken with it, to absorb the soluble gas, and the finger being removed from the aperture, either under mercury or water, those fluids will enter and supply the place of the absorbed substance. The insoluble and purified remainder may now be examined in successive portions in the manner just described.

885. In numerous cases gas may actually be retained and examined in the tubes in which they have been generated; and no use of simple tubes is more important than the useful indications they furnish when substances are heated in them and the evolved vapour or gases examined at their mouths. Thus when a little piece of animal matter is heated in a small tube, it is easily ascertained by a slip of turmeric paper at the mouth of the vessel, whether ammonia is evolved: or if sulphur be heated with a vegetable substance, the appropriate tests applied in a similar manner will shew whether sulphuretted hydrogen gas be extricated. Several of the properties of oxygen are exhibited by putting a little chlorate of potash or oxide of mercury into the bottom of a glass tube and applying heat so as to evolve oxygen; the source of heat may be removed after sufficient gas has been liberated to fill the space above, and that may be judged of in the one case by the ebullition of the chlorate, and in the other by the appearance of metallic mercury. The gas may then be examined as to its power of supporting combustion, and that being done, the impure mixture remaining after the experiment may be blown out, and by a fresh application of heat another portion of pure gas evolved.

Carbonic acid gas may be examined in a similar manner in a tube, at the bottom of which is a piece of marble and a little dilute muriatic acid; and so also may muriatic acid gas, sulphurous acid gas, chlorine, and euchlorine, very conveniently. Perhaps, with regard to the latter gas, this is the safest way for a tyro to examine its properties. A little pulverised chlorate of potash and strong sulphuric acid should be put into the bottom of such a tube, the acid first, and the chlorate in successive small quantities; euchlorine

will gradually rise and fill the lower part of the tube, the gas appearing of a deep yellow colour. Occasionally the liberation may be hastened by the warmth of the hand, or a little warm water, the mouth of the tube being directed from the operator. By warming the upper part of the tube with a small lamp-flame, or by immersing a hot wire into the gas, its explosive nature will be observed, and even the chlorine and oxygen liberated may be recognised by their proper qualities. Afterwards, if a little more time be allowed or warmth applied, a fresh portion of euchlorine will be evolved from the materials for another experiment.

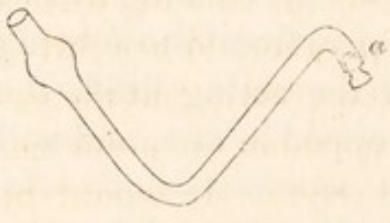
886. There are certain chemical actions which take place between solids and fluids, where the fluid from its price is of no great consequence, and may be used instead of some other fluid for collecting the gas evolved during the action. This is the case, for instance, when a formiate is acted upon by sulphuric acid to shew the immediate evolution of carbonic oxide; and also when the same acid is made to act by heat upon oxalic acid, to shew the evolution of carbonic oxide and carbonic acid; and many similar cases occur. These actions may very conveniently be effected in a form of tube first described by Mr. Kerr.* A simple tube closed at one extremity is to be bent near the middle, but rather towards one end, in such a manner that when placed as in the figure, the vertex on the lower side shall not be directly under that on the upper side, but nearer the closed end; this is easily effected during the bending by making one part softer than another, or by blowing it out as is to be described (1096). The part from *a* to *b* being then filled with the sulphuric acid or the acting fluid, the substance to be acted upon is to be dropped in at *c*, and will



* Edinburgh Phil. Journal, x. 53. Mr. Kerr has the merit of first describing the utility of the bent tube above referred to, and of making the important improvement in the position of the vertices. This tube without that improvement, and all other tubes described in this section, except the modification suggested by Mr. Kerr (887), have been in use in the laboratory of the Royal Institution for many years, and it was supposed were resorted to in most other laboratories of research.

descend into the acid at *d*. When the action commences, either at common temperatures or by applying a little heat, the gas formed at *d* will ascend in the closed limb and cause the fluid to occupy the other. The experiment should be made over a basin of water, that the acid may occasion no harm if a little should be spilt; and when the tube is full, or the action has ceased, the acid should be replaced by water or mercury, and the gas examined. To replace it by water, it is only necessary to immerse the tube in that fluid, and then to raise the closed end so that the place of the acid pouring out of the tube may be supplied by the water: to replace it by mercury, it is necessary to pour mercury into the open limb allowing the sulphuric acid to flow over, and also, if there be any portion in the closed limb of the tube in consequence of the insufficiency of the gas to fill it, to displace it by inclining the tube carefully, so that it may flow over the mercury between it and the glass into the other, or open limb, without allowing any gas to follow. In this way all the sulphuric acid may be removed, except that portion which adheres to the glass, which may be cleared away from the greater part of the open limb after the mercury has been poured in, by wiping the glass first with a little plug of wet tow upon the end of a wire, and afterwards by dry tow. When the acid has been replaced by water or mercury, the gas may be examined in successive portions in the manner already described (884).

887. Mr. Kerr suggests an improvement of this tube, * by making it of the accompanying figure, with an aperture



at *a*, stopped with a ground stopper, or a cork covered with wax. Its use is the same as that of the former, but it affords a further facility of transferring a little gas from it to another vessel without interfering with the fluid in the apparatus. As the gas collects in the closed limb, the small quantity of fluid remaining in the short part, is to be turned out, by inclining the tube, and this may be done safely from the mu-

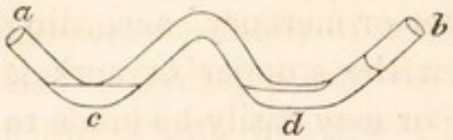
* Edinburgh Philosophical Journal, x. 251.

tual inclination of the parts, without spilling any of the acid at the open extremity. When gas is to be transferred from this vessel to a separate one, as a small tube-jar, the inferior end of the descending part of the closed branch, is to be dipped beneath the surface of water or mercury, according to the nature of the gas, and when the stopper or cork is taken out, the gas will issue forth, or may easily be made to do so, by raising the extremity more or less in the water, or by rendering the column of liquid in the other leg more or less vertical, or slightly urging the gas forward by the mouth. When sufficient gas has been transferred, the stopper or cork is to be replaced, and the circumstances are then nearly as they were at first.

888. Tubes thus intended for the production of gas over the acid from which it is evolved, are often advantageously bent into a form, which may be described, by assuming them to have been coiled obliquely in the manner of a long-threaded screw, about a triangular prism of which the planes are one inch wide, so that each straight portion of tube is an inch and a half or two inches long. It will be found, if sufficient acid be introduced to fill one and a half of the straight portions of the tube, and the substance to be acted upon, as oxalic acid, be introduced with it and heated, that by inclining the tube in different directions, relative to a horizontal axis supposed to pass through the prism about which it was moulded, the whole tube, with the exception of the last divisions at the open end, may be filled with gas. It is confined safely during the revolution by the quantity of acid within, which as the gas increases in volume, travels before it from one end of the tube to the other. When full of gas, the acid may be replaced by water (886), and the gas conveniently examined in successive portions, in a manner similar to that already particularized (884). It would be tedious to explain minutely all the motions and positions required in working with these useful tubes; these, as well as their forms, will easily be understood, by bending a piece of wire as described. The facility with which the gas may be managed in them, may be easily acquired, by putting some water and a little air into such tubes, and observing

their relative positions and changes of place, while moving the tubes.

889. A minute apparatus, resembling Woulfe's in its powers and uses, is easily formed of a piece of tube, one third or one half of an inch in width, bent as in the figure. The gas should be passed in at *a*, and will bubble up through the water at *c* and *d*, and if soluble will form solutions. If it be required that the gas should come into contact with a large surface of water, one of the lower bends should be extended in a horizontal position, as at *d*. If the tube be bent as in the second figure, then the portions of fluid in the four lower angles may be removed in succession, beginning either with the strongest or weakest; or for comparison they may be removed alternately from either extremity; all that is necessary being the careful elevation of one or other end of the tube (865. 867).





890. The extremities or apertures of tubes are frequently to be closed for a short time during operations; thus after a substance has been placed in an open tube, it may be desirable to close one or both ends, to prevent the establishment of a current of air through it when heated, or the dispersion and loss of volatile but condensable substances. The opening may be closed in the temporary manner required, either by the finger, or a cork, or a piece of cement, according to circumstances, and may be opened with equal facility when necessary.

891. The readiness and ease with which gases are passed over substances in tubes, either at high or low temperatures, has been already fully pointed out (672, &c.), those practices indeed form an important part of tube chemistry. Detached instructions and instances of this kind may be referred to by means of the Index.

892. It was by an apparatus constructed entirely from tubes that chlorine and many other of the gases were first distinctly condensed; and the results sufficiently indicate the value of such arrangements. It will be advantageous briefly to describe the method of condensing one of the

gases which are most easily rendered fluid, as cyanogen, and point out the attentions necessary in making the same experiment, with those which, requiring higher pressures for the purpose involve the risk of greater danger.

The tubes chosen should be of such thickness as is sufficient to resist thrice the pressure that is expected to be exerted (814). A piece of about eight inches long is to be selected, and its extremity sealed; then, being softened in the lamp, at about five inches from the closed end, it is to be bent, not sharply, but obtusely and roundly, until the two limbs make an angle of about 130° or 140°. Some cyanuret of mercury is to be pulverized and dried in a Wedgwood basin, on the sand-bath, or over a lamp, at temperatures, which, being above that of boiling water, are insufficient to decompose the salt, or at least to cause much change; it may be allowed to become a little brown, and is then to be introduced into the tube until it fills three-fourths of the closed limb. The open limb is afterwards to be wiped clean and dry, if there be occasion, with a wire and tow, and then to be heated and drawn off (863. 1079) so as to leave the tube with only a minute aperture.

893. The apparatus is now to be filled with an atmosphere of cyanogen sealed hermetically; and then the part containing the cyanuret is therefore to be heated in the flame of a spirit-lamp, until enough cyanogen has been evolved to expel all the atmospheric air. This may be ascertained by bringing the aperture towards a flame, when if the small jet of gas which issues is found to be combustible, it indicates that the tube is filled with cyanogen. Cease to decompose any more cyanuret, and by introducing the contracted extremity of the tube into the lamp, seal it hermetically. This is the more easily done in consequence of the gradual diminution of temperature in the tube, which causes the cyanogen within to contract in bulk, and allows the soft glass to coalesce and thicken. Then permit the whole to cool before proceeding to the evolution and concondensation of the cyanogen.

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* Philosophical Transactions, 1823, p. 512.

894. The tube is next to be supported on a retort stand, or on pieces of wire, in a position proper for distillation, that is with the vertex uppermost, and the two extremities nearly in the same horizontal line. A piece of wet bibulous paper is to be wrapped round the short and empty limb, which is to retain the condensed cyanogen, and the flame of a spirit-lamp carefully applied to that containing the cyanuret, so as to decompose the compound: the progress of the operation may be judged of by the discoloration, fusion and ultimate solidification of the cyanuret. This process must not be carried on rapidly, or the heat allowed at any time to rise so high as to sublime much mercury: the appearance of globules of sublimed mercury to any extent in the upper part of the long limb, is a proof that the heat has been higher than was necessary or proper. The heat should never be allowed to rise considerably in the part of the long leg above the place of the cyanuret; and if the condensation of cyanogen in the shorter limb is so rapid as to make the moistened paper sensibly warm, or the water from it visibly evaporate, the operation must be retarded. The progress of the condensation should be observed by slipping the moistened paper off the end of the tube occasionally, restoring it immediately the information has been obtained. In this way cyanogen may be condensed without the slightest risk of explosion, the pressure within never rising above five or six atmospheres, and when all is cold, being not more than four atmospheres; half an inch or more in depth of the liquid will be obtained in the shorter end of the tube. When left for some days the fluid generally returns to the black mass remaining in place of the cyanuret, that substance having apparently an attraction for it resembling that possessed by hygrometric bodies for water. But upon repeating the distillation as just described, a very moderate heat is sufficient to separate the cyanogen and to exhibit it in a pure and isolated form.

895. Such is an instance of the condensation of a gas in tubes, which any one may repeat. It will easily be understood that, in the condensation of gases requiring higher pressures, the risk of explosion from the bursting of the

vessels is comparatively greater. To diminish the danger as much as possible, certain general precautions should be attended to. The tubes chosen should be sufficiently strong, and be estimated according to the directions before given (814). They should be regular and uniform, and free from the specks or minute cracks to which thick tubes are frequently liable. Upon sealing the ends and bending the angle, the parts heated should be exceedingly well annealed; for which purpose the glass should be withdrawn gradually from the flame, and not allowed to cool suddenly, otherwise the tubes will have a tendency to crack or fly at these unannealed places, even without pressure, and are then unsafe for the experiments. For this reason the tubes when sealed at one end and bent, should be laid aside for a week or two, and then examined in all positions with regard to light, and if any cracks or fissures appear, however minute, the tube should be rejected. The bend should be gradual and not sudden, that great flattening or distortion there may not injure the general form of the tube; when bent irregularly and left in a wrinkled state, there is usually an irregular tension of the different parts when cold, which renders the glass exceedingly apt to crack. On sealing the end of the tube at first, it should be observed, that it be left of a thickness equal to that of any other part, that it may have sufficient strength. On drawing out the other extremity also, for the purpose of finally closing the tube, the conical part and the capillary tube which terminates it, should be allowed to thicken a little in the flame, that it also may have sufficient strength. It will easily be understood, that the tube being of smaller diameter in that part than elsewhere, does not require the thickness of the other parts; but if it be drawn out without attention to this point, it may be rendered so thin as to give way to the force afterwards exerted. It should also be observed in closing the aperture, that the extremity be compact and firm, and not blown out or left in a thin film. All the directions necessary for effecting these objects relative to the sealing and bending the glass securely, will be given in Section xix (1081. 1084, &c.)

896. The operation of condensation should always be conducted slowly. The condensing end of the tube should be well cooled (861. 421); in experiments where gases difficult of condensation are operated upon, it is of essential importance that the heated and the cooled parts of the tube should not approximate closely, but that portions of intermediate temperatures should intervene, so that the temperature shall change gradually and not suddenly from one end to the other.

897. A tube containing the result of an operation, may generally be preserved for years, without any further change or injury than what may be rectified by cooling the receiving end, or moderately warming the other extremity. But one or two instances have occurred, where tubes have burst some months after an experiment has been made in them. They should always be handled with great caution. Any sudden contact with a hard substance, in the manner of a tap or blow should be avoided with the utmost care. And if from the exertion of the internal pressure, a crack should gradually appear in any part of the tube, such tube should never be examined, except with every precaution, even though it may seem to be secure, and have retained the gas for months oryears as well as at first.

898. After the addition of some further brief instructions, this part of tube manipulation may be dismissed. Cyanogen and ammonia may be evolved and condensed in dry tubes. So also may sulphurous acid; or at least the part in which the gas is condensed, may be retained dry, but the arrangement is different to that for cyanogen and similar gases. When the straight piece of tube selected is sealed at one extremity as described (892), mercury is to be put into it for about the depth of an inch, and over that the most concentrated sulphuric acid, to the depth of about three inches, is to be introduced through a small tube funnel, so as not to soil the upper part of the vessel (859) An inch and a half or two inches above this the tube is to be bent as before described (892), and at two or three inches further on is to be contracted. Then holding the tube as vertical as may be, the mercury is to be heated very carefully in the

sulphuric acid, until sufficient sulphurous acid gas has been evolved to eject the common air of the apparatus; this will be ascertained by the well known smell of the acid, or by the fumes which it will yield when the aperture is brought near to paper moistened with ammonia. The operator must then cease to evolve more gas, and having allowed the temperature of the tube to fall, until scarcely any gas passes out at the aperture, the capillary extremity of the tube should be introduced into the flame of a lamp for a moment, that it may fuse and become sealed; but it should instantly be withdrawn, that it may cool without expansion by the gas, which is still slowly evolved within. The tube and its contents are then to be cooled by a little water, or ultimately even by ice and water, which will cause such condensation of the gas within as to make the internal pressure less than the external; and this being the case, if the sealed termination be not sufficiently strong, it may be again introduced into the flame, the glass softened and allowed to coalesce into a thicker mass. The distillation and condensation of the gas may then be proceeded with, according to the directions already given (894).

899. Many of the gases, such as muriatic acid, carbonic acid, sulphuretted hydrogen, &c. are evolved from materials which, liberating gas the moment they come into contact, must not be brought together in the tube of condensation *before* the second extremity is securely sealed up; as that can only be done whilst the gas or air has no tendency to pass out of the tube. The procedure necessary in such cases may be briefly illustrated in the instance of muriatic acid: the tube is to be closed and bent as already described (892), except that the curve is to be near the closed end, so that the shorter leg may be the closed one. The latter is then to be filled by means of a tube funnel with sulphuric acid, to within the half or the third of an inch of the bend, especial care being taken that none of the acid touch the inner surface of the longer leg: a piece of thin platina foil is to be crumpled up loosely, and thrust up the long limb until near the bend, and afterwards long angular fragments of muriate of ammonia, cut with the grain from a lump (294),

are to be put up the tube by a wire, until it is full to within an inch of the open end: these are prevented from passing into the sulphuric acid by the interposed piece of platina foil, and are required of an angular form, that the acid may easily pass afterwards between them and the glass. Being so far arranged, the open end of the tube is to be sealed hermetically; during which operation, the apparatus must be held in a position nearly horizontal, that no contact of the sulphuric acid with the muriate of ammonia may take place. That being done the tube must be allowed to cool, and then placed in a corner with the acid end upwards; the acid will immediately flow past the platina foil, and upon the salt beneath, rapid action will take place and much gas appear to be evolved. The action will gradually seem to diminish almost entirely, because the pressure within increasing continually for some time, the bubbles will thereby be reduced into a smaller bulk. The tube should be left in this position for some days, or even a week, at the end of which time a very limpid fluid will be perceived here and there, occupying cavities in the dense acid sulphate of ammonia. The tube being placed in a distilling position, and the shorter leg cooled (414. 859. 868), the limpid fluid will pass over into it, and its characters may then be observed. The pressure will be about forty atmospheres at a temperature of 50°. A tube of half an inch internal diameter and ten inches long, will, in such an experiment, resist and support a pressure upon its internal surface of above 6000 lbs.

900. In all cases where the condensation of a highly elastic gas is to be effected, the tube should be filled as nearly as possible with the materials, that the space for aëriform matter may be the less; or else it may happen that the quantity of gas evolved from the substances is not enough to do more than fill that space with an atmosphere, equal to or less in density than that required before fluid will be deposited.

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901. One constantly valuable use of tubes is for the retention and preservation of different substances, for

which purpose they may often be used instead of phials and bottles, and are not unfrequently superior to them. The tubes in the drawer already spoken of (848), will in these cases be had recourse to, but they are improved and strengthened, by softening and turning the edge of the aperture outwards, so as to make it like a phial mouth; they then allow the cork, which is to be used for closing them, to be applied with more force. When deliquescent substances, or such as would be injured by access of air, are to be preserved in them, the cork should, either before or after its insertion, be covered with wax, or, which is better because it is not liable to crack and separate, soft cement (1035). The arrangement and economical use of tubes intended to receive and contain small quantities of valuable fluids have already been described (863).

902. A tube, different in its kind from either of these, is exceedingly useful for the preservation of such portions of valuable fluids or solids as, being intended for specimens, may be left undisturbed for long periods of time, and consequently may be sealed up hermetically. The tubes selected for this purpose should be rather thicker than usual, that they may bear packing together when required, or be laid with other things without injury. They should be perfectly clean previous to the introduction of the substance, and when sealed up at the end last closed, the termination should be made thick and strong in the manner described in Section xix. (1085, &c.). The substance thus permanently secured, may be preserved for years without change or injury, is always readily examined as to its appearance, and external characters. Its name, with the date, and other necessary circumstances, should be written upon the exterior of the tube with a scratching diamond (115), which is best done by laying a book or board of equal thickness with the tube upon the table, and holding the latter in the angle formed by the two, by which steadiness is given to it: the diamond should be held in a vertical position during the writing, and the hand retaining it should be rested on the book. Upon trying to write on a piece of flat glass with a scratching diamond, turning the latter round slightly at the same time,

it will be found that one position of it is more advantageous than any other, the writing being then performed with greater facility: this being ascertained, a notch or mark should be made on the handle of the diamond, so that at any future time this favourable position may be immediately given to it.

903. When tubes are required for the conduction of gas or vapour, it has been already shewn that in cases of emergency such as are made of paper (225, 249, 786) may be substituted for those of glass or metal. It is often advantageous to render the paper difficult of combustion, that the accidental, and at times even necessary approach of flame, may not occasion injury. This may be done by washing the paper with a strong solution of alum, or phosphate of soda, or common salt, or better still with alkali or carbonated alkali, provided these do not interfere afterwards with the uses of the tube, or paper, or the substances which are to be passed through them (1223).

904. Such are some of the numerous applications of tubes for the performance of chemical experiments. Many variations of the forms mentioned will suggest themselves in practice as affording facilities in particular cases. It would have occupied far too much room to have enumerated all that have been found useful; and indeed throughout this chapter general forms have been referred to and described rather than particular ones; for their uses and properties once known, the variations will easily be understood. The economy and exceeding facility afforded by this kind of apparatus in situations distant from the usual sources of more perfect instruments, and its superiority in some cases over any other that has yet been devised, is sufficient to recommend it to full and general attention; and when combined with the use of a few fragments of glass and paper vessels as is hereafter to be described (1222), places in the hands of every one, whatever his situation may be, opportunities of pursuing chemical researches to a very considerable extent.

SECTION XVII.

Electricity.

905. In consequence of the very general and close association of chemistry with all the other sciences, the chemist is often obliged to work with instruments, and to make arrangements which, although they seem essentially to belong to other pursuits, are at times highly influential over his peculiar results. The powers of Electricity, for instance, are so closely allied to those of Chemistry, and possess such vast influence in aiding or opposing them, that the experimenter in this science is continually resorting to them in his peculiar and ever varying examinations of matter. For this reason so much of the management of electrical machines and apparatus as is frequently required in the laboratory will be described in this section, and the circumstances necessary to facilitate investigation or secure success, will be particularly pointed out.

906. The common electrical machine is of constant use for the passing of sparks or currents of electricity through gases, for charging a jar, or for conferring particular states of electrical tension upon insulated bodies. When required for use it generally wants some degree of preparation to bring it into strong action. In favourable weather, merely wiping the machine with a warm linen cloth, and afterwards with a silk handkerchief, is sufficient for this purpose; but usually, and especially in damp weather, it will require warming. This may be done occasionally by placing it before a fire and turning the handle at intervals, that all parts may be exposed to the heat; but it is more advantageous, as well as safer, to attain the same end by placing the machine in a current of hot air. Or if it be required for continued use in one particular place, to pass a stream of hot air against and about it. A machine may be very effectually warmed by placing it over a sand-bath or hot iron plate of a temperature not more than 212°, by which not only does the plate or cylinder, but also the glass insulations

of the conductors, become thoroughly warm. At other times a current of air heated by a crucible furnace (246) may be conveniently conveyed to the machine, the warm air being occasionally conducted by paper pipes (1223). Another expedient, and a very good one with cylinder machines, is to place a chemical lamp (189) with a low flame beneath the cylinder, and to support a plate of metal about six inches square nearly an inch above the chimney of the lamp. This plate prevents the ascent of the comparatively small hot current of air from the lamp against the cylinder (which would heat in spots only, and those far too highly), it becomes itself hot, warms the air lying upon it, and thus produces a large current moderately heated, which surrounds the cylinder on all sides and thoroughly warms it.

907. During the warming of a machine, care should be taken to give it as equable a temperature as possible, and it should be continually watched that no part becomes so hot as to melt the cement used in its construction. The warmth of the insulating parts should be particularly attended to; for in damp weather a machine which will appear to be in excellent action and give out long electrical brushes from its cylinder or plate, will often scarcely give a spark from the conductor, because of the dampness of the insulating glass pillar.

908. Whilst a machine is warming it should be wiped with a dry cloth or a silk handkerchief; the rubbers should be examined, all dust taken from them, and amalgam applied if required: this may be known by observing whether the amalgam has broken away, or has, by age and disuse, concreted into a hard brittle mass that will not adapt itself, or present a good surface, to the passing glass. If the cylinder have many spots of amalgam upon it, and several of them large, they should be removed: they may easily be scraped off by the thumb-nail or a piece of wood. A few small spots appear rather to increase than diminish the activity of the machine, and the silk which proceeds from the rubber to a certain distance over the glass, is far better when from use it has become impregnated with amalgam, than when it is quite clean and free from that substance. It is often advan-

tageous, especially when the machine is required in haste, to hold a piece of silk with some amalgam upon it against the plate or cylinder, whilst it is turned, and also to rub up the surface of the amalgam upon the rubber with the same amalgamated silk. To apply the amalgam to the silk, it is necessary first to put a little tallow upon the latter, after which the amalgam will adhere. The amalgam itself should be rubbed in a mortar with a little tallow, before it be considered fit for any use about the machine. The rubbers should press lightly against the glass.

909. When the machine is in good order, the prime conductor away, and the handle turned, it should send out an uninterrupted series of brushes from the edge of the silk, with continual sparks flying round the glass. The appearance presented by bringing the knuckles near the edge of the silk, is a very good indication of the exciting power of the machine. These effects should take place without causing considerable friction between the glass and the rubber and silk, or if there be much, it should be from adhesion between the glass and the silk, and not from the pressure of the rubber. In that case it is easily diminished, and the labour of turning lessened, by folding back the silk more or less, so as to lessen the part in contact with the glass.

910. Upon putting the prime conductor into its place, and continuing the motion, sparks two or three inches in length should fly rapidly from it to the knuckle, or to a clean brass ball held near it. For these trials of the length of spark, and for discharges, where the passage of a spark is necessary in other circumstances, a metal ball is better than the knuckle or back of the hand; the hairs, moisture, and adhering filaments of the latter, frequently diminish the effect.

911. The machines when out of use, should be set aside in a dry room or cupboard, away from the fumes of the laboratory (25), and it is advantageous to throw a green baize bag over them as a cover to keep off dirt, and to a certain extent, moisture and fumes.

912. The manner in which plate machines are mounted, namely, by an axis passing through the middle of the plate, made tight by collars or screws, generally causes an

irregularity of tension, by which a tendency to crack from the centre is produced. This renders the machine liable to injury from circumstances otherwise unimportant; and warming it too much at the middle before a fire, or partially only, or slight mechanical strains, cause cracks to originate there, which, though small at first, gradually extend until they reach the circumference, unless means be adopted to stop them. This is best done by directing an instrument maker, to drill a small hole through the glass a little in advance of the crack, and in its course. When the crack reaches the hole it generally stops, and the plate is saved for a time till other cracks are formed, which gradually weaken, and finally destroy the machine.

913. The machine is used to give sparks directly from its conductor: these, when passed through eudiometers, either inflame the mixture of gases within, or occasioning chemical changes of a slower kind, require to be repeated a great number of times. A spark of sufficient intensity to inflame a combustible gaseous mixture, may often be taken from a machine to one of the wires of an ordinary eudiometer, the other wire being in contact with the finger or connected with the earth through conducting matter. But it will occasionally be found exceedingly difficult to succeed in the experiment, solely from inattention to some slight circumstance about the arrangement. The wires which are fixed into a detonating eudiometer, are so placed as to have their inner extremities at a small distance from each other. These terminations are not always finished off with sufficient care, the wires being either simply cut by pliers, or if filed into shape, are still left with some projecting corner or irregularity. Sometimes the wires themselves are too thin.

914. All these circumstances tend to make an electric discharge pass rather as a coarse brush, or as a succession of minute sparks, than as one decided luminous flash. This tendency is still further increased if the exterior ends of the wires are also small, or are only turned into a little loop; and it will then be found almost impossible to send a spark from the prime conductor in an undivided state through the interior of the tube. When defects of this kind are found to exist,

they may be remedied by putting a ball half an inch or an inch in diameter upon the wire, which is to be brought near the conductor; this ball will receive a large distinct spark, and will transmit it from the one wire to the other within the eudiometer in a single discharge, even though the latter were to terminate almost in points.

915. Sometimes a eudiometer which permits a spark to pass with perfect facility, through gas confined in it over mercury, will not with gas over water. The interference in this case arises from the film of water with which the interior of the instrument is moistened, and which so far conducts the electricity of a spark given in the ordinary manner, as to prevent its passage from point to point of the wires within. In these cases the application of the large ball on the outside (914) will often remedy the evil, by enabling a more powerful spark to be drawn from the machine. If it has not this effect, the charge of a Leyden jar must be used: the ball in these cases need not necessarily be fixed upon the eudiometer, it may be hung from it by wire, or the knob of a discharging rod, the metal of which is held against the end of the eudiometer wire may be substituted, or it may be arranged in some other way. The necessary points to be attended to are, that the ball and the eudiometer wire make an undivided metallic communication, the whole of which is insulated, and that the spark be received by the ball.

In all these eudiometric explosions, the other wire of the tube must be in communication through a finger, or a chain, or some conducting matter with the ground. The whole of these operations are effected with admirable facility by a single person, with the detonating eudiometer of Dr. Ure (923).

916. A Leyden jar of the capacity of a quart, will be sufficient for all ordinary laboratory purposes. The ball should be at least an inch in diameter, and with the wire and wooden top should be so firmly fixed to the jar, that the latter may be placed in any required position without fear of their falling, or being deranged. For the same reason the connection between the ball and the coating within, should be made by wire and not by a chain, that the communication may be

perfect in every position. The jar when new, should be warmed and wiped on the outside, and then examined relatively to certain points, and first as to its freedom from the fault of permitting spontaneous discharge. The jar being held by its exterior coating, should have its knob placed in contact with the machine in good order, and should be as highly charged as possible. If the jar does not discharge itself, or permit a spark to pass over the external uncoated glass, it is in that respect good; if it discharge spontaneously, but only when very highly charged, it is moderately good; if it discharge spontaneously with readiness and freedom, even with comparatively low electrical charges, it is bad. This fault may sometimes be cured by paring away half an inch or more of the exterior coating at the upper edge, so as to make the distance between it and the wire of the ball greater; or by removing some accidental angular projection or point on the wire or wooden top, which has facilitated spontaneous discharge.

917. If a jar prove good in this respect, it should then be examined as to its power of retaining a charge undiminished. For this purpose the jar should be highly charged, and then immediately discharged by the discharging rod, the length, brilliancy, and sound of the spark, being at the same time observed. It should then be charged to the same degree as before, and being removed from the conductor, should be left a minute in the air before it be discharged, and the spark again observed and compared with the former. It will readily be seen whether in consequence of standing for the minute the spark is smaller, and also whether the diminution has been much or little. There are no jars which do not lose considerably even in a short interval of time if very highly charged, but if only moderately charged, they should suffer much less dissipation of electricity, and ought to yield a spark of considerable force after a lapse of five minutes. A jar of the size above mentioned, when dry and warm and well charged, should, after a lapse of ten minutes, give a spark at least half an inch in length to the ball of the discharging rod, the ball being one third of an inch in diameter.

The retention of the charge by an electric jar in chemical experiments, is frequently of great importance, from the unavoidable delays which often occur before the spark can be passed.

918. A jar for eudiometrical experiments, is much more conveniently discharged by a wire, than by the usual glass-handled discharger. A piece of copper wire about one-twentieth of an inch in thickness, should be connected with the outside coating, by being passed round the body of the jar, and made tight by twisting it, the piece left to act as a discharger, being about 18 inches in length. The loose end should be coiled up into a flat spiral of a couple of turns, to prevent its acting as a mere point, or if a little metallic ball or a very small bullet be fixed upon it, the arrangement will be more complete. This wire performs the part of a discharger whenever it is required, and being in constant contact with the outside, and also very flexible, it may be adapted to nearly every possible occasion. Suppose, for instance, that the machine will not yield a spark sufficiently powerful to inflame a mixture of gases in a eudiometer tube (913), and that a discharge is requisite, the jar must be charged and then discharged in the following manner. The end of the attached wire is first to be placed and retained in contact with one of the eudiometer wires, and then the ball of the jar approached to the other wire, the discharge will immediately be made through the instrument without any risk of inconvenience to the experimenter, even though he hold the wire and jar in his hand during the operation.

919. There are certain points in the management of a eudiometer, relative to the method of holding it during an explosion, which require the attention of the student. The common detonating eudiometer is a short glass tube closed at the upper extremity, and having two pieces of platina wire passing near that extremity through the glass, so that their inner terminations are within a very short distance of each other. These wires being made parts of the metallic communication of a charged jar as before described, conduct the electricity, and cause a discharge to be

effected through or between them. The gas to be subjected to the spark is generally such a mixture as will inflame. It is to be transferred into the tube over water or mercury, according to circumstances (720, 741), and the lower open end of the eudiometer is necessarily retained in the water or mercury during the experiment to confine the gas. When the gas has been introduced, the outside and upper part of the eudiometer is to be wiped clean and dry, so that no water or mercury may adhere to it. The instrument should then be held firmly and upright, which is perhaps best effected by grasping it with the first three fingers on the one side, whilst the thumb and little finger are pressed against it on the other. The hand should be about the middle of the tube, and out of the way of the wires above, that the knob of the charged jar may not come near it during the experiment. The tube should be supported by the hand alone, its lower end not being allowed to touch the bottom of the vessel in which it stands during the explosion, lest it strike against it with such force as to be broken or injured. It is advisable, wherever it can be done, to apply a finger of the unoccupied hand with slight force to the bottom of the detonating tube under the fluid at the moment of explosion; this allows the descent of the water or mercury during the explosion, but as contraction takes place it is drawn against the aperture, and prevents the fluid rushing in at once. By withdrawing it gradually, the water or mercury is admitted in a more tranquil manner than would otherwise be the case; and indeed the impetuosity of the action is altogether restrained, and the probabilities of loss of the contents of the eudiometer diminished.

920. As before mentioned relative to a spark from the conductor (913, &c.), so also here if the wires be pointed, a ball may be advantageously used; and if the interior be so moist as to transmit all the electricity of a small or moderate charge, then a larger charge must be passed.

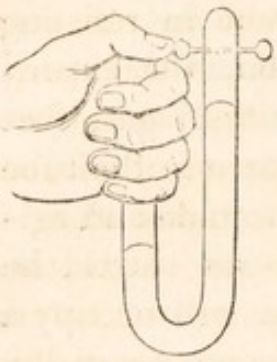
921. The proportion of gas which may be detonated with safety in an eudiometer tube, depends considerably upon the explosive power of the particular mixture under exami-

nation, and also upon the quantity detonated at once. A mixture of oxygen with carbonic oxide expands, when inflamed, with much less force than a mixture of oxygen with hydrogen or olefiant gas; and a large quantity will of course expand with more force than a smaller. But besides considering the efficiency of the eudiometer tube in resisting the expansive force, occasioned by detonation, the experimenter has also so to proportion the quantity of gas, that whilst expanding there shall be abundant space in the tube to retain the products under their greatest volume and agitation, that no loss may occur. No more gas should be introduced into a tube for detonation than will occupy a sixth of its capacity at common temperatures, and, generally, it will be safer and advisable to employ much less.

922. In operations with the ordinary eudiometer tube, two persons are usually required, one to hold and manage the instrument, the other to pass the electric discharge. The second person may however be dispensed with by a little contrivance. The jar may be placed upon the table with its knob in contact with the prime conductor of the machine, and with a wire of two feet in length, made fast to one of the eudiometer wires, that sufficient motion may be allowed in connection with its outside. One end of another wire of equal length, is to be attached to the second eudiometer wire, and the other end made fast to a metallic ball, which is to be placed within half an inch of any part of the prime conductor. The ball with its wire, though it is not essential, may be insulated with advantage, and for this purpose it may be supported on the mouth of a glass or a bottle, raised upon a stool or other convenient support (16). The operator may then hold the eudiometer tube (919) in one hand, and turn the machine with the other: when the charge in the jar has acquired such intensity as to pass over the half inch of air between the conductor and the ball, the jar will be discharged through the eudiometer wires. The hand which holds the tube should be, as before mentioned, clear of the wires (919); and it is proper not to touch the outside of the jar or any of the wires during the experiment,

lest from some unperceived circumstance the discharge should be made through the body.

923. Dr. Ure's eudiometer* (914), renders the experiment easy of performance by a single person. This instrument is furnished with wires in the usual manner, but is



bent, so that the open extremity is turned up nearly as high as the closed one. It is to be filled with water or mercury, and the gas transferred into it in the ordinary manner; then, being placed upright, part of the fluid in the open leg is displaced by inserting a glass rod, or in some other manner. The open leg being grasped by the hand, the thumb is to be placed tightly over the aperture, so as to close it, and at the same time to touch one of the wires; a spark taken from the conductor to the other wire passes through the gas, inflaming it, and is conducted off by the thumb and hand. The gas in expanding depresses the fluid beneath it, whilst the air in the part closed by the thumb, acts as a spring to restrain the violence of the explosion. If a charge from a jar (918) is to be passed, then the thumb must not be allowed to touch the wire whilst closing the aperture; when the jar is charged, the wire connected with the outer coating is first to be hooked upon the eudiometer wire nearest the thumb, and securely retained there, so as not to slip during the experiment, and then the knob of the jar is to be brought to the other wire, and the gas will be inflamed.

924. It will be unnecessary particularly to describe the arrangements of a battery, which belong principally to the electrician. Whenever its use is required in the laboratory, it should be ascertained that all the outside coatings are well and securely connected together by metallic substances, as wires or sheets of metal; that the internal coatings are in proper connection with each other, through their appropriate mountings and wires; that no wire or thread, or conducting matter of any kind, extend in any way

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* Edinburgh Philosophical Transactions, 1818.

from the case or externally coated parts of the jars, towards the knobs and wires connected with the insides; and that no filamentous or pointed substance, nor any projecting metallic body remain in the neighbourhood of the battery during the time it is in use.

If a Henley's electrometer be used to shew the progress of the charge, it should be so placed that, as the index moves, it shall not approach to any ball, or wire, or surface charged similarly to itself, but recede from it; if placed upon the end of the conductor, therefore, the index should be allowed to move outwards and away from the conductor, and not in a direction over it towards its more central parts; the latter would interfere with the free indication of the instrument, and sometimes even render it quite useless.

When a battery is in use, the operator should beware of discharging it accidentally by means of his own person; for though the shock might do no bodily harm, it might cause involuntary movement, and the derangement of an important experiment; being therefore once well and securely arranged, the wires and metallic connections should not be unnecessarily approached after the charging has been commenced, until after the explosion. When a battery has been used, the experimenter should beware of the residual charge. During the time occupied in charging a battery, a diffusion of electricity takes place over that part of the uncoated glass, which is near the edge of the foil; this is not entirely removed on the discharge of the coated part, but afterwards gradually returns to the coatings and recharges the battery, occasionally to a considerable extent: hence if, after the discharge of a battery, it be left a few minutes with its internal coating uncommunicated with the earth or with the exterior coating, it will be found, upon applying the discharger, to afford a considerable spark.

925. When a regular electrical jar cannot be obtained, an excellent substitute may be formed from a large thin medicine phial, by filling it two-thirds or three-fourths with metallic filings, coating the outside to the same height with pasted tin foil, and closing the mouth by a cork, thrust in

nearly to a level with the top of the neck; a thick wire is to be passed through the cork, so that one end shall enter the filings, and the other project about three inches above the cork; a bullet or other convenient metallic ball is to be attached to its extremity. A ready substitute for a jar may also be made of a piece of thin glass tube of large diameter, coated on the inside and outside with tin foil, to within two inches of each end, and furnished with a knob and wire connected with the inside coating as just described. A plate of crown glass coated on both sides with tin foil to within an inch and a half of the edges, also makes a good substitute, but requires care in the handling, lest it be discharged through the fingers.

926. A very effectual and cheap discharger is made of a piece of thick wire about twelve inches long, curved, terminated by a bullet at each end, and supported in the middle by a stick of sealing-wax as a handle.

927. The *electrophorus* is an instrument which would not claim the attention of the chemist, but that, being easily constructed with materials obtainable in almost every place, it may be rendered effectual in supplying the want of an electrical machine for usual laboratory purposes. A sheet of tin foil is to be laid smoothly in the bottom of a flat dish, so that its edges may rise up all round; or it may be laid upon a flat surface, with its edges rising up against the inside of a hoop placed to confine them. Equal parts of common resin, shell-lac, and Venice turpentine are to be mixed together, and heated in a metallic vessel, the mixture being retained in a state of fusion at temperatures from 230° to 240°, until all evolution of vapour has ceased, and the fluid is quiet. It is to be allowed to cool until it thickens, and is then to be poured tranquilly, so as to avoid the formation of air bubbles, upon the tin foil laid out as before described, so that, when cold, it may form a cake one-third of an inch in thickness. The tin foil should ultimately be trimmed round the edge, and if convenient a board attached to the cake to serve as a bottom, and to prevent accidental fracture or injury. This is one part of the electrophorus.

The second part may be a piece of flat deal board, one-third or one-half of an inch in thickness; less in size than the cake of resin, by an inch, or an inch and a half on every side, and with the edges rounded and smoothed. This board is to be covered with pasted tin foil, smoothly laid on, especially at the edges, and all asperities rubbed down. The smoothest and flattest side is to be appropriated to meet the surface of the resinous plate: a piece of glass tube, about seven or eight inches long, is to be fixed perpendicularly on the middle of the other side to serve as a handle; and towards the edge, on the same side, should be fixed a piece of thick brass or other wire, about two inches long, curved outwards, and terminated at its upper extremity by a smooth metal ball. This is the cover of the electrophorus.

928. Before using this instrument, the resinous plate should be warm and dry, and placed upon its board in a convenient horizontal position, with the tin foil on its lower surface, connected by a chain or wire with the floor of the place, or with neighbouring metallic bodies. A piece of warm dry flannel is to be doubled up loosely, so as to form a roll about ten inches long; one end of the roll is to be held in the hand, and the other being swung round in an inclined direction, by a quick motion of the wrist, is to strike the surface of the plate in an oblique manner each time it passes, so as to produce an effect between that of a rub and a blow. This is to be done over the whole surface of the warm resinous plate, by which it will be excited electrically to a considerable degree. Having previously warmed the cover of the electrophorus, it should now be lifted by the handle and placed on the middle of the plate; if the knob of the cover be touched when all is in order, a spark will pass between it and the finger. The cover is then to be lifted by the handle in a horizontal direction, and when two or three inches above the plate, the knob upon it is again to be touched by the finger or a ball, when a spark much stronger than the former will be occasioned; the cover is again to be put down, when a third spark will pass between the knob and the knuckle; being again lifted as

before, a spark as strong as the second may be taken from it: similar effects will follow for a long time by repetitions of the process. All the sparks which pass immediately after putting the cover down are negative as to the approximated ball or knuckle, and those which pass after taking it up are positive.

929. When the electrophorus is in good order, the sparks taken after lifting the cover are quite sufficient to inflame the greater number of explosive mixtures operated upon in eudiometers. All that is necessary is, to substitute the knob of the cover for the conductor of the electrical machine. If a stronger spark be required, a jar must be charged: this may be done either positively or negatively at pleasure. For the first purpose it is only necessary to bring the knob of the electrophorus cover into contact with the knob of the jar, immediately after raising it from the plate; upon doing this thirty or forty times in succession, the jar will be charged positively: if the ball of the jar be applied to the knob of the cover each time, the latter is to be put down until several sparks have passed, when it will become negatively charged. It must be understood, that to obtain strong positive sparks, it is necessary to touch the cover when on the resinous plate with a finger or other conducting body, which must be removed before the cover is raised; and that to obtain the strongest negative sparks, the cover, when raised, should always be discharged of all its electricity against the hand or some other convenient conductor, before it is again placed on the plate. The cover must always be in a good state of insulation, when it is put down to give negative sparks, or when it is taken up to give positive sparks; and inasmuch as glass has a powerful tendency to attract moisture to its surface, and thus becomes a bad insulator, it is advisable to varnish the glass tube handle with sealing-wax dissolved in spirit of wine, or to make the handle of a stick of sealing-wax or other resinous matter.

930. Instead of a resinous electrophorus plate, that part of the instrument may be made of a sheet of thin crown-glass, the metallic base (927), which is essential as a bottom for

the electrophorus, being tin foil pasted and attached to it. A large plate of mica without fissures, coated in the same manner with tin foil on one side, makes a most excellent electrophorus. The cover, instead of a board, may consist of a plate of tin having its edges turned up round a thick wire, that no sharp edge or angle may be presented outwards. These parts are to be used exactly in the manner already described; but if glass be the substance employed, it must be well warmed at first, and kept warm during the experiments. It is most powerfully excited by being rubbed with a piece of silk, having some amalgam spread upon it (908); this should be passed briskly over its surface backward and forward, and at last slidden rapidly off at the edge, so as not to rest upon any one part of the glass, as it would then discharge that portion of its surface.

931. Bennet's gold leaf electrometer, as improved by Singer, is highly useful in the laboratory, for the facilities it affords of detecting electricities of low tension, and determining their kind. These are constantly developed by chemical action; by the voltaic pile; and by other causes which relate to chemical science. This instrument, as improved by the application of Singer's mode of insulating the cap and gold leaves, will, when warm and dry, retain a charge for hours. It would be improper to enter minutely into its uses; but repeated experience that its indications are not generally well understood by persons having occasion to resort to it, induces a more particular notice of the kind of change it receives under different circumstances, and the precautions requisite in interpreting its indications.

932. If an insulated portion of conducting matter, as a brass ball at the end of a glass handle, be electrified, and then placed in contact with the cap of the electrometer, the cap and leaves will immediately partake of the electricity of the ball, and the leaves will diverge. If the charge in the ball be of considerable intensity, the leaves will be torn to pieces by their mutual repulsion, and that of the attraction of the sides of the glass jar; but if the intensity be small, the leaves will diverge moderately, so as not to touch the glass; and

the degree of divergence will be in some proportion to the intensity of the charge communicated. The appearances will be the same whether the electricity communicated be positive or negative.

933. The circumstances will be different if the body brought near to the electrometer is an electrified portion of what is usually called non-conducting matter; if for instance it be a stick of sealing-wax rubbed with flannel, instead of a metallic ball. If highly electrified, this will cause the same disturbance and appearances in the leaves during its approach as the ball; if moderately electrified it will, when in contact with the cap, cause the usual appearance of divergence in the leaves, but upon removing it, the leaves instead of remaining diverged, will either collapse, or remain very slightly, and frequently uncertainly, electrified. This is a consequence of the non-conducting power of the wax; and the method of transferring electricity to the electrometer in such a case, is, to draw the excited parts of the wax over the edge of the cap; small portions will be communicated, and the electrometer will be left electrified similarly to the wax. Such a process is, however, very uncertain; for if the electricity of the wax be weak, the friction of the substance against the electrometer cap will sometimes generate an electricity stronger than that previously existing on the surface of the wax, and the electrometer will become charged, not by the previous electricity of the wax, but by that produced during its friction against the cap.

934. This difficulty may, however, be avoided in most circumstances, simply by bringing the electrified non-conductor into contact with the cap, and retaining it there during the experiment; for the electricity which in this way is made by *induction* to exist in the leaves, and causes their divergence, is the same as that which would exist over the whole of the cap and leaves, if the electricity of the wax could be transferred to them.

935. Such are the circumstances relating to the charge of the electrometer, by bodies brought into contact with it, and communicating to it part of the electricity they previously possessed. As before mentioned, when highly electrified,

they cannot be so applied to the instrument without tearing the leaves to pieces; but they may then, when held at a distance, be made to diverge the leaves by *induction*, and even to communicate a charge to the instrument, and thus enable it to exhibit divergences when the inducing electrified body is removed. The effects thus produced by induction are the same in kind and extent, whether the electrified body be a mass of conducting or of non-conducting matter, so that in this respect the metallic ball and the stick of wax are equal; the only difference being in the kind of electricity produced, which, with bodies charged positively, is the reverse of that occasioned by such as are charged negatively.

936. When an electrified substance is placed at such a distance from the cap of the electrometer, as to occasion considerable divergence, and is retained there for a few minutes, the divergence of the leaves will generally diminish, and the more rapidly as the instrument becomes cold, the glass damp, the leaves ragged, or any part of the cap angular and pointed. On removing gradually the electrified substance to such a distance that it can no longer affect the instrument, it will be found that the leaves will collapse at first, and afterwards expand again more or less, according as they had lost more or less of their first divergence. This ultimate divergence of the leaves will be due to a charge of electricity in the instrument, of the *opposite kind* to that of the inducing or approximating body.

937. If no effect of this kind takes place, and there be no diminution of the first divergence, nor any ultimate change, then the insulation and goodness of the electrometer is proved by a powerful test. This being ascertained, then, if whilst the electrified body is in the neighbourhood, and the leaves diverged, the cap be touched by the hand, or any other conducting substance communicating with the earth, the divergence of the leaves will instantly cease. In this state of the instrument, if the communication be broken, so as to leave the cap and leaves insulated, they will still remain collapsed; but if the inducing electrified body be now removed from the situation in which it at first caused the divergence,

the leaves will immediately diverge, and the electrometer become charged with electricity of the *opposite* kind to that of the inducing body. The degree of charge thus given to the instrument will be in proportion to the degree of divergence induced in the leaves *before* they were made to collapse by the touch of the finger.

938. In the case in which a weakly electrified non-conducting substance was directed to be laid on the cap of the electrometer (934), to occasion a divergence by electricity like its own, it may be observed that, if, during the experiment, the cap be touched by the fingers, and the electrified body afterwards removed, the leaves will first collapse, and then diverge with *opposite* electricity, although at the commencement of the experiment they were diverged with the *same* electricity as that of the body to be examined.

939. If therefore the electricity of an excited body is to be examined, the leaves of the electrometer are in the first place to be diverged. This may be done with the *same* electricity, by bringing the body, if *weakly electrified*, into contact with the cap, leaving it there if of non-conducting matter (934), or removing it after contact if of conducting matter (932)); or, if *strongly electrified*, by approaching it so near as to cause a sufficient divergence of the leaves, and retaining it there until the conclusion of the experiment. On other occasions however with strongly excited bodies, it may be convenient, either because of their size or other circumstances, to communicate a charge of the opposite kind, in the manner described (937) ; then upon determining what that kind is, in the manner to be immediately described, the electricity of the originally electrified body will of course be known to be opposite to it.

940. The tests of the kind of electricity by which the leaves are diverged, are of the following nature. A stick of sealing-wax rubbed with warm flannel becomes *negatively* electrified ; a tube of warm glass rubbed with a dry silk handkerchief, or, better still, with a piece of silk, having a little amalgam upon it (908), becomes *positively* electrified ; both these excitations being so strong, as to make the leaves of an uncharged electrometer diverge, whilst the wax or

glass is at a considerable distance. If one of these excited substances be brought near the cap of an electrometer already diverged, it will either cause the divergence to increase or diminish. The divergence will *increase* if due to electricity of the *same* kind as that of the body approached, but will *diminish* if of the opposite kind; so that the electricity of the body approached being known, that of the electrometer will also be known, and consequently that of the excited body which had originally caused its divergence. The sealing-wax for instance is rendered *negative* by flannel; being approached to a diverged electrometer it may cause the leaves to collapse; the conclusion to be drawn is, that the electrometer leaves were in a *positive* state: being approached to another diverged electrometer it may increase the divergence, in which case it will indicate that the leaves of the electrometer were in a *negative* state. An excited rod of glass brought to these electrometers would make the first diverge still more, and would cause the second to collapse, in both cases indicating the same states as the wax.

941. Some precaution is required with respect to the manner in which these excited rods are to be applied. The electrometer being diverged, the wax or glass is to be excited at such a distance as to have no influence over it; the most strongly excited part of the wax or glass is then to be gradually approached to the cap, the hand and all other unnecessary conducting bodies being kept out of the way as much as possible, or at least not moved in the neighbourhood of the electrometer during the experiment. As soon as the rod begins to affect the leaves (even though the distance be two or three feet) the effect must be watched, and then their collapse or further divergence will become evident immediately on moving the rod a little way to or from the instrument. It is this first effect that indicates the kind of electricity in the electrometer, and not any stronger one; for although, if the repulsion be increased from the first, no approach will cause a collapse to take place except the actual discharge of the leaves against the sides of the glass, yet where collapse is the first effect, it may soon be completed, and a repulsion afterwards occa-

sioned from a too near approach of the strongly-excited test tube. It is therefore the first visible effect that occurs, as the test rod is made to approach from a distance, that indicates the nature of the electricity; and when this effect is observed, the rod should not be brought nearer, so as permanently to disturb the state of the electrometer, but should be removed to a distance, and again approached, for the purpose of repeating and verifying the preceding observations.

942. It is to be understood, that the approach of the test rod, though it affects the divergence, causes no permanent change of the electricity in the instrument, unless it be brought much too near, and cause considerable disturbance of the leaves. The electrometer will remain, after a good experiment, in the same state as at first.

943. When the body to be examined is so strongly electrified that it may not be brought near to the electrometer, but has been placed at such a distance as to affect it (939) and cause a proper divergence, its place should not be directly over but rather on one side the cap, that the test tube, when applied, may be brought towards the instrument on the other side; the originally electrified body and the test tube being retained in directions as widely apart as they conveniently can be.

Voltaic Pile.

944. Great variety in the forms of the voltaic pile, trough, or battery have been introduced at different times, of which a knowledge may be obtained from elementary works on Chemistry or Electricity, and from particular memoirs on the subject. The information here to be conveyed does not concern these varieties of form so much as the management by which they are to be rendered serviceable and effectual in the performance of experiments. This management, though to be spoken of generally, will be described with reference, principally, to the ordinary form of apparatus, in which the plates being arranged in sets of ten each, and fixed to a bar of wood, are inserted into earthenware troughs, like those suggested by Dr. Babington.

945. Troughs are usually charged with a diluted mixture of acids, which, when the plates are immersed, confers power and activity upon the arrangement. A mixture of a proper strength is obtained by adding two parts in bulk of oil of vitriol and one part of common nitric acid to 100 parts of water, the whole being well stirred together until well mixed. Its power should in all cases be ascertained before it is poured into the troughs, by dipping a piece of clean zinc into a little of it in a glass and observing the degree of action exerted upon the metal. A stream of bubbles should be disengaged so small that their size can hardly be distinguished by the naked eye, and which, as they rise up through the fluid, should be carried freely in different directions by the currents in the fluid itself. If the action be so strong as to evolve bubbles of a considerable size, which rapidly rise to the surface, and are numerous, the acid must be diluted. If, on the contrary, little or no chemical action can be perceived, the charge must be strengthened by the addition of acid.

946. The cells are to be filled to within half an inch of their upper edges; when the plates are in their places the mixture should not flow from one cell into another. The fluid in the cells may be levelled and made equal in all by raising the trough on one side, so that the liquid may flow from one cell into another over the divisions; its passage from the trough is prevented by the height of the edges of the latter all the way round, above the level of the divisions. This superior height of the edges of the trough is attended to in all constructions of voltaic apparatus with cells, whether formed of earthenware or whether the cells are made by the plates themselves set at equal distances and cemented into a trough of wood.

947. When the plates of the battery are separate from the troughs and are to be immersed after the latter are charged with fluid, great care is necessary that they be properly introduced; the zinc and copper plates of two contiguous pairs are to be placed in the same cell, but not the zinc and copper plates of the same pair. There is no fear of erring on this point with Wollaston's double coppers, but when the copper

plates are single, considerable risk of this kind is incurred. It is also essential that the plates be arranged in the same relative position, i. e. all the zinc plates in one direction, and all the copper plates in the other. When by accident 10 pairs of plates are turned the wrong way in a battery of 100 or more, they do considerably greater harm than merely results from the loss of their own power, and the neutralization of that of 10 other pairs. It is always advisable so to arrange a battery that whatever the number of troughs may be, the two extremes of the series should be within two or three feet of each other. The troughs may stand very well on dry boards; and no material loss of power will occur, if, in the convolution of the battery, the rows are two feet apart, unless indeed the series be very extensive. Damp ground or damp boards occasion considerable loss in the power of extensive batteries, especially if the intervals between the rows are small, and the wires of communication for the experiments thin and long.

948. When the battery is charged, and the plates immersed in the acid, the good order of the whole is to be ascertained by fastening two wires to the extreme plates to serve as poles, twisting their ends round two pieces of well burned box-wood charcoal, and bringing these together. An immediate discharge of electricity will take place, producing an exceedingly brilliant spark of light, which will be larger or smaller in proportion to the size and power of the battery. If therefore it be wanting altogether, or by no means equal to what was anticipated from a trial with a single trough in the same manner, then the obstruction, or whatever it may be that interferes, is to be sought for by the following method.

A piece of copper wire about the $\frac{1}{20}$th of an inch in diameter, and four or five feet in length, is to have one end twisted round a piece of box wood charcoal, and the other brightened; then beginning at one extremity of the battery, the bright end is to be pressed tightly against the last plate with one hand, whilst by means of the other, the corner of some plate, as far off as can conveniently be reached, is to be touched with the charcoal at the opposite extremity. If

the spark be as brilliant as could be expected, it will prove the perfection of the arrangement in the portion tried. The bright end of the wire is then to be brought to the plate last touched, and a second portion of the battery tried in the same manner, until the whole has been tested. If, during the trial, the discharge of any portion seems imperfect, or is altogether wanting, then keeping the bright end of the wire against the plate with which it was in contact at the time of the failure, every fifth or sixth plate is to be tried backwards with the charcoal, which is to approximate at each remove that to which the bright end is applied, and it will be found that on a sudden the discharge is effected, though with less force, because of the smaller number of plates between the ends of the wire. Whenever this discharge occurs, it points out the place where, from some derangement or untoward circumstance, the obstacle to the action of the battery exists.

The battery is to be examined at this point, and it will be found that a plate is in the wrong trough; or that acid is wanting; or that a wire lies across to some other part of the arrangement; or that the metallic communication is bad, the zinc plate being either broken or injured by corrosion; or some other cause for the obstruction will be found. This must be removed, or if it be of such a nature that it cannot immediately be corrected, either the trough where it occurs must be rejected, or a good metallic connection by thick copper wire must be made between the plates on different sides of the obstruction, so as to allow an efficient and concurring action of the rest of the battery. This trial of the battery need not necessarily be made on portions of four or five feet, but when from the convolution of its course an opportunity is offered of connecting the battery across, more extensive portions may be tried, as for instance one half, at a time, and thus the half containing the obstruction may be at once discovered.

949. The charcoal used in these and similar experiments, with the voltaic battery, is made from box-wood, which being cut into pieces, having a length of two inches, and a thickness of about a quarter of an inch, are to be

charred in close vessels. The wood may be packed in an earthenware crucible, and being covered with dry sand, should be heated until it ceases to flame. Although the greater part of such charcoal will conduct electricity almost as well as metals, some pieces will probably fail. Before being set aside therefore for use, it should be examined by a single trough, a wire being brought from each end of the trough against the opposite ends of each piece of charcoal in succession. Such as easily conduct the electricity and yield a brilliant spark, are to be preserved in a stoppered bottle; those which afford a small spark or do not act, should be rejected.

950. When two or more troughs are to be connected, and the instrument maker has not furnished the necessary means, or attached them to the sets of plates, the arrangement should first be examined to ascertain that the plates of both troughs are placed in the same relative position and order; when that is the case they may be connected, and considered but as one trough. The connexion should be made by a single, or double copper wire, one-fifth of an inch in diameter; and the operator should not be satisfied with merely bending the wire, so that the ends may drop into the two cells containing the plates to be connected, but should bring them into firm and close contact with the plates in those cells, so that a good metallic communication may exist between them. If the ends of the wires merely dip into the fluid charge of the cell, which, in comparison to the metal of the apparatus, is a bad conductor of electricity, then all the electricity has to pass from the fluid to the wire by a very small surface; it has consequently to pass through a great length of the badly conducting body, and also, near the wire, has to be compressed as it were into a small mass of it: both of which are circumstances causing obstruction to its course, and waste of power in the battery. But on the contrary, if the wire touch the metallic plate, the electricity then passes, comparatively, without obstruction. Nor is it the case when the wires are soldered to plates equal in size to those of the troughs, even though they may not touch the trough plates, for then a

large surface of metal is afforded for contact with the liquid, and, consequently, for the transmission of the electricity: the stratum of fluid between the communicating plate and the trough plate, is, virtually, not a fifth or sixth of its former quantity; and the additional plates act by induction as well as the other plates of the arrangement. When these communicating wires with plates at their extremities are not at hand, ordinary wires are to be used, and brought into contact with the plates already in the cells; this is easily done by bending the wires, so that when introduced into the cells they may act as springs, and press against the plates in them.

951. The two extremes of the whole arrangement are called the poles, and require to be connected in various ways with the solids and fluids to be acted upon, according to the nature of the experiments. Metallic rods or thick wires are usually made to proceed from these extremes, and, as long as they remain in communication with them, are often termed the poles. It is essential that these pole-wires should communicate with the extremes of the battery, either by plates at their extremities, equally large with those of the battery, or by actual and good metallic contact with the end plates of the series. The simple immersion of their extremities in the fluid in the last cell, should never be considered as sufficient.

952. These poles or terminal wires should be of considerable thickness. Copper wire (950) one-fifth of an inch in diameter, answers the purpose very well in ordinary cases. In experiments, when, from the rigidity of such wire, it may be found necessary to complete the communication with the substance to be experimented upon by a smaller wire, still the thicker wire should be continued as far as it can be, and the small wire as short as possible. Even the large wires, which conduct the electricity from the battery to the substance under examination, should be as short as convenient; for though with electricity of considerable intensity they may seem to cause no obstruction, yet when of slight power, they will offer considerable resistance. Metals themselves vary much in their

power of conducting electricity, but no one of them is more advantageous for the purpose of effecting voltaic communications than copper: it is easily drawn into wire; is very flexible; has a high conducting power; and when pure and in a state of rest, exhibits no magnetic effects, and consequently does not interfere with the magnetic phenomena occasioned by a current of electricity passing through it.

953. When voltaic electricity is resorted to for its chemical power over imperfectly conducting matter (on which hitherto it has only been rendered efficient), the substance to be acted upon is placed between the two poles or extremes of the wires, being made the medium of conducting communication from the one to the other. These extremes are best formed of platina, which, of the metals, is least acted upon by the substances likely to be operated with or evolved. The nearer those extremes or acting poles are to each other, i. e. the smaller the portion of imperfectly conducting matter between them, the more powerfully is it affected; and the same holds good to a certain extent with respect to the size of these poles, for the greater the surface of their contact with the matter to be decomposed, the greater is the action, provided the distance between the two surfaces be not increased.

954. These remarks are intended to apply to an extent of the acting surfaces, considerably less than the size of the plates of the battery, and they become more applicable, when the substance acted upon is a worse conductor of electricity. Thus suppose a battery of 100 pair of plates of four inches square, to be in use, and water were to be placed between the poles for decomposition; then, instead of holding the poles, which may be two small platina wires, in the water, point to point, half an inch apart, it would be better to hold them side by side at the same distance. It would be better still to use two slips of platina foil instead of the wires, placing them parallel to each other in the water, and half an inch apart, and every increase in size of these slips, until they were at least two-thirds the size of the plates in the battery, would be advantageous, by increasing the surface of action without materially diminishing

its intensity. But if instead of water a very strong solution of potash were the substance to be acted upon, then though the general effect would be the same, and the advantage very striking by the substitution of small plates of foil for wire, it would cease if the plates were as large as those of the battery, or even of a size, which would be beneficial if water alone was used.

955. It is essentially necessary that the metallic communication between the battery and the *acting poles* or the extremes of the wires, should be good and perfect. In any place where a permanent junction may be allowed, it is best to effect it by a sound metallic soldering or brazing. Where a temporary junction only is required, it is effected by bringing the clean surfaces into close contact, and retaining them so for the time by pressure or otherwise. Wires may be twisted together, their surfaces being first well cleaned and brightened, or if from their thickness, they are stiff and rigid, they should be first slightly twisted together, and then bound round by twenty or more turns of clean copper wire of smaller size. Either in twisting or in binding wires, two or three loose turns must never be considered as sufficient, but the two pieces must be so twisted or bound together, as to have the steadiness of one piece.

956. When a junction is required to be made and broken again frequently, as happens in many electro-chemical and electro-magnetical experiments, it should be done at one place only in the metallic communication. The ends of the wires should be perfectly clean, and when put across each other for the purpose of effecting the communication, should be held tightly in the hand, or pressed together by a weight placed upon them for the time; or in peculiar situations, such a bend must be given to the wires that they may act as springs and press against each other. It is often advantageous to amalgamate the surface of these ends, for then, if they be moistened with a little mercury, the fluid metal causes a perfect contact over a comparatively large surface at the point where the wires meet, the moment they are connected together.

Clean copper wires are readily amalgamated on the sur-

face, by washing them with a solution of nitrate of mercury, then washing them in water and afterwards dipping them in mercury. When the experiments are of long continuance, it is convenient to put about a quarter of an ounce, in bulk, of mercury into a cup or glass, with half an ounce by measure of moderately strong solution of nitrate of mercury; on cleaning the curved end of the wire a little, dipping it into the nitrate, and moving it about in contact with the solution and the metal beneath, it will quickly amalgamate, after which it should be removed into another glass containing water, with a little mercury at the bottom, the adhering solution washed off, and the wire dried by a piece of bibulous paper. This method is very convenient for insuring the amalgamation and perfect contact of chain or link joints, by which the necessary mobility of part of the metallic communication in electro-magnetic experiments is attained. The ends of wires thus amalgamated, if not well washed, frequently oxidate, and become covered in a few days with a thick crust of badly conducting matter. If, from the duration of the experiments, this be inconvenient, the wires should be amalgamated, not by nitrate of mercury, but by the use of a little tallow and metallic mercury, putting the tallow, with a few globules of the metal, on a piece of chamois leather, and rubbing the wire with it until the adhesion is effected. Wires thus prepared do not tarnish or become foul, nearly so soon as those prepared in the former method.

957. Where flat surfaces are to be brought into contact, the intervention of a little mercury is very useful, but the surfaces should previously be well cleaned, and if amalgamated, the contact is more secure. A cup of mercury is also convenient for making metallic communications, which require to be broken frequently, for which purpose the ends of the two wires to be connected should be cleaned, amalgamated and dipped into the metal. The wires may be readily arranged, so that one may be displaced and restored, without the slightest shake or disturbance of the apparatus, and the perfection of the contact is insured every time the wire is replaced.

958. The importance of these four points, namely, accurate metallic contact; sufficiency of thickness in the conducting wires; their shortness; and also extent of surface where a good conductor and a bad one are in contact, should never be forgotten in practice; and though one or the other, or most of them, may now and then be of little consequence in particular experiments, yet attention to them is always useful, and often essential. This is especially the case in electro-magnetic experiments, where electricity in great quantity but of low intensity is frequently the subject of investigation. One person will not be able to perform electro-magnetic revolutions and motions with five or six troughs, which another, by attention to these circumstances, will effect with a single pair of small plates.

959. In all experiments with large batteries it is advisable to retain only one of the poles in the hand at a time, unless indeed they are previously in communication with each other by good conducting matter, or by large surfaces and masses of badly conducting substances. The pole-wires should be preserved distinct from each other in all parts of their course, so that no accidental discharge and consequent waste of power, may take place between them. For this reason both should not be allowed to come in contact with the same piece of metal or wire, or connected by good or even moderately conducting matter. All their energies should be preserved unimpaired until they are exerted upon the substance placed purposely for decomposition between their extremities.

960. In all cases the experiments should be prepared as far as possible *before* the battery is put into action, that none of its power may be unnecessarily wasted during such preparation.

961. The methods of subjecting substances to the poles of the battery for the purpose of effecting their decomposition, and of collecting the results, are very numerous. If the substance be a fluid, for example water or a saline solution, it may be put into a glass, and the two platina poles (953) immersed in it: the nearer they are brought to each other the more powerful will be the action. Tubes will an-

swer the same purpose. They may be prepared very conveniently for such experiments by closing one end, but with a platina wire passed through it, extending nearly to the other end. This may be done by passing the wire through a cork, and using that cork to close the tube; or by sealing the platina wire into the tube, and at the same time closing its extremity in the manner to be described in Section xix (1100). Such a tube being fixed on a cork (58) with its open end uppermost, may be filled with the fluid, and then, if one pole be brought into contact with the external end of the tube wire, and the other pole immersed in the fluid, action immediately commences. In all these arrangements it is necessary, that however near the poles may approach each other, they should not be in contact, for then all chemical action on the surrounding fluid ceases.

962. When the quantity of fluid to be acted upon is small, a watch-glass, or a piece of broken flask or retort, is very convenient as a receiver, or when a drop only of the fluid can be spared, a glass valve (1234) will support it. The poles are on such occasions to be brought towards each other on opposite sides of the drop, and the effect minutely examined and noted.

963. With a view of increasing the acting surfaces, a platina capsule may be used to receive the fluid: one pole is then to be placed in contact with the exterior of the capsule, and the other dipped into the fluid within. Even the surface of this immersed pole may be extended by attaching a piece of platina foil to it. When the experiment is to be continued for some time the immersed pole may be supported and kept from contact with the capsule, by putting a little piece of glass, or in delicate experiments, a fragment of rock crystal into the solution, allowing the wire or foil to rest upon it.

964. When the products of the experiment are gaseous, they are best collected by the use of tubes similar to those already described (961), but placed in an inverted position. If such a tube be filled with a saline solution for instance, and inverted in a portion of the same solution in a glass or other vessel, not of metal, then by dipping the negative

pole of a battery into the fluid of the vessel, and connecting the wire of the tube with the positive pole, action will take place, and the oxygen evolved from the water of the solution at the positive pole will be collected in the tube. If in place of one such tube two be used, both standing in the same vessel, and their wires connected with the poles of the battery, the gases evolved at those poles are collected separately in the tubes. Or if both poles be introduced into the same tube, then the gases are collected in a state of mixture.

965. A very convenient form of tube for the collection and examination of the gases evolved in small experiments, by either one pole or the other, is shewn by the figure. The tube is first to be filled with the solution to be acted upon, and then held in the position represented. The kind of gas collected is dependent upon the pole which is made fast to the wire at *a*; the other is to be inserted at *b*, but not so far as to allow any of the gas from it to pass round the bend into the tube; the fluid will flow out of the mouth of the tube as the gas is evolved at the pole *a*. When the vessel is sufficiently full of gas, the pole *b* is to be removed, and the gas examined as described (884), or else, if necessary, transferred and examined in a more minute and accurate manner.



966. In the arrangement of these tubes and in all decompositions of solutions, it is better to use platina foil for the termination of the poles, than wire, because of the greater surface of contact presented by such a pole to an imperfectly conducting substance (954). For tubes therefore which have platina wires fused into them, the wire should be thick, and the extremity, for a length nearly equal to that of the tube, flattened out into foil; or a piece of platina foil should be prepared for the pole inside the tube, and be made fast to a piece of wire, either by close contact or gold soldering, before the latter is put through and fused into the glass (1100).

967. In all arrangements relative to the decomposition of water or aqueous solutions by voltaic electricity, the young

experimenter should keep in mind the effects dependent upon variations in the quantity and situation of the fluid. The fluid, as compared with the metal of the poles, is a very imperfect conductor, and when in large quantity, offers a serious obstacle to the passage of electricity of the low intensity generated by the voltaic pile: and yet in proportion as this passage is free or obstructed, is the action more or less energetic and effectual. The necessity for bringing the poles near to each other, has therefore been insisted upon (954), that the column of fluid which intervenes between them may be as short as possible. But the injurious effect which occurs by contracting the width of this column, has not yet been pointed out.

Suppose that the poles of the battery are two platina wires, and that they have been immersed in a saline solution contained in a glass, and placed half an inch apart; gas will be evolved, and a certain degree of action will be observed. If then a plate of mica be cut into such a form that it will serve, when introduced into the glass vertically, to divide the solution into two parts, each containing a pole, and if a notch be then cut in the mica somewhat wider than the immersed wires, and of equal depth with them, so that when returned into its place there shall be a passage for the solution through the notch, directly between the two poles, and of equal size with them, or even rather larger, it will still be found, though the distance between the poles is exactly the same as when no mica was present, that their action is very greatly diminished. This effect is entirely due to the contraction of the thickness of the connecting column of imperfectly conducting fluid; and if the mica were of considerable thickness, so as to extend the notch into a channel of half or three-quarters of an inch in length, then, notwithstanding its width and depth would be the same as before, the poles would hardly exert a perceptible power.

968. All this may be easily understood by considering that what the fluid wanted in conducting power had been partly made up by its mass, and that by diminishing this mass, the channels of communication had been in a great measure

closed; but this is very often forgotten in the construction of apparatus, and in conducting of experiments. When two poles rise through the bottom of a glass, they may act perfectly well; but if a tube of glass be put over each, to collect the gas evolved, the circumstances are entirely altered. There are very few parts of the opposite poles that are now virtually as near to each other as before, and those farthest up the tubes are removed to a distance equal to the length of the line, which might be drawn from the end of one pole to the edge of the tube containing it, across, to the edge of the other tube, and upwards, to the extremity of the pole within it. Besides this increased length, the thickness of the intervening and conducting mass of fluid is very much diminished also, being equal to the diameter of the tubes only, whereas before, it was in some parts equal to the diameter of the glass containing the solution and poles.

969. A similar influence is exerted to a great extent in experiments where the poles are placed in different vessels. These vessels require to be connected by syphon tubes filled with the solution, or by moistened threads of cotton or amianthus. If these bridges of communication be small, much power will be wasted, which would be active were larger tubes or bundles of fibres applied; and besides making them large, they should, for the reasons before given, also be as short (967) as the other circumstances of the experiment will allow. Generally, with regard to the fluid intervening between the poles of the battery, the endeavour should be in all cases to make it virtually as short, and, if the expression may be used, as massive as possible, no more insulating or retarding matter being allowed to occupy the space between the poles than can possibly be helped.

970. Aqueous solutions generally have greater conducting power than pure water, and advantage may be taken of this circumstance in effecting the decomposition of water, and even of some other bodies. It will be found that a battery which will scarcely act upon water, so as to evolve sensible portions of gas, will appear to acquire twice or thrice its former power by putting a little common salt, sulphate of soda, or almost any saline body, into the water under de-

composition. A small quantity only is required, one part of a saturated solution of these salts to six or eight parts of water, producing a great effect. These solutions are very useful as tests of the existence of a voltaic current, capable of effecting chemical changes. When substances are so arranged, that it is supposed an electrical current of some intensity is produced, all that is required to ascertain the correctness of the opinion is, to bring a wire from each end of the arrangement, and immerse their extremities in a drop of a weak solution of salt; if gas be evolved it is a proof the opinion is well founded.

971. The plates of a voltaic battery should be removed from the action of the charge at every considerable intermission of the experiments. The acid rapidly dissolves and destroys the zinc plates during the time it is in contact with them, and though the degree of action may not be of such importance as to justify the raising of the plates during the cessation of experiments for a minute or two, or even for a longer time in particular circumstances, yet they should never unnecessarily be left to the action of the charge, when the electricity they evolve is not actively employed on other bodies. When five or ten minutes intervene between one experiment and another, it is worth while raising the plates of a battery of ten or twelve troughs, or less, from the cells; this affords the additional advantage of an increase of action upon their re-immersion, due in some way to draining or exposure to air. Instrument-makers sometimes hang the plates to a frame, which being suspended by a cord, and connected with a lever, allows the whole to be raised or depressed at pleasure; and Dr. Hare has constructed a trough,* in which the cells being formed by the metallic plates (946), the charge is poured on and off at pleasure, by a quarter revolution of a handle.

972. Although it is highly advantageous to operate with a large battery, as for instance of 100 pair of plates four inches square, when such can be had, and when the object is to render the experiments and other results evident at a

* Philosophical Magazine, lxiii. 241.

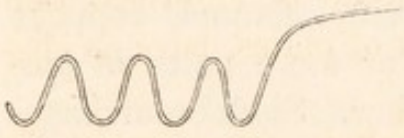
distance; yet such a power is by no means always necessary. Even the repetition of the most refined and admirable experiments may be made with a battery no way comparable to one of this size, if the object of the experimenter be only to satisfy himself or those close to him, and if he use the precautions as to contact, vicinity, &c. already given. A single trough, of ten pairs of plates four inches square, will suffice to repeat nearly all the experiments that have yet been made on the decomposition of bodies in solution, and all those relating to electro-magnetism. Nor is it essential that a greater power should be used in many new investigations. In the same manner a small trough with 40 or 50 pairs of plates, one inch square, will be found a very useful instrument in a laboratory not affording the opportunity of working with a larger arrangement; and the habit of experimenting with small apparatus, and on a minute scale, is highly valuable for the independence, which it gives to the philosopher, of larger, more expensive, and consequently scarcer instruments.

973. Where copper and zinc in sheets can be obtained, (and there is now scarcely a large town in England without them), a voltaic arrangement may easily be constructed. They are to be cut into single plates of equal size, two inches square for instance, and are then to be arranged as a pile with equal-sized pieces of flannel dipped in dilute acid (945) in the order zinc, flannel, copper; zinc, flannel, copper; zinc, flannel, copper; until twelve or more pairs of metallic plates have thus been put together. Such an arrangement should be made in a plate, that any acid exuding from it may be caught and retained. The surfaces of the contiguous metallic plates should be clean, that the contact between them may be good. To insure this, it is convenient to solder the plates together at their edges into pairs, each comprising a zinc and a copper plate. On building these up with the intervening flannels, the order will be copper, zinc, flannel; copper, zinc, flannel; copper, zinc, &c. The wires, which, when attached to the top and bottom of this pile, serve as its poles, should be clean and in good contact with the end plates, and then a pile of twenty of these pairs will

be found to have very considerable power, and will be competent to the performance of a great number of experiments.

974. The nature of the poles of an ordinary battery may be determined by inspection of any one of the pairs of metallic plates employed in its construction. The end of the battery on the zinc side of the pair examined is the positive pole; the end on the copper side of the same pair is the negative pole. This holds good wherever the pair may be in the battery, or however far the ends may be removed.

975. Electro-magnetic, and many other experiments relative to the transmission of electricity through good conductors, such as the metals, and the effects produced thereby, often require for their performance voltaic arrangements, consisting of a few large plates rather than many small ones. It is easy to arrange the ordinary troughs, consisting of ten pairs of plates four inches square, so as to produce intensity or quantity at pleasure. Thus if four of these troughs were to be used for chemical experiments, it would be best to place them end to end in their proper order, so as to form a battery of forty pairs of plates four inches square, connecting them if necessary in the manner described (950): but if large plates and few in number be more advantageous, then these four troughs may be arranged so as to form a battery equivalent to one of ten pair of plates eight inches square. For this purpose they must be placed with their sides together, their similar ends being in the same direction; and they should be connected by two thick pieces of copper wire, bent according to the figure, in such a manner that the lower angles of one piece will enter the four terminal cells at one end of the battery; this, if in perfect contact with the plates (950), will connect them together. The second piece will perform the same office at the other ends of the troughs, and the projecting terminations of these wires are to be used as the poles of the battery.



976. A single pair of plates is sufficient for the performance of nearly all electro-magnetic experiments, and a combination of this kind may be constructed with great facility by those who possess a piece of plate zinc and a piece of plate

copper. They require merely to be put near each other in a jar or vessel of dilute acid, and connected by a wire. The plates may be conveniently tied together with a couple of pieces of glass rod or tobacco-pipe between them, to prevent metallic contact. A thick wire a few inches in length, should be attached to each plate, to act virtually as the poles (though they are not really poles according to the usual acceptation of that word in voltaic electricity), and these wires or poles should be connected by the experimental wire, which, though thinner than the former, should not be unnecessarily long. This arrangement has been described as formed of flat pieces of zinc and copper plate, but any shape may be given to them, so that their relative position is the same: they may be coiled; or even a copper vessel may be used instead of a copper plate, and then the jar for containing the acid may be dispensed with altogether.

977. The double copper arrangement described by Dr. Wollaston, is excellent for ordinary experiments, and may easily be constructed. It consists of a plate of zinc surrounded on both sides by a plate of copper, so that a surface of the latter is brought into opposition with both surfaces of the zinc. This arrangement when immersed in acid is very powerful; a zinc plate of less than an inch square being able to effect the ignition of fine platina wire, the deflection of the magnetic needle, and most of the electro-magnetic experiments.

978. It is necessary the student should be informed that instruments consisting of a single pair of plates, have no chemical action.

979. Dr. Wollaston's beautiful voltaic arrangement for the precipitation (485) of certain metals, is so instructive, and in many cases so useful, that it must not be here omitted. It was devised for the separation of cadmium from the solution of the ore or metal under examination, after all that could be precipitated by zinc alone (484) had been thrown down. The solution rendered slightly acid was put into a platina crucible, and a rod of zinc also introduced, so as to rest on the bottom and at the edge of the vessel; this formed a voltaic combination with the platina and the fluid; electro-chemical action took place, and

the cadmium was precipitated on the platina, which was the negative part of the arrangement. When the separation of the cadmium had been completed, the zinc was removed, the solution poured out, the crucible with the cadmium adhering to it washed with distilled water; then a little nitric acid being used to remove the latter metal, the platina sustained no injury.

980. A very usual problem which the chemist has to solve is, whether a substance be a conductor of electricity or not, or what is the degree of conducting power which it possesses with regard to electricity. Whether it conduct like a metal or not may be ascertained in the following manner. If a piece of zinc and a piece of silver be placed one above and the other below the tongue, and the edges be then brought into contact, a peculiar taste will be perceived at the moment, which will be repeated every time the contact is broken and resumed. If instead of bringing the zinc and silver in direct contact, a piece of metal, as a wire, intervene, the taste will still be perceived; but if the interposed substance be a body not metallic, or one of those numerous substances which though they conduct electricity, are less efficient than the metals, a piece of wet paper for instance, a piece of starch, or even a piece of galena, then no taste will be occasioned. The experiment should therefore be made first with the zinc and silver, and having succeeded, the substance to be tried should be placed between the two metals and the attempt repeated; the production or non-production of taste will immediately indicate whether it conducts electricity or not. All the pure metallic bodies, and all combinations of them with each other, conduct electricity so well as to occasion the taste; but as yet no other substance has been ascertained to do so, nor even any of the definite compounds of metals with other substances, as sulphur or oxygen. Dr. Wollaston's method of preventing accidental contact of the zinc and silver on one side of the substance to be tried is very useful:* it is to cut a hole in a piece of card, and lay the doubtful body in this hole between the other

* Philosophical Transactions 1823, p. 20.

metals; its contact and retention in its place is secured, and the accidental contact of the known metals, perfectly prevented.

981. Evidences of the conducting power of solutions and transparent fluids are of the following kind. If on placing a small portion between the voltaic poles, gas be evolved, or metals or other substances separated, or any change effected which would not have taken place by mere contact of the liquid and the metal of the pole distinct from the battery, such action is a proof that a current of electricity is passing, and consequently that the fluid is a conductor: and the energy of the action is to a certain degree an indication of the degree of conducting power. A small voltaic battery is sufficient for this purpose.

It is however possible, though not usual, that no apparent change may take place notwithstanding the body is a conductor, equally good with those fluids which suffer decomposition; this is the case with fluid chlorine. In such instances, besides the portion of fluid to be tested, there should be in another vessel a portion of a solution of salt; one of these should be connected with one pole of the battery, the other with the other pole, and a piece of platina wire should be bent so as to dip into both portions of fluid, and its ends should be brought near to the ends of the poles immersed. There are thus two portions of matter ready to be decomposed by the electric current: if the decomposition is seen by the liberation of gas to proceed in the solution of salt, it is a proof that the other fluid is a conductor of electricity sufficient for this purpose: if no decomposition take place in the solution, then the other fluid will not permit voltaic electricity of this intensity to pass, and is in that respect a non-conductor.

982. The same kind of trial serves for such solid bodies as are not comparable to metals with regard to this property, they being then substituted for the liquid in this experiment, and the solution of salt acting the part of a test as before. It will in this way be found that several of the native and artificial compounds of the metals and other bodies conduct electricity, though by no means with a

readiness sufficient to answer the test of taste first proposed (980).

983. Again, there are very many substances which, though so inferior in conducting power as to appear perfect insulators by these modes of trial, will yet shew many degrees of it by more powerful tests, that is, by electricity of higher intensities. These are generally classed amongst very bad conductors, and are most readily examined perhaps by the gold leaf electrometer (931). If the electrometer be diverged, and its cap then touched by any substance held in the fingers, or at the end of a wire, it will be discharged, and the leaves collapsed with more or less rapidity, according to the conducting power of the substance. If the leaves retain their first divergence, it is a proof of the entire absence of conducting power as far as our tests usefully extend. For the application of this method to a liquid, the latter should be placed in a convenient vessel, a capsule or tube for instance, connected by a wire or the hand with the earth, and then a piece of bent wire, well insulated by a stick of sealing wax or gum lac, is to be made to touch the cap of the electrometer by one end, and the surface of the fluid by the other. If the leaves collapse entirely, it is a proof that the fluid conducts electricity.

984. M. Rousseau* has devised a very ingenious variation of this test. He brings one end of a dry electric column into contact with the cap of the electrometer, and retains it there. This occasions a divergence of the leaves to an extent dependent upon the power of the pole. He then connects the cap of the electrometer with the earth through a portion of the fluid or substance to be tried, and observes to what extent this reduces the previous divergence of the leaves. If the divergence be entirely destroyed, it shews a conducting power which is considerable, as compared to that of most bodies which may be tried by this method; if but slightly diminished, it indicates but little conducting power. Decided distinctions may be established between even the different oils by this method.

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* Annales de Chimie. xxv. 373.

985. Although the great use of the voltaic pile is to effect chemical change by means of the peculiar power of its poles, it is often otherwise applicable. When the discharge of a powerful battery is made through air between two pieces of charcoal, the heat is very intense, and is extended over a larger space than when the discharge takes place between two pieces of metal. To this temperature any gas may be subjected in which the discharge is made and the effects upon it may be observed. Carburetted or sulphuretted hydrogen are thus decomposed. Other gases examined in the same manner would probably present peculiar phenomena.

986. By transmitting the voltaic current through thin wires, they are heated, ignited, and fused. This effect supplies a means of conveying, or rather of producing and applying, heat in situations in which it could not otherwise be excited, and thus facilitates certain refined experiments. Substances having wires passed through them may be placed within globes under water, or in remote situations, and then be heated, ignited, and exploded: eudiometers have been constructed in which a fine wire passing across the cavity, has been ignited by a voltaic battery, and thus used to inflame the included mixture of gases.

987. The *insulation* of substances is frequently required in electro-chemical investigation, and numerous methods must be resorted to, according to the circumstances of experiments. When an insulating plane is required, a plate of mica is the best substance for the purpose, then a plate of resin or wax, or in their absence, a plate of warm glass. In all similar insulations, the substance to be supported should be placed so far from the edges of the insulating planes, as to be independent in its electrical state of the neighbouring bodies; and it is also convenient to support the insulating planes themselves upon a glass jar or other vessel, in those cases at least, where the state and degree of electricity of the insulated substance is to be minutely examined. For if the insulating plane lie on a table or other conducting body, it allows of induction through it; and thus, without any actual communication, permits the electricity of the body upon it to be influenced in an uncertain and variable man-

ner. For the same reason, when a body is insulated for minute and delicate examination, no projecting mass of conducting matter should be allowed to exist in its immediate neighbourhood, because of the influence which will then be exerted upon it by *induction* through the air.

988. When glass pillars, or stools with glass legs, or a common glass (343), is used for insulation, they should always be well warmed and dried, and apparatus of this kind, which is constantly appropriated to this use, should be varnished with a solution of sealing-wax in strong alcohol. Glass has such an attraction for water, that at common temperatures its exposed surface is constantly moistened to a certain degree; in consequence of which it becomes a conductor of electricity of such tensions as are sensible by the gold leaf electrometer, and is therefore a bad insulator. A glass rod well warmed and rubbed, and then left exposed to the air to cool, will be found after a few hours, capable of discharging a gold leaf electrometer, solely by the film of moisture on its surface; for if glass be examined in an unexceptionable manner, it has not itself those conducting powers at common temperatures. Resins are very superior to glass in this respect, and hence the use of the varnish recommended.

989. When a small mass of solid matter is to be insulated by a handle, it may be effected by a piece of white silk thread dipped into and stiffened by melted gum-lac, or by a rod or thread of the same resin. This substance is easily melted and drawn out into threads of different diameters, and surpasses every other in insulating power at common temperatures.

990. If a body is to have a suspensive insulation, then silk thread or cord may be advantageously resorted to, but in such cases white silk should be used. Black silk frequently conducts as well as a moistened thread, and coloured silks are often very inferior in this respect to white, in consequence of the dye stuff they contain, conferring a certain degree of conducting power.

991. There are no particular instructions required in relation to electro-magnetic experiments beyond those which

have already been given. The contacts should be carefully attended to; the part of the connecting wire which is experimented with, removed and preserved as far as it can be from other parts of the wire, and from the battery, that the needle or apparatus experimented with may be subject to no other influence than that of the wire alone. The magnets used should be strong; their magnetic poles well determined, and not irregularly diffused over the steel of which the magnets consist. The points of support for the magnetic needles should be attended to (1275. 1281), and the needles should be in an active state.

SECTION XVIII.

Lutes—Cements.

992. It is intended in this Section to comprize such an account of Lutes and Cements, with the methods of applying them, as shall enable the student to select that which is most fitted for his particular purpose, and make it answer the required end with the greatest success.

993. Lutes are soft adhesive mixtures, principally earthy, used either for closing apertures existing at the junction of different pieces of apparatus, or for coating the exterior of vessels which are to be subjected to a high temperature; the latter application being either for the purpose of strengthening them and preventing their fracture (453), or for repairing a fracture, or to prevent the contact of the air. There are but few lutes used for the latter purpose; and the success of the operation, which is usually called coating, is generally more dependent upon the manner in which it is performed than upon the lute itself. But those which have been applied for the purpose of rendering junctions tight are very numerous, in consequence of the variety of vapours which require to be confined, and the difference of temperature to which they are occasionally subjected. The term luting has generally been confined to this application.

994. The lutes which are used for junctions, pass by degrees into cements; the two sets of bodies, if considered as distinct, being frequently convertible in their uses into each other. For this reason both will be comprized in this Section, and also such other applications of these substances as may be useful in the laboratory.

995. The vessels which require coating, are generally retorts, flasks, and tubes, sometimes crucibles and other vessels. Occasionally the temperature to be sustained is very high, at other times a high red heat only is to be provided against; and in other instances the coating is rather for the purpose of rendering vessels impervious to air (455, 456), than to defend them from, or strengthen them in the fire.

996. When the coating must sustain a very high temperature, as in the preparation of potassium by the gun-barrel, or in the attachment of a crucible to its support, it should be made of the best Stourbridge clay, no other earthy substance found in this country being capable of resisting fire without softening or fusion, so well as it.

The lute is to be made into a paste, varying in thickness or composition according to the opinion of the experimenter, as will immediately be pointed out. The paste should be beaten until it is perfectly ductile and uniform, and a portion should then be flattened out into a cake of the required thickness, and of such size as shall be most manageable with the vessel to be coated. If the vessel be a retort or a flask, it should be placed in the middle of the cake, and the edges of the latter raised on all sides, and gradually moulded and applied to the glass: if it be a tube, it should be laid upon one edge of the plate, and then applied by slowly rolling the tube forward. In all cases the surface to be coated should be rubbed over with a piece of the lute dipped in water, for the purpose of slightly moistening and leaving a little of the earth upon it; and if any part of the surface becomes dry before the lute is applied, it should be remoistened. The lute should be pressed and rubbed down upon the glass successively, from the part where the contact was first made to the edges, until all air bubbles are excluded, and an intimate adhesion effected. If the lute be

inconsiderately and carelessly pressed upon small surfaces, as by the thumb or a finger, it will frequently extend laterally, become of greater dimension than the vessel beneath, and consequently will form a kind of bag about it, with air intervening. This must be avoided by moderating the pressure, making it more general, and applying it so that the coat rather tends to thicken than otherwise; and if an air bubble should accidentally be formed, the endeavour should not be to expel the air by passing it along between the coat and the vessel to the edge of the luting, but by a hole to be pricked with a pin through the luting over the bulb.

997. When one cake of lute has been applied, and is not large enough to cover the whole required surface, another must be adapted in a similar manner. Particular care must be taken in joining the edges; for which purpose it is better to make them thin by pressure, and also somewhat irregular in form, and if at all dry they should be moistened with a little soft lute. Afterwards they should be well pressed together, that the adhesion may be as perfect there as in every other part.

998. If from irregularity in the form of the vessel coated, as for example about the neck of a retort, the thickness of lute, after a little pressure and moulding, should be somewhat uncertain, it may easily be ascertained by pressing a needle through it, and observing the depth to which it penetrates. The minute hole thus formed is rarely of consequence, and may be obliterated by a little pressure towards it upon the lute in the immediate vicinity. The general thickness may be from one-fourth to one-third of an inch.

999. Being thus luted, the vessels are afterwards to be placed in a warm situation over the sand-bath, or near the ash-pit, or in the sun's rays. They should not be allowed to dry rapidly or irregularly, and should be moved now and then to change their positions.

1000. With respect to the best state of the lute, there is considerable variety of opinion and practice. The object is to diminish the contraction which the moist clay undergoes, first in drying in the air, and afterwards when heated in the fire. By some, the clay is beaten into a very fine and uniform

paste with water, just so much of the latter being added as to make the mass ductile and capable of application; it is then applied to the surface of the retort or tube in the manner described, until it forms a coat upon its surface, from the fourth to the half of an inch in thickness, according to the size of the vessel, and the degree of strength required in the coating. During the drying this coating will crack; these cracks are to be carefully filled up with a portion of the same lute, again dried, and again repaired if necessary, until the exterior appears sound and perfect.

1001. Others apply their lute in a much softer and more ductile state. This facilitates the operation, but upon drying the cracks are generally larger, and though these may be filled up, and the whole exterior made to appear sound and perfect, it will be evident that the separation of the coating from the vessel, which must necessarily occur during the contraction of the clay, must proceed to a greater extent with the latter kind of luting than the former.

1002. When vessels thus luted are introduced into the fire and highly heated, further contraction of the aluminous coating takes place. If the vessel itself be iron or earthenware, it does not give way to the diminished bulk of the coating, but actually expands beneath it, and thus new divisions in the coating are produced; the former partial adhesion of it to the vessel is much diminished, and its tendency to separate and fall off in fragments is much increased. When the coated vessel is glass, this does not happen to such an extent, for the heated glass yields and gives way to the contraction of the coating, which, if it retain its unity and form until the glass has softened, actually becomes an earthenware vessel lined with vitreous matter (453).

1003. To prevent cracking during desiccation, and the consequent separation of the coat from the vessel, some chemists recommend the introduction of fibrous substances into the lute, so as mechanically to increase the tenacity of its parts. Horse dung, chopped hay and straw, horse and cow hair, and tow cut short, are amongst the number. When they are used they should be added in small quantity, and it is generally necessary to add more water than with

simple lute, and employ more labour to obtain an uniform mixture. It is best to mix the chopped material with the clay, before the water is put to it; and upon adding the latter to effect the mixture at first by stirring up the mass lightly with a pointed stick or a fork; it will then be found easy by a little management to obtain a good mixture without making it very moist. If the fibres be long, more than an inch in length for instance, it will be almost impossible to mix them uniformly with the lute, and they will interfere much with its after application. Hay cut to the length of one-half or one-third of an inch, is a very good substance for the purpose.

1004. Retorts coated with lute thus prepared, may be dried gradually without the production of any considerable cracks on the surface. The effect of these intermixed substances is not merely to confer additional tenacity on the lute but to give a direction to the separations which are formed during the contraction occasioned by drying, so that ultimately instead of having the lute in three or four pieces with large open cracks intervening, the separation has resulted in numerous minute fissures. These do not, however, prevent the whole from adhering together as one coating; the removal of any one part of the coating far from its original situation during the contraction from drying is thus avoided, and the places of adhesion between the tube and the vessel are more generally dispersed and more numerous than before.

1005. A similar object is sometimes obtained by applying a bandage of coarse canvas or other open wove cloth over the surface of the freshly applied lute (661). Thus a tube when coated may have a moistened slip of such canvas carried round it, the edges of each turn being allowed to overlap considerably, the whole being afterwards rubbed with a little moist lute, so as to make the adhesion between the wrapper and the coat perfect. When dried, the lute does not crack, and the coating remains whole, but it has a tendency to split when in the fire in the direction of the edges of the folds. Where the form of the vessel is such as to prevent the application of a slip of cloth, tow or hemp

drawn out into lengths may be used for the same purpose, but it must be carried over the surface in different directions, or the cracks will not be prevented, but merely a direction given to them. The tow envelope should be afterwards well moistened with soft lute, so as to adhere closely to, and form one mass with, the coating.

1006. The most serious evil to which the lute or coating is liable is, cracking in the fire; and unfortunately this evil increases with the heat, and consequently is greatest when the coating, if good, would be most valuable and serviceable. A luting of pure clay contracts much more in the fire than a luting of clay mixed with as much sand as it will contain without entirely losing its plasticity and tenacity. The mixture of sand with the lute however renders it more fusible; and hence, though this is a very useful expedient when the vessel to be luted has not to support more than a bright red or a yellow heat, it is not applicable with equal, or with any advantageous effect, when very high temperatures are to be sustained. In the latter cases it has been found advantageous first to heat a portion of the clay highly, then to break it small and use it instead of sand, adding so much to the recent clay as shall leave the mass, when moistened and beaten, with such a degree of plasticity and adhesion as to allow of its application. If access can be had to a glass-house, the fragments of the broken glass pots may be pulverized and used instead of the heated clay, particular care being taken that all parts with glass upon them, or with the exterior glaze which occurs upon glass pots, be rejected. Or, pulverized Hessian or Cornish crucibles may be used for the same purpose; but old crucibles, when soiled by flux or other impurities, must not be so employed.

1007. Luting which has had fibrous substances diffused through it (1003) does not separate by contraction and fall off so readily as that which is altogether earthy, probably because the contraction is compensated by smaller fissures in greater number. Those fibrous matters which have comparatively large apertures, as hay, straw, dung, &c. appear to be the best, and lute which has been mixed with one-third its weight of pulverized coke, according to Mr.

Marshall's method of making crucibles (613), has appeared to be improved in cases where the luting had no great weight or mechanical power to resist.

1008. The liability to crack by heat in all these coatings is diminished by their being washed over when dry with oil.

1009. Retorts, flasks, and other vessels of irregular forms, are sometimes coated by being dipped into a thick cream of the lute with water, and sprinkling dry lute over them during desiccation; when dry they are again to be immersed in the thin paste and re-sprinkled, and the process repeated until the coat which they have received is of sufficient thickness.

1010. All coated vessels should be supported as much as possible when in the fire (454), to prevent or retard the derangement or separation of the lute in consequence of its weight.

1011. The methods of effecting *lutings* vary according to the joint or aperture to be closed, and the kind of lute to be employed. In the time of Lavoisier accurate lutings were more essentially necessary than at present. The general directions then given were, to fix the apparatus firmly, and to cement it tightly and stiffly by strong luting. In this way many complicated instruments were combined into one great apparatus, so rigid in all its parts as to render it almost impossible to retain every junction perfectly close. The number of these junctions has in later times been very much diminished, and the introduction of elastic caoutchouc connecters (416) has almost entirely removed that rigidity which was so dangerous to the apparatus and fatal to its soundness.

1012. The following are brief accounts of various lutes and cements that may be advantageously used in different circumstances.

Stourbridge clay: it should be ground to fine powder; is highly useful in coating retorts, tubes, &c. and in effecting junctions between crucibles and their stands. It is to be applied in the manner already described (996). It sustains a higher heat than any other English lute.

1013. *Windsor loam:* obtained at Hampstead, &c. It is a natural mixture of clay and sand in such proportions as to

make an excellent lute, though it will not resist the heat sustained by Stourbridge clay. It is frequently used for the lining of furnaces, pots, &c.

1014. These lutes are also very useful for making the hot joints of metallic vessels tight, as, for instance, the iron tube which is attached to an oxygen bottle for the purpose of conveying away the gas. These joints are generally ground air-tight at first, but by use in the fire soon become unsound. When that is the case, a little smooth and rather soft lute should be mixed up, put round the end of the tube, and the latter pressed into its place. Care should be taken in moving the apparatus afterwards that no agitation or blow be given it, so as to derange the junction and break the continuity of the lute.

1015. *Willis's lute.* When earthenware retorts (455) are required to be rendered impervious to air or vapours, Mr. Willis directs that an ounce of borax be dissolved in half a pint of boiling water, and as much slaked lime added as will make it into a thin paste. This is to be spread over the retort with a brush, and when dry, a coating is to be applied of slaked lime and linseed oil beaten together until it becomes plastic. This will dry sufficiently in a day or two, and is then fit for use. Earthenware retorts thus prepared may be used, it is said, several times with safety, the coating of lime and oil being renewed each time.

1016. Mixtures of fused and pulverized borax with the clay lutes above described, or with common clay, form fusible fluxes, which are often useful in glazing over the surfaces of vessels so as to close their pores. About one-tenth by weight of the pulverized borax is sufficient for the purpose. The mixture made into a thick paste with water may be laid on with a brush, and the vessel should be handled carefully until the heat has attained redness, lest the slightly adhering crust should be knocked off previous to its fusion.

1017. *Fat lute* is applied to the junctions of apparatus which are liable to considerable elevation of temperature, or to prevent the escape of corrosive vapours (440). It is prepared by beating dried and finely pulverized clay

(pipe-clay or Cornish clay,) with drying linseed oil, until the mixture be soft and ductile. It is to be closely applied to the junction intended to be made tight, the glass or other substance being first wiped perfectly dry. If the joint has to sustain heat, the lute will soften; it then requires to be confined by strips of bladder, which being put round it, should be tied tightly above and below the mass of lute, and afterwards two or three turns of twine should be passed round the middle part. When moisture or vapours escape between this lute and the vessel, it is very difficult to close the leak, and hence the great importance of making a dry tight joint at the commencement. Glaziers' putty resembles fat lute, and may be used for similar purposes.

1018. *Parker's cement* is a brown powder, which should be preserved for use out of contact with the air. When mixed with water into a thin paste, it gradually sets, and becomes quite solid and hard. It may be used occasionally with advantage in making joints tight, either at common or moderately high temperatures. It may be rendered quite tight by being brushed over with a melted mixture of equal parts of wax and oil. It resists a red heat sufficiently well to make it a useful coating for glass retorts or tubes upon numerous occasions.

1019. *Plaster of Paris,* when mixed into a thick cream or thin paste with water, sets after a short time and becomes solid. It is best mixed by putting a little water into a cup, sprinkling the powder into it, and stirring the mixture. It may be used for the same purposes as Parker's or Roman cement (440), being generally superior to it in convenience; and may be made air-tight in the same way by washing it with oil or wax and oil, and should also be preserved from the air when in powder. When Plaster of Paris is mixed up with very weak glue instead of water, it is somewhat longer before it solidifies, but ultimately makes a very hard and strong lute.

1020. A lute of Plaster of Paris may be raised to a dull red heat without injury, but if oiled or waxed to prevent the passage of vapours, it will not support so high a temperature without change.

1021. *Caustic lime*, mixed with various mineral and vegetable substances in solution, affords numerous cements and lutes, which when dry are hard, and are very impervious to vapours. The lime should be well burnt, and slaked with just sufficient water to make it fall into a dry powder; after which it should be preserved in a close bottle until wanted. One of the most powerful of these cements is obtained by using white of egg diluted with its bulk of water. The fluids are to be beaten together until the mixture pours with perfect liquidity. This is best effected by means of a little stick made to rotate by rolling it between the hands, and having at its lower end a cross piece, the arms of which, when in motion and immersed in the liquids, effectually mix them. This being done, the dry slaked lime in powder is to be added by sprinkling in such quantities, that the whole when mixed shall have the consistency of thin paste. This should be done quickly, after which the mixture should be put upon slips of cloth and applied round the junction to be luted, and a little of the dry lime should be sprinkled over the exterior. The substance soon hardens and adheres strongly.

1022. This cement is often conveniently applied by moistening slips of cloth with white of egg beaten up without the addition of water, and then sprinkling the lime in powder over it, in such quantity as to make a moist paste on the cloth. The slips should be immediately applied to the junction, a little lime being shaken over the exterior.

1023. In place of white of egg, a moderately strong solution of glue may be used; or the serum of blood; or diluted blood; or a mixture made by rubbing down very poor cheese with water in a mortar, until of the consistency of cream.

1024. If a leak take place through or by these lutes during an operation, no difficulty occurs in stopping it by the application of a fresh portion of the lute, which adheres readily and perfectly, and is not liable to the difficulty which occurs with fat lute. They will bear a heat approaching to visible ignition without injury.

1025. *Iron cement.* This mixture is used for making

permanent joints generally between surfaces of iron. Clean iron borings, or turnings, are to be slightly pounded, so as to be broken but not pulverized; the result is to be sifted coarsely, mixed with powdered sal ammoniac and sulphur, and enough water to moisten the whole slightly. It is then to be rammed or caulked into the joints, and the latter drawn together as tightly as possible. The proportions are, 1 sulphur, 2 sal ammoniac, 80 iron; and no more should be mixed than can be used at once.

1026. *White lead* ground up with oil, when spread upon slips of cloth, is very useful for making joints tight, especially those of metal, glass, or other tubes. The lead when laid on the cloth should be made to penetrate it. The slips should be drawn tightly round the joint, and then bound with twine, the ends of the joints being tied first, and afterwards the middle. Sometimes tow is used with the white lead instead of cloth; it should then be so laid over the joint as to allow the fibres to pass each other and the joint obliquely, that lateral strength may be given to it.

1027. *Bladder.* Moistened bladder is in constant requisition in the laboratory for closing joints; when soaked for some time in water, till it becomes clammy, it is very adhesive, and adheres well to glass. It should be cut into slips of the proper size, and then applied as a bandage to the place. It does not always require the application of twine to keep it in its situation, so that occasionally, when inconvenient, tying may be dispensed with.

If after being soaked it be wiped dry with a cloth and then moistened on the surface with white of egg, its adhesion is increased, and the use of twine rendered quite unnecessary.

1028. *Paste and Paper* are frequently useful in making joints. The paste should be well boiled and thick. It is better to use bibulous than sized paper, for the paste more freely enters its pores and incorporates with it, and the joint is less permeable; but from the greater tenderness of such paper when moist, more care is required in handling the pasted slips and applying them. If sized paper be used, the pasted surface should be doubled inwards, then re-

doubled several times, and left for a few minutes to soak: evaporation is thus prevented, and the paste and paper preserved moist. When opened out, the pasted surfaces should not be separated from each other, until the doubled paper has been cut into slips of the size required.

1029. Paper which has been pasted, and has been allowed to dry without having been folded togther, is very useful in the laboratory. A slip of it moistened on the pasted side and allowed to soak for a few moments, is ready for application to a joint, or in any other situation where its adhesive powers may be useful. It is also very convenient for making labels, to be attached to bottles and glasses the instant they are required (1196. 1231).

1030. *Glue* with paper makes a useful and convenient application. With cloth it makes a strong one, which may be rendered nearly tight by an exterior fold of paper, and quite tight if the joint when dry is brushed over with drying oil, or drying oil and wax (1018).

1031. *Linseed meal* or *almond paste*, well beaten up with water until of an uniform and proper consistence, is an excellent lute for cold joints of glass (440), or metal apparatus. It should be applied thickly, and will then adhere well: it will in some hours become a hard mass, and will resist most vapours; but water must not be allowed to run upon it, either within or without the joint. It will not bear a heat above 600° Fahrenheit. When made up with milk, lime-water, or weak glue, it becomes firm sooner, and forms a harder substance, than when water alone is used.

1032. *Caoutchouc.* Connectors of this substance have been already referred to and described (416). Joints may be made tight by means of them, and consequently stiff tubes may be dispensed with, in a great number of instances. These connectors when applied should be tied round the edges with twine, but not be drawn so tightly as to incur any risk of cutting the caoutchouc, for a slight degree of tension is sufficient to make the joint secure. When the caoutchouc tubes require slight extension to make them pass over the joints, their own contraction is generally

sufficient to make their contact with the tube (if of glass) perfectly air tight.

1033. *Cap cement.* This is one of the numerous cements which contain resin or wax, and are applied for causing adhesion or making close joints at common temperatures. Their principal use is with pneumatic apparatus belonging to the air-pump and the water and mercurial troughs. Cap cement is used for the attachment of caps to retorts in the manner described (780). It may be formed of 5 parts by weight of resin, 1 part of yellow bees wax, and 1 part of red ochre or Venetian red in fine powder. The earthy substances should be well dried in a Wedgwood's basin on the sand-bath, at temperatures above 212°. The wax and resin should be melted together, the powder stirred in by degrees, and the heat continued a little above 212°, until all frothing ceases and the mixture becomes tranquil. It is then to be cooled, the stirring being continued, until it has become so thick that no probability remains of the separation of the earthy matters by standing.

1034. *Yellow wax* may frequently be made to answer the purposes of a cement. It resists most acid fumes at common temperatures, and hence is often applied not merely for making the joints of apparatus used in operations with acids, but even for coating or lining vessels intended for the retention of peculiar vapours and liquids, as those of the compounds of fluorine. It will not, however, resist the action long. It is less brittle (though more fusible) if melted with one-eighth its weight of common turpentine. It should be moulded into cylinders or sticks, and thus preserved for use.

1035. *Soft cement* consists of yellow wax melted with half its weight of turpentine and a little Venetian red to give it colour. When cold it has the hardness of soap, but by the warmth of the fingers and a little pressure, it becomes pliant, and may be moulded into any form required. It is very serviceable in many hasty operations at common temperatures, as making a tube and cork tight into the neck of a flask (448); closing the apertures where tubes have passed through vessels which are afterwards to be filled with water; inclosing deliquescent substances in tubes (901), &c.

In all these cases it requires merely to be moulded into form and pressed upon the joint in a dry state, and will then adhere perfectly. It will not adhere to wood or other porous substances in a moistened state, but in cases of necessity it may be made to adhere to wet metal and glass. The surface of cement to be applied should then be of a convex form at first, that as it meets with and adapts itself to the surface to which it is to adhere, it may thrust the water before it; more care than is ordinarily required should afterwards be given to press the cement into perfect contact.

1036. Soft cement is better for joints of apparatus which are liable to be shaken during the operations performed in them than hard cement or lutes, for it allows of a degree of motion which would infallibly cause the separation of the hard substance from the glass or metal, and so occasion leakage. It not unfrequently happens that this allowable motion is a cause of safety to the vessels by permitting such slight changes of adjustment as are sufficient to relieve the apparatus from any degree of tension or irregular bearing, which may have occurred during the experiment, and which if not thus allowed for, might endanger the fracture of the weaker parts.

1037. The mouths of bottles which contain gases, mineral waters, or acids, whether corked or stoppered, are frequently covered with cement to render them perfectly tight. In these cases soft cement is very superior to hard cement, or sealing-wax, being much more likely to retain its adhesion to the glass during travelling. The top of the bottle, with the cork or stopper, should be made quite dry, and the cement then applied all over it to a considerable thickness. After being pressed into its place, the whole should be covered with a piece of moistened bladder or cloth, and tightly tied down. When the object is to preserve a corked bottle of water or any other substance having no action upon the soft cement, it is well to melt a little of the latter, to dip the cork into it (901), and having previously dried the neck of the bottle within, immediately to thrust it into its place, and then to proceed as above. In this way many waters containing carbonic acid, and holding particular substances in

solution, may be sent to a considerable distance with scarcely any change.

1038. Soft cement is also very useful for taking up small particles, as crystals or fragments of bodies, for the purpose of submitting them to ocular examination. It is easily moulded between the fingers into an acute cone, the fine termination of which being brought into contact with the body, adheres to it by a mere point, with sufficient power to support it, and allowing its examination in any position. It is also convenient for effecting the adjustment of any crystal or reflecting body placed upon it, in the desired position; a circumstance which makes it serviceable in experiments on light or with the reflective goniometer.

1039. *Powdered gum* should be kept in the laboratory, as supplying a ready means of attaching paper labels to bottles, minerals, or other articles. A little of the powder stirred up by the finger with a drop of water, and, if necessary, upon the label or paper itself, is ready for immediate application. Paper which has been covered on one side with a thick solution of gum, and dried, is useful in the same manner as the pasted paper already described (1029); but there are few bodies to which gum adheres so well as paste, and the former almost always separates from glass. The best kind of prepared paper is made, by using a paste formed of equal parts by bulk, of flour and powdered gum, and a small quantity of alum; these being mixed with sufficient water to make them into a thin cream, are to be heated in an evaporating basin and continually stirred until they boil; the ebullition is to be continued a few minutes, but evaporation should be prevented as much as possible, lest the paste become too thick. If that happen, a little more water should be added, and the whole well mixed together. This paste is to be applied to one side of the paper, and allowed to dry as before described (1029).

1040. When a leak occurs at a luted joint, or at any other part of the apparatus, it is often necessary to search for the exact place of the aperture. If the vapours or gases which issue are acid, the place may be detected by bringing a piece of paper dipped in solution of ammonia towards it;

fumes will be produced. If they are ammoniacal, then a little muriatic acid on paper, or a glass rod, will detect the aperture whence they issue. If the vapours are aqueous, the spot may frequently be found, by bringing a cold glass plate or the surface of a bottle towards it, the condensation and dimness on the cold surface leading to the aperture. On other occasions a small taper flame may be brought near, the bias given to the flame, when it comes across the issuing current, or the actual inflammation of the vapours, will show the spot where they find vent. When it can be allowed, that is, where the heat is not great, and the luting will not be injured by a little water, a thick solution of soap-suds, or of gum, or paste, may be washed over the suspected place: a bubble will be blown over the aperture at which the gaseous contents of the apparatus issue forth.

1041. The leak thus found must be stopped by applying a little soft cement (1035), or fat lute (1017), or lime and white of egg (1021), or paste and paper (1029), according to the nature of the lute originally used, and other circumstances. Many leaks, which can hardly be remedied in any other way, may be stopped by tying a piece of sheet caoutchouc (416) upon them.*

SECTION XIX.

Bending, blowing, and cutting of glass.

1042. Many occasions upon which a knowledge of the methods of softening, bending, and blowing of glass by means of a lamp and blow-pipe, would be useful, have been already mentioned (117, 430, 532, &c.) The attainment of a ready practice on these points, together with that of a

* For further instruction relative to the subject of this section, see Lavoisier's Elements of Chemistry, chap. vi. § 5. and Aikin's Chemical Dictionary, vol. i. 273.

facility in effectually substituting an apparatus or vessel at hand, for another that is wanting, are, perhaps of all other experimental acquirements, those which render the chemist most independent of large towns and of instrument-makers.

1043. The apparatus necessary for the most effectual practice of this kind, is the table blow-pipe already described (221), the precautions with regard to the state of the flame, which have been pointed out, being particularly attended to. The methods of working glass with this instrument, will be first described, and afterwards the best mode of supplying its deficiency, by means of the common spirit-lamp and mouth blow-pipe. The chemist's operations are generally confined to glass in the form of tube or rod; but though thus limited, they are daily useful, and it is only by practice and the frequent performance of such manipulatory processes as those described in Section xvi. that any adequate idea of their great value and service can be obtained.

1044. Supposing the operator sitting before the table (221), the lamp trimmed and burning, the bellows put in action by the foot, and the flame clear, pointed, and steady, it will be desirable in the first place, to consider the particular circumstances requiring his attention whilst raising the middle or the end of a piece of glass tube to a red heat, and also whilst cooling it to its first temperature. This is the simplest case requiring instruction, and must be performed with facility and readiness, before any further steps may be taken. If the tube is to be heated in the middle, its ends may be held by the fingers of each hand, so that the hands shall be beneath them, with the palms upwards; and the arms may be rested (till by practice they have acquired steadiness) upon the edge of the table. The part to be heated is to be brought, not into the flame but, into the current of hot air which passes off in the same direction from it, and the tube is to be turned so as to become heated all round, and also moved a little to the right and left, that the temperature of the neighbouring parts may be raised. After a few seconds, when the glass has become hot, it should be brought towards the point of the flame, and ultimately into it, being turned round all the time,

and also moved laterally, though not to the same extent as before, that the heat may be generally applied. By the time that the tube (supposed to be about half an inch in diameter, and one-tenth of an inch in thickness) is within the flame, occupying a place about midway between the commencement and end of the nearly transparent part, it should be of a bright red or yellow heat, to the width of half an inch all round, so as to be perfectly soft at that part; and the heat should gradually diminish from it on each side, towards those parts which are still but little above common temperatures.

1045. The tube is brought at first into the heated air, and not into the flame, because the hasty application of heat endangers fracture. Glass suddenly heated breaks, because a part is rendered hot directly in the neighbourhood of a cold part, and expanding, tears the cold and unexpanded part asunder. But when the heat is gradually applied, it has time to diffuse itself over the neighbouring parts, so that no contiguous portions have such differences of temperature as to occasion differences of expansion greater than the glass can allow, without separation of continuity. Hence the reason why the heat is directed to be applied gradually; and hence the reason also why the parts near to the particular spot requiring to be heated, are also purposely raised in temperature.

1046. Thin glass, being heated through more rapidly than thick, requires less precaution than the latter; sometimes but little previous warming will be necessary for it, and on other occasions it may be brought directly into the flame. Some tubes are so small and thin that it will be found impossible to break them by the most sudden application of the flame; whilst with large and thick tubes it will be found almost equally impossible to heat them without making them fly to pieces. The precaution adopted must be in proportion to the size and thickness of the tube, and by a little practice will soon be duly appreciated.

1047. When the end of the tube is to be heated instead of the middle, more care is required, in consequence of the great facility with which cracks commence at a sharp edge.

A heat which would cause no danger if applied to the middle of a tube, would instantly cause the extremity to fly to pieces. In such cases it is best to begin by warming the tube an inch or a little more from the end, and from thence proceed slowly to the end; always keeping the temperature of the part first heated rather higher than that of the end, until the glass softens, which will be below a visible red heat in day light; after that the end is safe, and the highest heat may be applied there.

1048. The glass must not be blackened or discoloured during the operation of heating. This is a fault that may happen from either of two circumstances, namely, the incorporation of charcoal with the glass, or the reduction of the oxide of lead in it. When glass below a red heat is brought into the bright part of the flame,* a coat of charcoal is deposited, which in many cases does not disappear as the heat rises above redness, because of the incorporation of the charcoal with the melted glass; and occasionally it even increases in quantity. Being thus brought into contact with the oxide of lead in the glass, that substance is decomposed by the carbonaceous matter, and the lead being reduced, forms another kind of stain which mingles with the former. When the stain happens by accident, it is removed by bringing the glass to the apex of the flame, that the oxygen of the air may act upon it; and if the discoloration be superficial, it is soon reduced and disappears. But this process is often inconvenient, because during the time the charcoal is burning away, and the lead becoming oxidized, the glass, which is necessarily in a melted state, is gathering together and thickening, or is contracting into inconvenient forms.

1049. If after the glass has been raised to a full heat without any stain, it be brought into the bright, or especially the smoaky part of the flame, a part of the oxide of lead is reduced and a stain occasioned. This should be immediately rectified, and removed as before, but it is far better that it should be altogether avoided.

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* The brightness of the flame *depends* upon the presence of particles of charcoal ignited in it. See Sir H. Davy on flame, Quarterly Journal of Science, ii. 124.

1050. The heat produced should not be irregular or patchy, varying with every turn or motion of the glass, but uniform all round a certain length of the tube : the greater the length which by the turning and lateral motions of the tube can be thus retained at a fair uniform red heat, the greater and more efficient is the skill of the operator. To this end it will occasionally be found advantageous to incline the tube to the direction of the flame, and not to hold it directly across.

1051. After having proceeded thus far successfully, the operator should vary the temperature, and obtain the power of governing it ; sometimes retaining the tube at a low red-heat by carrying it out of the flame ; or raising it to as high a temperature as possible, by bringing it into the flame ; or by confining the greatest heat to a narrow ring, or extending it as before mentioned over a broad one.

1052. By this kind of practice, a knowledge of the heating power of different parts of the flame will be acquired. It will be found greatest within the pale flame just before the point of the bright flame, and that part will also heat the greatest quantity of matter. Its power will diminish towards the extremity, though it will still be very considerable and capable of heating a large tube. The current of air which issues from, and may be considered as a prolongation of the flame, should also be properly appreciated. It has the power of keeping glass at a visible red heat at the distance of two or three inches from the point of the flame, and is of constant use in annealing tube and tube-apparatus, both in raising and lowering its temperature.

1053. Besides this examination of the flame in the direction of its length, it should also be investigated laterally, as regards the power it possesses over a piece of tube, placed directly across and through it, compared with that which it exerts when the tube is a little above or below the axis of the cone. In this manner every variation produced by approaching the glass in different directions to the hottest part of the flame, may be ascertained and fixed in the mind. The glass worker, instead of varying the temperature of his source of heat, varies the position of his material in relation to it, and thus gains command of all temperatures, up to

the highest which the flame can produce. The more perfectly he knows the necessary position, and the more readily he applies his knowledge and attains the temperature required, the quicker and the better will his operations be performed.

1054. Besides the difference of heat dependant upon the different parts of the flame in which the glass is placed, much depends upon the size and thickness of the tube itself. It must be a powerful flame, and well managed, that will fully heat an inch in length of the middle of a glass tube two-thirds of an inch in diameter, and the eighth or more of an inch in thickness. But a tube half an inch in diameter is easily heated; and when thin, or with one of smaller size, care is actually required that it be not brought into the most powerful part of the flame, and become so over heated and soft, as to be unmanageable. Practice alone affords a perfect acquaintance with these points: the size and thickness of tube, the state of the flame itself, and its power in different parts varying almost infinitely.

1055. The softness of the glass depends upon the temperature to which it is subjected. It begins to soften and bend below a visible red heat, and when in small portions is easily brought to a semi-fluid state. The condition of the glass is judged of as much by the fingers as the eye; the feeling which it has in the hands of bending with greater or less facility, or of giving way more or less readily as the ends are pushed or pulled, is a better criterion as to the proper moment of working it than the appearance. Glass, being a transparent substance, does not assume such striking appearances, when ignited to different degrees, as opaque bodies, and its visible red heat is far higher than the visible red heat of metal or charcoal. Hence it is that, if the glass has become stained as above described (1048), those parts will appear red-hot long before the glass. Notwithstanding these circumstances, glass when highly heated becomes visibly ignited, and these appearances help, together with the feel, to indicate its state. When of moderate thickness, the glass, in consequence of the oxide of lead that is in it, assumes a greenish yellow tinge when it is heated; this occurs

before a red heat, and helps with other circumstances to indicate its state. The experimenter should make himself well acquainted with these indicative appearances.

1056. When the tube is in a thoroughly heated state, the experimenter should bend it; draw it out so as to render it thinner; and press it up again to increase its thickness. Stopping one end with his finger, and applying his mouth to the other, he should also blow it out and expand it; and by introducing a smooth piece of thick iron wire into a tube heated at the end, he should observe in what manner it gives way to the pressure, and to what extent it may be moulded (446). He will find that the glass may be bent as soon as it yields in the hands; that it must be much hotter before it can be properly drawn out or pressed up again and thickened; and that generally, the heat must be still higher for blowing and moulding. These comparative but necessary degrees of softness should be observed and remembered, as also the variations necessary for tubes of different thicknesses; thin tube works generally at lower temperatures than that which is thick.

1057. The experimenter should also acquire that steadiness yet lightness of hand, and that power of retaining the tube between the fingers, which is necessary to prevent the distortion of soft glass. When heating a tube in the middle, it is impossible, whilst all is hard, not to hold it in a straight position, and any slight irregular strain or pull does no harm. But when the heat has brought the glass into a soft state, it is by no means easy so exactly to turn the tube at both ends alike, and so lightly yet equally to hold them, that the soft part shall retain its cylindrical shape; being neither twisted, nor bent, nor elongated, nor thrust up. Again, when the end of a tube is heated for an inch or more at once, or when a tube is heated so near the end that it cannot be supported there but must be sustained from the other end, then the soft glass will tend by its weight to bend downwards. This must be counteracted by turning round the tube in the hand, so as continually to correct the inclination; letting the weight of the soft part at one moment rectify the bend it had received the instant before. During

this practice it should rather be held with the hot end inclining upwards than downwards, the latter position having the apparent effect of tending to draw the soft piece of glass as it were from the remainder.

In these kind of practices is included that of retaining the glass steadily in one particular part of the flame at pleasure, and not moving it by uncertain motions of the hand from place to place. Very little experience will give a moderate degree of facility in these operations, and will enable a student to make his apparatus in a form adapted for use. Every fresh trial will increase his facility of working, and render his results more perfect.

1058. Work of this kind should generally be performed at or towards the lower surface of the flame, and almost always be removed out of the flame downwards. By this arrangement the hottest part of the glass is constantly at, or towards, the top of the tube, so that it may be seen; and consequently the operations whatever they may be, as sealing apertures, or fastening in platina wire, are more conveniently watched. The position of the hottest part of the tube being also constant and known, allows of an advantage in bending or forming the glass, the force necessary being applied in the proper direction with certainty and readiness.

1059. When the glass has received the required form, it is to be cooled; this must be effected with some care. It must never be taken directly from the flame and laid on cold bodies, as it is then almost sure to crack. When thin, it is not necessary to pay much attention to the annealing, but being brought to the end of the flame or beyond it, and there allowed to fall below a red heat, it may afterwards be laid aside on a tray or across some raised body, as a fragment of tube, that the hot part may be in the air. But if the glass be large or thick, it then requires annealing; for which purpose it should be carried slowly from the hot to the cooler parts of the flame, the appearances and tints being watched, that the temperature may be very gradually lowered; and it should be kept for several minutes in the stream of hot air beyond the flame for the same purpose, being gradually carried to

the less heated part of it, and ultimately entirely removed. An instance of the necessity of this kind of annealing has been already pointed out (895). When laid aside it is advisable to cover the cooling glass with a fold or two of paper or cloth, to make the loss of temperature still more gradual. These precautions are the more necessary if the glass varies in thickness, as for example, at the junction of one tube with another, or at the end of a tube sealed hermetically; and they are equally indispensable with the irregularities resulting from the aukward form of a bend, the fusion of wires into glass, or other circumstances.

1060. The applications of these general directions will be best understood by describing some of the more directly useful operations. One of the simplest of these is that of forming the termination of a piece of glass rod to fit it for use as a stirrer (348). The piece of which it is to be formed is to be cut of a proper length. For this purpose a deep mark is to be made round the rod with the edge of a sharp three-square file, and being then grasped by the two hands placed one on each side of the mark, force is to be applied in a manner similar to that which is adopted in breaking a stick in two, except that in addition the hands are to pull slightly in opposite directions. If the separation be not readily effected, the file-mark must be deepened. Tubes are cut in a similar manner (115. 848); such as are small, without difficulty or accident; larger ones with a little more care.

1061. When separated by the file, the end of the rod is flat and the edges are sharp. Being heated carefully (1046), because of its thickness, beginning at a little distance from the extremity, it will be found that as soon as the glass has attained a visible heat at the end, the sharp angle at the edge will disappear, yielding to the cohesive force of the particles of glass, which will cause the end to assume a form more or less approaching to roundness. This effect being attained, the rod is to be annealed for a short time, cooled carefully, and is then ready for use. If a conical termination be required (61), then, when the end of the rod is hot and soft, the extremity of a fragment of glass tube

should be heated and pressed against it, and will adhere. The rod should then be moved a little, so that the greatest heat may be given at a tenth or twelfth of an inch from the end, and then by withdrawing the fragment, which serves as a handle, the end of the rod will be drawn away with it, leaving the termination of a conical form. When this is obtained, the tail of glass may be separated from what is to be the blunt apex of the cone, by bringing the point of the flame upon it, which causes the thin thread to fuse, separate, and run together. By retaining the end of the rod in the hot flame, the extremity will become more and more rounded; but when the desired form is acquired, the temperature must be lowered and the glass cooled as before described.

1062. The operation next in simplicity is bending a tube, requisite for the making of syphons, tube retorts, and tube operations of all kinds. An unpractised person will effect this most easily with a piece of tube about six or seven inches in length, half an inch in diameter, and the twelfth or fourteenth of an inch in thickness. Such a piece is easily handled, retains its heat longer than a smaller or thinner tube, and requiring more power to bend it, it is for that reason more steady in the hand. Being heated in the manner already described (1044), nothing will be found more easy than to bend it: but if this be done hastily or inattentively, the bend will be of a bad form; contracted in its channel; thin in one part and thick in another; probably wrinkled and distorted, and then very liable to crack on cooling.

1063. To avoid these errors, when the glass is uniformly heated for the length of half an inch or more, and to such a degree that it is manifestly soft by the feel, it should be taken out of the flame; and the two ends being now simply inclined in opposite directions, but without any other tendency by the hand, the glass is to be bent gradually in such a direction that the convex part shall be towards the eye. The operation should be continued until the required degree of curvature or the desired angle formed by the two straight

parts is attained, or until the glass from cooling has become too hard to yield; in the latter case it must be re-heated, and the operation completed.

The heat should be nearly uniform all round the glass, that on applying force all the parts may give way together, the glass at the convex surface being extended to a certain degree, and drawn out, whilst that at the concave surface is equally but uniformly thickened by its necessary contraction into a smaller space. If the glass be much hotter, and consequently much softer, on one side than the other, weakness or distortion of the bend usually happens. For if the hot part be on the convex side, it yields during the operation much more than the stiffer glass on the cooler part, which consequently undergoes but little contraction, whilst on the contrary the soft glass is extended considerably, rendered very thin, and usually assumes a flattened form. Or if the hotter part be on the concave side of the bend, the cooler and convex part will scarcely extend during the operation, the hot glass beneath giving way to the force, and becoming generally thrust up into a sharp fold or into wrinkles. Or if the hotter surface be on one side of the bend, then the glass, yielding more easily on one side than the other, usually acquires an irregular and disturbed form. On the whole it is better that the heat should be somewhat greater on the convex than on the concave part, inasmuch as, though it yields rather more than it ought, it is not so readily formed into wrinkles, and also because it cools more rapidly than the concave side. This more rapid degree of refrigeration depends upon the fact that the glass on the convex side becoming extended and thinner, consequently loses heat faster than the concave part, which owing to contraction during the operation, becomes thicker; this circumstance may therefore be compensated by a little extra heat at the first.

1064. If the glass be too hot, it gives way so readily during the operation as to assume irregular forms, and sometimes, especially in sharp bends, becomes flattened; the convex and concave sides approaching each other, and the lateral portions extending outwards. This particular condition is even useful occasionally, as it prevents the neces-

sity of great extension or contraction of the glass on the convex or concave surfaces; but an irregular and wrinkled bend should never purposely be allowed, the bore of the tube being preserved nearly as round and free there as elsewhere. If a part be observed on bending to lose its proper form, and to become flattened or wrinkled into folds, from the heat being either too great or irregular, that part should be allowed to cool a little whilst the heat is applied to the neighbouring portions, particularly to such as by contraction on the concave, or expansion on the convex sides during the continuance of the operation, are likely to rectify the irregularity of form just commencing.

Thin and small tube will require much less heat and generally more care, than that which is thick or large; but it is the degree of softness which, indicated by the feeling, must principally guide the operator in his proceedings.

1065. When a considerable bend is to be made, the angle formed by the two arms being very small, as in a syphon for instance, it should not be effected entirely at one particular part of the glass, but a portion having been heated and bent as far as possible, without weakening or distorting the tube or contracting the bore, the neighbouring parts should be heated and the curvature continued until the desired inclination of the two arms is obtained. Small and thick tube may be bent more sharply than large or thin tube, the latter requiring greater extent of curvature for the preservation of the proper form.

1066. When, during the operation of bending, different parts are to be heated and bent in succession, it is best to begin the operation at one end of that part, over which it is to extend, and gradually proceed from it to the other end. By thus proceeding the operator may contrive, when one part is heated and ready to be curved, to remove it sideways from the flame, so as to bring the next portion into the heat, which will then be acquiring temperature whilst the former part is bending, and in consequence of its previous high temperature resulting from mere vicinity, will soon be in a properly heated state. This transition, as it were, of the tube through the flame, must not take place irregularly, but gra-

dually, the heating and bending going on without interruption, and over successive portions of the tube, at the same time. A clear idea of the manner in which this is to be done, and very useful first practice, may be easily acquired by using a spirit-lamp flame without a blow-pipe, and drawing a piece of quill tube through it so gradually, that the part in the flame shall be heated red hot before leaving it. It will then be found that by giving lateral pressure on one end of the tube the parts will be bent and curved in succession as they become heated, and fixed as by their motion onwards they become cooled.

1067. When the flexure is required so near the end of a piece of tube as to render it impossible to hold the shorter side with the fingers, the force required must be given by pressing against the end with a piece of wood or another piece of glass tube. But if the bend is to be continued to the very extremity, then wood or glass will not answer the purpose, for the first would burn and soil the tube, and the last melt and adhere to the heated part. In such cases cold metal, as a metallic rod, is the best adapted for use, but it should be applied only at the moment when pressure is wanted, and never be retained so long in contact with the hot glass as to reduce its temperature below the point of softness; for as soon as the glass becomes solid the cold metal would crack it. For the same reason, metal should not be used in the cases where wood and glass have just been recommended, as it would probably crack the hot but solid part of the glass. Whenever cold metal is brought into contact with glass for the purpose of moulding or working it, the glass should be hot and not be allowed to cool to its point of hardness. The metal itself should always be cold in such cases, or at least not very hot, otherwise it will adhere to the glass and cause injury; neither should it be small, like a wire, lest the glass itself should communicate so much heat as to cause its adhesion. If the metal be hot, and the glass below its soft point, they may be brought together without risk of fracture to the glass.

1068. Quill tube, as has been already remarked, may be bent in the flame of a spirit-lamp. It may also be bent over

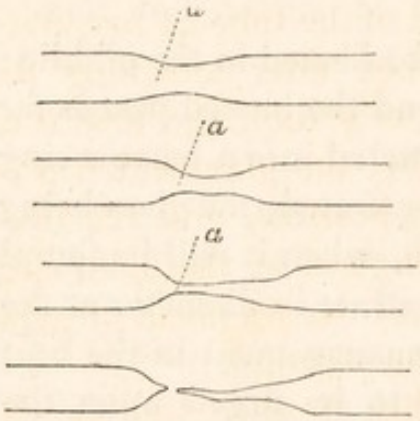
the glass of an argand lamp in good combustion. Larger tubes may be curved over a charcoal fire, either in the crucible furnace (142), or arranged on a piece of metal plate. Their flexures are large and gradual, not so short and sharp as those effected by the lamp and blow-pipe. Cooper's lamp furnace (672) is a very excellent instrument for softening considerable lengths of tubes when the bend required is to be very gradual and extensive. The tube should be continually moved in the flame, both with a lateral and rotatory motion, until uniformly heated to a sufficient degree.

1069. The next operation to be described is equally useful with the last: it is that of closing the extremities of tubes so as to shut up one end and form those useful vessels (114. 848) already often referred to. This operation is most readily performed with a piece of straight tube, open at both ends, and long enough to make two closed tubes. Let it be therefore supposed that a piece of tube, such as that before mentioned (1062), is now to be formed into two tubes, each closed at one extremity.

1070. The piece of tube is first to be heated in the middle; but in place of endeavouring to extend the heated part as far as possible, it should rather be contracted into a narrow ring (1051). The hands are then to be separated, the glass being pulled in the direction of its length, when it will be found to elongate, and at the same time contract in diameter at the hot and soft part. Some degree of management in the heat is now required. If it were still to be urged upon the middle of the contraction, and the pulling force also continued, the tube would suddenly be divided into two parts with irregular, long and pointed terminations. For as the glass is drawn out, and the diameter as well as thickness diminished, the flame acts upon it as if it were a smaller tube; the smallest part is consequently always hottest, it yields most readily to the force applied, and thus the hasty and imperfect result mentioned, would be obtained. If on the contrary, to avoid this, the glass were moved so that the flame fell upon and heated the portions at the side, then their softness might be made to surpass that of the contracted part of the tube, and the pulling would merely tend to elongate

and contract this part also, and so to reduce, as it were, the whole of the tube to portions of tube of greater length but smaller diameter.

1071. It is an effect between these that the operator should produce. As soon as the glass yields to the pull, and in proportion as the diameter diminishes, he should relax the force so as to apportion it to the softness of the glass, and proceed gradually with the operation; he should at the same time move the glass towards the extremity of the flame, and even out of it, that he may be able to moderate the heat and apply it principally to a small surface. He should no longer endeavour to keep the two pieces of glass of equal form, but using one as an adjunct, turn all his attention to finishing the extremity of the other, which probably will be that in his left hand, because the piece in his right hand becomes the tool with which he works, and which is most adroitly used by it. Directing therefore the point of the flame upon what is to be the bottom of the closed tube,



a little above the thinnest part but still not so much above as to render the thicker part the softest, let him carefully retract his right hand, by which operation the narrow part will become more and more attenuated, and finally, when capillary, fuse and separate. The end of the tube will be left closed of a round form, with probably a little knob of glass at the middle of the bottom, whilst the other piece will be drawn out rather irregularly though closed also at its extremity. The accompanying wood-cut illustrates the successive changes in the form and appearance of the tube; the part to which the greatest heat should be applied being pointed out by the lines *a a a*.

1072. The tube is seldom perfectly finished by this operation. To complete it, the knob of glass at the end, if small, and the whole of the bottom of the tube, should be heated until the glass is soft. Then applying the open end of the tube to the mouth and propelling air into it

with a degree of force proportionate to the heat of the glass, it will yield, the knob expanding more than any other part, because of its greater temperature, and of its continuing for a greater length of time in a soft state. In this manner, by a little address, the knob may be made to disappear, and the bottom of the tube to assume a regular, round form (114. 129), and a thickness nearly equal in every part.

1073. If the knob be so large and clumsy in consequence of the partial failure of the first operation, that if heated so as to run up and make part of the bottom of the tube, it would cause the formation of a very thick portion of glass there, then it must be removed. For this purpose it is to be heated, and a piece of waste glass previously warmed in another part of the flame while held in the right hand, applied to it: then directing the point of the flame above the junction and against the part intended for the bottom of the tube, the glass should be melted, the thick clumsy knob drawn off, and a fresh closing of the tube effected and finished as before. Or if from want of practice the end of the tube be irregular, mishapen, and altogether bad, then after attaching the piece of waste tube, which serves as a tool, the heat is to be applied a little way up the tube, the glass softened in another place as near to the first as possible, and the operation recommenced; the piece of glass at the end being drawn off and managed by means of the fragment of tube which had been attached to it for the occasion.

1074. If the end of the tube when finished be thin, it should be raised to a red heat, with a little of the neighbouring thicker part, when it will gradually contract and thicken, and it may thus be made of equal strength with the sides of the tube. Its thickness must be judged of by inspection, in the manner formerly described (346). On the contrary, if it be too thick, it may be rendered thinner by being blown out as mentioned above (1072). The precautions requisite in doing so will be immediately described (1093, 1097).

1075. Having finished one of the tubes to be formed out of the original piece, the other which had been laid down is to be resumed and completed. For this purpose, when held in the left hand, the point of the flame is to

be directed as before mentioned upon that part of the contracted termination, which is to form the bottom of the tube, and when soft the tail of glass is to be drawn off in the manner just described for removing a knob (1072). The tube is then to be finished according to the directions already given (1072).

1076. When the piece of tube to be operated with is thin, the extent of surface heated at first must be greater, and the operation carried on more carefully, than is necessary with thicker tube. For if a small extent only be heated, and then drawn out quickly, the glass becomes so attenuated, that when very hot it will of itself run into holes, or if it remain undivided, will form a bottom to the tube, so thin that it will not be safe to trust such a vessel for an experiment, lest a slight accident should break it. In this case, after the tube is partly drawn out and its diameter contracted, the heat should be raised considerably but uniformly round the thin narrow part, and the glass being retained in an undisturbed state, should be allowed to draw together and thicken. When that has taken place to a sufficient degree, it is again to be drawn out, and if a second time it become too thin, it must be thickened as before: in this manner the operation must proceed, until the bottom is closed and completed.

1077. When a piece of tube is too short to be formed into two tubes, it must be sealed at one extremity: an operation often required for other purposes. In these cases the end to be sealed must be heated carefully (1047), the tube being inclined a little with the heated aperture towards the direction of the course of the flame, that the force of the blast may not throw hot air into and along it, and burn the hand at the other extremity; and also that the products of the combustion may in other cases be prevented from entering the tube and affecting the substances already placed within it. When the end is soft, a piece of waste glass tube is to be held in the right hand, and its extremity used to press the sides of the hot end together, and when three or four places on the

edge have been thus made to approach each other, the end of the spare tube is to be attached to them, and the heat being raised a little above its termination, the piece is to be drawn off and the operation proceeded with exactly in the manner already described (1071, 1073.).

1078. The information given relative to glass-blowing will enable the student to make much of the apparatus already referred to. Tube retorts (859) are made by first closing the end of a piece of tube, and then the parts representing the body and the neck are to be separated by a bend more or less sharp, according to the intended application of the vessel. In the same manner are the tubes necessary for the condensation of gases to be made (892). syphons (522) are made merely by bending glass tube; or if their apertures are to be contracted, the proceeding is the same as that necessary in the first part of the process for closing a tube (1071), the operation being carried no farther than to lessen the diameter: that done, the glass is to be allowed to cool, and the narrow part is then to be cut by a file (1060).

1079. If when the glass tube is heated all round and much softened, the parts be pulled asunder quickly, and not in the guarded manner already advised, then instead of a mere contraction of a small portion of the tube to two-thirds or one-half its first diameter, it will become extended and capillary; and the two portions of the tube held by the fingers, thus connected, will be found to contract in diameter for the space of half an inch or an inch, gradually becoming capillary. This operation is frequently useful in the preparation of capillary tubes for various purposes, as in the contraction and elongation of the ends of glass retorts, or other similar apparatus (430. 532); and in making tube funnels, syringes, &c. It should always be performed in the air, and not in the flame of the lamp, unless the operator be very expert: when the glass therefore is heated, it is to be removed from the flame and drawn out. The greater the heated portion of glass, the longer will be the tube. Its length and fineness also increase with the rapidity with which it is drawn, and with the temperature given to it in the first instance. The velocity with which the hands should separate,

is most generally useful, at the rate of about a foot in a second. The thickness, length, and general character of the capillary tube produced, is also considerably dependant on the kind of tube out of which it is made: the relation of the diameter to the thickness of the glass, will be nearly the same in the tube, both before and after it is drawn out.

1080. When a contracted tube is required, and too long to be made at once, then having drawn one length, the original tube is again to be heated so near to the part already drawn, that when extended, only a little swelling or bulb may intervene between the capillary portions. It is not safe to endeavour to heat the tube so near to the already extended part, as, on drawing it out to make one tube with the latter without irregularity, for owing to its delicacy, the previously extended part will almost certainly give way: no difficulty occurs in afterwards softening and drawing down the small expansions; for by making use of a little spirit-lamp flame (182), placed under the bulbs, they are soon raised to a red heat, and then by careful management are easily drawn down.

1081. When the ends of retorts or other tube apparatus are to be thus reduced in diameter (430), they should not be drawn out more than is necessary, but left with sufficient strength to resist the slight mechanical accidents to which they are liable in the course of experiments. The same remark applies to such vessels as the small receivers or retainers, recommended (863). If the neck of the retort, or tube, to be drawn out be thin, it is for the same reason advantageous to thicken the part before it is extended (1076), for which purpose the glass must be softened in the flame, and retained at a high temperature for some time, and rather thrust together than pulled out; in this manner the thickness of the glass may be nearly doubled, and consequently the capillary tube resulting from its linear extension, rendered stronger.

1082. When capillary tubes are drawn for air-guages (1254), several should be made of different diameters, thicknesses, and lengths, and the most advantageous afterwards selected.

1083. The same proceeding, with slight variations, is sufficient for the production of several kinds of useful apparatus. A tube funnel (859) is made by elongating a piece of tube in this manner, at about an inch from the end, and then separating it, leaving the short piece with so much of the capillary tube attached to it, as will form a funnel of sufficient length. Tube syringes of various kinds, for the removal of azotane, washing of precipitates, &c. (518, 533), and the tubes recommended as being useful in estimating volumes and in measuring (117, 126), are made with equal facility. When the end of a piece of tube is heated and drawn out, a form more or less acute may be given to the termination, which being cut so as to leave an aperture of the proper size, is only to be held for a moment in the flame to soften and obliterate the edges (1061), and a very good syringe body is formed. A little tow, wrapped round the end of a wire and moistened, forms an effectual piston, and thus an instrument of great use in numerous operations is quickly made. If it be required that the termination of the syringe should pass off obliquely, it is effected by drawing out the tube in that direction when hot.

In the same manner the separator delineated (532) is made, by drawing off the end of a piece of tube so as to form a moderately stout capillary continuation, and then bending this upwards as in the figure. The gas tube, for conveying products into small tube receivers (415, 430), is made by drawing out the end of a tube until of capillary dimensions, and then bending it downwards.

1084. It is very frequently necessary with tube apparatus, to seal apertures hermetically, so as entirely to close the vessel, and make it continuous in every part. This process resembles that by which one end of an open tube is sealed (1077), so far as regards softening the glass, bringing it together, contracting the aperture, and ultimately closing it; but it differs very much in other circumstances, dependant upon the state of the interior of the vessel. In the open tube the glass is equally pressed on both sides; but that is rarely the case in the closed tube, a tendency

of the contents to pass outwards, or of the air inwards, almost always occurring.

1085. The simplest case of the kind is, where solid fixed matter is to be confined in a tube for the purpose of preserving it, in the manner already spoken of (902). The included substance then sends off no vapour, and all that is to be guarded against is, the expansion and contraction of the air within by the variations of heat. Suppose the tube closed at one extremity, and that one-half or two-thirds of it is filled with the substance; care should be taken that the latter does not rise so near to the upper part of the tube as to be affected by the heat, especially if it be an easily fusible or changeable body. The top of the tube when brought towards the flame, should be inclined (1077), that the products of the combustion may not enter it; and the bottom should be inclined downwards, that the contents may not fall towards the heated part. The upper part, being heated, should be drawn out and contracted, precisely as if it were the end of an open tube that was to be closed, except that the glass generally should be retained as thick (1076) as it will be required when finished, in order that the capillary tube may be of considerable comparative thickness, and that an aperture for the air through the middle of it may be preserved the whole time. The wood-cut will illustrate this state of the tube. No difficulty will be found in directing the heat about *a*, in drawing off the end piece, and in leaving the tube sealed, for the glass will readily coalesce at the moment of separation; but the object is to make this end as strong as any other part of the tube, and of a form similar to that of the opposite extremity; for effecting this, the following explanations and precautions will be found useful.



1086. Supposing the piece drawn off and the end closed; the glass is so hot and soft at the moment, that if from an accidental contact of the flame any part of the tube becomes hotter than before, the air within will expand, the glass will be blown out into a thin bubble, which,

breaking even by the mere pressure of the atmosphere as the tube cools, will leave a large hole. It will now be more difficult to close the tube than before the extremity was removed, for the sides of the aperture must again be collected together and drawn off, and a capillary neck again formed.

This may be avoided by purposely heating the upper part of the tube before sealing it hermetically, so as to expand and expel the air from within; then, removing the flame and applying it to the capillary neck as the general temperature of the tube sinks, the piece is to be drawn off, and the aperture sealed, and as the pressure is inwards rather than outwards, the glass will be pressed in the former direction. This is in fact the method to seal the tube strongly, and to make it of a desirable shape, but it is subject to an accident, which to be avoided must be known. If the glass at the end has been left thin, and it be heated until perfectly soft, the pressure of the external air will frequently force it inwards, sometimes into a decided bubble, or sometimes into various wrinkled and irregular forms, which, when cold, are almost sure to crack in numerous directions.

These accidents are avoided by making the end of the glass and the capillary neck of considerable comparative thickness, which is done by allowing the glass to gather itself up when in a fluid state (1076, 1081), and also when warming the tube to expel a part of the air, by not raising the temperature too much; then upon proceeding to soften the neck and seal the extremity, the flame should be directed rather generally to that end of the tube in such a manner that, the whole being softened, the apex shall still be retained at the highest temperature. In this way it will be easy by a little practice to make the external pressure effectual in forcing in the end of the glass generally, and causing it to become altogether thicker and stronger, instead of having a small portion suddenly blown inwards, and the whole rendered irregular. Or if, by too long a continuance of heat, the air within begins to expand, still as all the glass at the end is of equal softness, the whole will gradually enlarge outwards; an effect

which will be immediately perceived, and the operation may be stopped before any injury is occasioned.

1087. When the tube contains a fluid instead of a solid body, the care required is greater, and must be proportionate to the volatility of the substance. A fixed fluid, if alone, merely requires to be retained in the lower and colder part of the tube, away from the end to be sealed. Sudden motion should be avoided, lest drops be thrown upon the cold part, and cracks be occasioned: during cooling, the tube should also be placed steadily with its heated end uppermost (864). There are particular cases in which great care is necessary to prevent disturbance of the contents of the tube. Such are the experiments upon the condensation of gases (892), in which the strength, uniformity, and annealed state of the end hermetically sealed, are essentially necessary.

1088. If the substances to be confined are volatile, but yet like alcohol, ether, chloride of sulphur, &c. have their boiling points not lower than 100° or 150°, then additional precautions will be needful: these apply particularly to the moment when the capillary neck is to be finally drawn off and closed, and the end thickened and made strong. The effect of heat upon tubes with such contents, is not only to expand the air within them, but also to increase its bulk, by raising and mixing with it the vapour of the substance. The formation of this vapour, and consequently the tendency of the gaseous matter within to expand, is not simply in proportion to the heat of the end of the glass tube with which the vapour is in contact, but depends also upon the heat communicated to the fluid beneath. This effect is produced more slowly than the former, and may, in the hands of an inexperienced person, lead to confusion. The temperature of the glass near the end may be actually falling, and may lead to the expectation of a diminution in bulk of the gaseous or vapourous matter within, and consequently of a pressure from without inwards, whilst at the same time the temperature of the fluid may be rising by *contact* with the neighbouring hot or warm glass, and may cause an increase in the quantity of vapour given off, and upon the whole a tendency of gaseous matter

to pass out of the tube; which not being anticipated would spoil an experiment (864). In these cases the upper part of the glass (1086) should be heated so as to expand the gaseous contents a little, and at the moment the capillary neck is drawn off, and the aperture closed, a piece of moistened bibulous paper should be applied round the part of the tube containing the fluid, and if the substance be very volatile, even a little higher up, though not to the heated part of the glass. This will prevent any further elevation of temperature in the fluid, and the end may be safely heated and thickened (1086), in the manner already described for tubes containing solid bodies.

1089. When the aperture to be sealed is small, and at the end of a capillary tube, as in the vessels described (863), nothing more is required than to hold it in the flame of a lamp or candle, when the glass will fuse and coalesce. Or if the end be broken and rather wide, the part softened by heat should be touched with another piece of glass, and be drawn out and sealed as before. In these cases when sealed, the glass is to be removed from the flame, not being suffered to run into a little ball, which will generally break off when cold, or after an interval of three or four days.

1090. When substances so volatile as to boil almost at common temperatures are to be sealed up, the tubes containing them must be cooled by refrigerating mixtures. This precaution has been described as it respects sulphurous acid, and the description will illustrate the process for similar substances (864). The only additional remark here necessary is, that if the fluids are to be preserved as specimens, the capillary neck should be of considerable thickness, and when effectually sealed, whilst the tube is in the frigorific mixture, should not afterwards be altered, nor should any attempt be made to give it more thickness, or a better form. A spirit lamp and mouth blow-pipe is more convenient for softening the capillary necks, and sealing these tubes, than the table blow-pipe.

1091. When the object is merely to close the ends of capillary tubes (863), it is easily effected, the tubes being cooled at the same time. When the fluids are of such vola-

tility as to cause only a feeble stream of vapour from the aperture of the vessel,(and several such may be found amongst the substances held in vapour in oil gas), the cohesive force of glass is sufficient to cause it to run together when softened, and to seal the orifice, even though there be a slight pressure outwards. For this purpose the end of the capillary tube is to be introduced into the flame, and being touched with another piece of glass, the extremity is to be drawn off, and at the same time sealed: at the instant of doing this it is to be removed from the flame, that it may cool and solidify, lest the heat of the lamp or hand should increase the tension of the vapour, and cause such pressure outwards as would be sufficient to expand the soft glass.

1092. The process of sealing tubes hermetically, which have previously been exhausted of air, requires certain precautions to prevent the pressure of the atmosphere from either making an entrance, or forcing in the glass. Suppose it were necessary to enclose some camphor hermetically in a tube exhausted of air, that certain of its habitudes as to vaporization and crystallization under such circumstances might be observed. A tube of sufficient length is to be selected, and being closed at one end, the camphor is to be introduced; the tube should then be heated at about an inch from the open extremity, and should be contracted and thickened in the manner described (1076, 1085), so that the smallest part may be about half an inch in length, about one-twelfth of an inch in internal diameter, and one-third of an inch in external diameter. A retort cap is to be cemented upon the open extremity(780), and a stop-cock attached to it. This being done, the tube is to be connected with the air-pump and exhausted, and the stop-cock being closed, the tube is to be removed from the pump in its exhausted state. The small flame of a spirit-lamp is now to be applied to the middle of the capillary part, so as to heat it gradually all round; as the glass softens the pressure of the atmosphere will make it collapse and become solid, the passage will be obliterated, and the tube will be converted into a rod. This done, the heat is to be applied more immediately to the middle of the solidified part, which, when

it has become soft, is to be drawn asunder. No difficulty will be found in doing this, without letting in the smallest portion of air, and if proof of the accuracy of the process be required, it may be obtained to a certain degree by plunging the piece attached to the stop-cock under water, and breaking off the point there; if the water should enter in such abundance as to fill this piece, it will shew that no common air has entered by the stop-cock, and the appearances will sufficiently indicate whether air has entered or not at the part heated. No attempt should be made to thicken, or in any way bring into form, the sealed end of the exhausted tube; for the pressure of the air will be almost certain to force in the softened glass, unless the operator be very skilful.

1093. A more delicate operation than any yet described, and one that requires considerable practice for its performance with even moderate success is, the blowing of bulbs and other expansions, either in the middle or at the end of a tube. Facility will be best obtained by practising with a piece of tube about nine or ten inches in length, one-third of an inch in diameter externally, and one-tenth of an inch in internal diameter. The end is first to be closed; and then about two-thirds of an inch in length of the closed extremity is to be uniformly heated, until so soft as to bend from side to side by its own weight. The aperture is immediately to be placed between the lips, and by means of the mouth (202, &c.), air is to be propelled for the purpose of expanding the soft glass. This must be done quickly but cautiously; and as soon as the eye, which must be constantly fixed upon the heated end, perceives enlargement there, the force exerted by the mouth should be slightly diminished, and the operator should hold himself ready for its instantaneous cessation. For if the power which expands the glass at first be continued in full force, the glass will suddenly burst out into a large irregular thin bubble of no use. This follows as a natural consequence, for every enlargement of the bubble diminishes its thickness, and consequently its resistance, and at the same time increases its internal area, and in that respect increases the power of the

air impelled into it; and if the enlargement take place quickly, so that the glass has not time to cool, it cannot but happen that the bubble should expand to a large size. To avoid this, air should be thrown in from the mouth only (203), and not from the lungs: as the glass expands, the force with which the air is impelled, should be diminished: and the operator should not endeavour to finish the bulb at once, but having succeeded in expanding it to such a size that the internal diameter is five or six times the thickness of the glass, he should heat it again, and complete the bulb at a second operation.

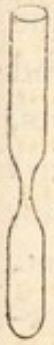
1094. The glass must never be blown whilst it is in the flame, for it is impossible to make it retain an uniform temperature there, but is always to be expanded in the air: as it swells it must be continually turned, and those parts which are thinnest brought to the lowest position; they are easily recognised by their sudden expansion, by a greater degree of transparency, and a peculiar reflexion from them different from that of the neighbouring parts. They are directed to be brought into the lowest situation, because the glass in that position cools most rapidly, and consequently its further extension is prevented. The operation must be quick to be good, for the temperature of the thin glass is so soon lowered, that it cannot be done at all if not done rapidly. The bulb when finished should be round, set straight on the end of the tube, of uniform thickness at the bottom and sides, and without lumps or knots. The size will vary with its thickness and the quantity of glass heated.

1095. These operations may then be repeated with tubes of different sizes. If their internal diameters are much smaller than that mentioned, as in barometer tubes, the end may be heated until almost solid, and even thrust up into a lump. This being uniformly ignited, should be blown until the air just begins to expand into a small bubble at the end of the bore, and then the temperature of the glass being well raised, it should be blown out into a bulb at once, being turned in the air as before directed during the operation. It will be understood from what has been said (254, 1148), that these bulbs will not serve for thermometers, because of

the moisture they receive from the air thrown in by the lungs; but they are useful in the practice they afford, and for numerous experimental purposes.

1096. Sometimes an expansion must be formed in the middle of a tube (531, 887), and the operation in general resembles that just described. If the end of the tube be closed, the glass merely requires to be thickened and heated at the part to be blown out, and then expanded by the breath. If it be not closed at either extremity, then the finger or a cork must be applied to one end to close it, and the part being heated, the lips are to be applied to the other end, and the expansion made.

1097. A little practice of this kind will soon enable the student to remove the knots at the ends of his closed tubes (1072), and make their terminations perfectly round, and of uniform thickness. By similar trials he will succeed perfectly in forming the little vessels referred to at (85), some of which are blown out of small tubes, whilst others may often be made without any blowing at all. For this purpose it is only necessary to take a piece of tube of the proper diameter, (or if too large at first it must be drawn down to the diameter required (1070),) and contracting one part into a neck of such width as is necessary to be given



to the intended vessel (1071), the flame is afterwards to be removed further down, to fuse the glass, which is to be contracted, drawn out, and closed. In this way the body of the vessel is obtained of any required capacity, according to the length given to the piece of tube forming it. Or by warming the body and then blowing it, it may be expanded until of much larger size. The flask is afterwards to be separated from the remaining piece of tube, either by cutting it off with a file (1060), or drawing it off at the lamp to a fine termination, if required.

1098. The bulbs referred to (67, 98), are made in a similar way. A piece of small tube is to be drawn out, closed, and the end rounded. The end of the piece of tube drawn off is to be melted in the lamp, and suddenly applied to the extremity of the tube just closed, which, if at a temperature below the soft point of the glass, will allow of its

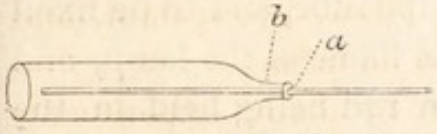
adhesion in a manner sufficiently strong to bear the force required in working and finishing the vessel, yet so slight, that a feeble tap or blow will readily cause its separation. So arranged, the glass tube is to be heated a little way from the end, that a sufficient length of it to form the bulb, may be drawn by the attached fragment, and finally hermetically sealed in the manner already described (1089). When cold it is to be tapped against the table, it will then separate from the waste piece of glass which previously supported it, and will be ready for use.

1099. Two pieces of tube are sometimes to be melted together so as to form one, with a continuous bore; and pieces of the same, or of very different thickness, may, if necessary, be joined. The ends should be straight, and of nearly equal diameter, so as to apply almost accurately against each other. If they are not so at first, the extremity of the larger one should be contracted until they become so. They should be brought into the flame so as to be raised separately, but at the same time, to a good heat, that the glass may be quite soft; and then the ends, being applied to each other, should be pressed together in the flame, until the glass adheres in every part, and runs up into a ring round the tube. The ring should be immediately drawn down again, unless it be permanently required, and then by working the glass in the flame, the joint should be brought into a good shape and condition. If, during the operation, the tube contracts, it should be blown out (1096); if it become thin, it must be thickened (1076) and pushed up; if it be thickened too much, it must be pulled out and rendered thinner, the contraction of the diameter occasioned by doing so being rectified by expanding the glass again. The joint when finished, should not be of imperfect adhesion at any part, or be distorted in form, or involve any great irregularity of thickness, for then it will almost certainly fly asunder when cold. Small irregularities may be allowed to remain, and if the glass be well annealed, will do no harm.

1100. It is of great importance in many experiments to be able to seal a metallic wire into glass, so that

the glass shall close round it and adhere to it, in a manner perfectly air-tight and sound. The detonating eudiometer tubes (919), and the tubes for the collection of gas (961, 964), during the voltaic decomposition of liquid substances in solution, are common instances of their valuable application. Platina is the only metal which answers well for this purpose, and fortunately it is that which, in consequence of its chemical relations, is the most useful in such situations. The superiority of platina depends upon its infusibility at the temperatures required to work the glass, and on the close agreement of glass and platina, in the rate of their expansion and contraction by changes of temperature. Other metals, as iron, differ much from glass, and when wires of these are inclosed in the most secure manner, they either separate when cold from the glass, by contraction, destroying the continuity all round them, or, if that does not take place, they retain the glass in the immediate neighbourhood in such a state of tension, that very slight accidents cause it to fly, and cracks to proceed from the wire into the glass in several directions. This rarely happens with platina inclosed in the thickest glass, if the junction has been good, and the glass well softened.

1101. Suppose a tube like that figured (965) be required, with a platina wire passing through it, and hermetically sealed into its summit. A piece of tube of the required diameter, thickness, &c. is to be selected, and also a piece of clean platina wire: the tube should be heated at the part where it is to be closed, and should be drawn out so as to form a capillary neck (1076. 1085), the end of the tube and the neck being preserved of considerable comparative thickness, so that no occasion for afterwards increasing it shall exist. The neck should be of such internal diameter as freely to receive the wire but no more, and when cold, should be cut with a file, so as to leave the proportion represented in the figure attached to the tube. The wire is to be introduced through the aperture thus opened, and placed in the position required when the tube shall be completed. The point of the flame is then



to be applied first to *a*, that the extremity of the aperture may become heated and the wire also, the temperature being kept down to such a point as is sufficient to soften the glass considerably but not to make it run; and both glass and wire being hot, a very little motion of the latter will cause the edge of the former to adhere to it all round, and make a tight though not a strong joint. This done, the heat must be applied more towards the tube, so as to make the glass and the wire adhere gradually from *a* to *b*. This should be done without any twisting or distortion of the glass, and will be found more or less easy according as the end of the tube has been well or ill prepared at first to receive the wire. Finally, all that part by which the wire is surrounded and held should be raised to such a temperature as to make the glass soft and semi-fluid, that no irregularities in form or contraction may remain; the wire should be arranged so that it passes directly down the axis of the tube, and then the whole must be suffered to cool. It is erroneous in a beginner to make the capillary end of his tube thin, and trust to thickening it after the wire is sealed in by running the glass up. Such sealings are generally unsafe. The end of the tube should first be made of sufficient thickness, and then all that remains to be done is, to soften it, so that it may collapse round and adhere perfectly to the hot wire, in every part of the joint.

1102. When a tube of this kind is required for voltaic decompositions, having two parallel but insulated wires sealed into its closed extremity, then a piece of platina wire of sufficient length for the two is to be bent in the middle, so that the two parts may be parallel at the distance of the eighth or twelfth of an inch from each other. The extremities are to be fixed into a small piece of cork, which will retain the bent wire so steadily, that it may be worked with as a single piece. That part of the wire which is intended to pass through the end of the tube, and to be fixed in the glass, is to be brought into the flame of the lamp, and a thick filament of glass, or a thin rod being held in the hand, its extremity is to be softened also in the flame, and glass from it worked upon the wires, so as to form a small bead

which, lying between them, shall also extend outside of, and inclose, them on two of its sides, and when cold serve to tie them together at the distance before arranged. This done, the end of the tube is to be prepared, by drawing it down and contracting it, but only so much, that when the neck is cut off (which should be done closer to the tube than in the former case) the aperture may be so large as to admit the passage of the double wire, but not of the bead of glass upon it. The wire is to be dropped down the inside of the tube, so that its bent end may pass through the aperture, and the glass bead be received and stopped just within it; heat is now to be applied to melt the bead and the end of the glass tube together, and the temperature is to be raised until the cohesion is perfect, and the joint well formed, after which it must be allowed to fall. When the tube is cold, the piece of cork, now within, is be drawn from the ends of the wire, and the wire itself is to be divided on the exterior, at the bend. It thus forms two insulated portions, which may be connected with the poles of a battery, and rendered active in decomposing any solution put into the tube.

1103. If a wire is to be inserted through and sealed into the side of a tube, that part of the tube through which the wire is to pass, is to be softened in the lamp, and the wire pressed against it, until it appears in the interior of the tube: it should then be drawn out again in the same direction, and both tube and wire left to cool. The wire will be found coated with glass, which may easily be broken off. The tube will be drawn out at the place forming a conical projection, the end of which when broken off, will afford a passage to the interior. The wire is then to be put into the aperture, heated, and the glass fused around it: ultimately the wire is to be pushed inwards, until that portion of glass which projected has been returned nearly to its first position. By a little practice this may be done so that the glass shall be in perfect contact with the wire on all sides, and with little disturbance as to its form, or the position from that which it possessed at first, the wire at the same time having the exact position required. If fears be enter-

tained that, from the removal of glass on the wire, and by breaking off the end of the projection, enough will not remain to confer sufficient strength upon the tube in that part, it will be desirable, to put a bead of glass round the wire, in the manner just described for double wires (1102), and when the heat is applied, to work it into contact with the glass of the tube, that the latter may be of sufficient strength. When two wires are required in the same tube, at a certain distance from each other, as is necessary in a eudiometer, the distance is easily regulated by a little previous consideration; allowance being made for the extent to which the wires will require to be moved, before the operation is finished and they are finally fixed in their places.

1104. When green bottle glass tube is to be worked and submitted to these operations, they will be found more difficult of performance, because of the much higher temperature required for the fusion of this glass. Generally it is only the simpler operations that are necessary with green glass, such as bending, closing, or lengthening a tube. These may be performed readily by means of the table blow-pipe; and as from the greater strength and infusibility of green glass, it frequently happens that a thinner tube of this substance may be used than of flint glass, a greater facility in the operation is thus obtained.

1105. The use of the spirit-lamp in these operations on glass, even when not urged by a blow-pipe, has been noticed more than once. When its powers are increased by the application of the blow-pipe, it may often be made to perform the work of the table-lamp; generally not so well, though very usefully; sometimes quite as well; occasionally even better. Small tubes may be bent, closed, drawn out, extended, and worked, in almost any way by its means; and moderately large tubes, i. e. from one third to half an inch in diameter, may be bent and closed by it. If no other kind of blow-pipe than that for the mouth is at hand, it must be turned to account in the best manner possible. For this purpose the mouth-piece of the blow-pipe may be placed between the lips, and the instrument supported without any help from the hands, being allowed to hang

from the mouth with its jet opposite to the flame of the spirit-lamp. The flame may then be urged, whilst both hands remain at liberty for the purpose of moulding and working the glass. The student will at first find it difficult to hold the blow-pipe so steadily in his mouth, as to produce a certain and regular flame; but he may obtain assistance by placing a block of wood, a book, a weight, or a brick upon the table, between himself and the lamp, at such distance from the latter that the back of the blow-pipe may bear slightly against it. The pressure may be easily regulated by the mouth, and will be quite sufficient to render the blow-pipe, and consequently the flame itself, perfectly steady.

1106. The *cutting of glass* in the laboratory is an operation which is more frequently to be performed with tube and rod than any other form of glass. But occasionally old flasks, retorts, jars, &c. are required to be cut into useful pieces, and several methods have been devised for the purpose. These, though not at all equal in accuracy and security to the methods of the glass-worker, may be performed with such common tools as are to be found almost every where, require but little practice, are frequently efficient in facilitating experiments, and are highly useful to the student.

1107. The method of cutting tube or rod by a file has been already described (1060). A cutting diamond will answer the purpose as well as a file, and even a sharp flint may be used upon emergency. When the tube is very large, it is safer to go round the place first with a diamond, and to perform the operation over a cloth or some other soft substance, lest as the pieces separate they should fall and be broken.

1108. In all cases in which a diamond is used, it must be remembered that a cut, not a scratch, is required. A scratch by a diamond will rarely give direction to a crack, and is as likely to be crossed by one as followed. A cut on the contrary is a division of the glass independent of the abrasion, has actually penetrated to some depth,* and is

* See Wollaston, Phil. Trans. 1816, p. 265.

almost certain to be followed by any crack or entire division that may come across or even near to it. A cutting diamond operates well only in one particular position; which should be found by trial upon a piece of crown glass, and being ascertained should be marked upon the handle, that in any future operation it may always be in the same favourable position relative to the cut that is to be made. The scratching diamond (115. 902) is not fit for cutting, but is intended for distinct uses; nor should a cutting diamond be injured by employing it in writing and scratching upon glass.

1109. Old retorts, flasks, globes, and other convex pieces of glass apparatus, are often cut by iron rings into circular pieces, which then answer the purpose of dishes. The rings should be of different diameters, made of wrought iron about the third of an inch in thickness, with a stem attached to them, by which they are fixed into a wooden handle. When made uniformly red hot and brought into close contact with the convex surface of a glass retort or flask, a crack generally takes place in a few moments beneath the ring, which occasions the separation of the inner round piece. These pieces are sometimes used as evaporating basins; but from their great tendency to crack at the edges and gradually break to pieces, are not safe in precise or important experiments. The uses of the rings are much more valuable for the facility with which they cut a flask in half, or by similar operations afford entrance into any other vessel so as to allow of an examination of the interior and the state of the substances it contains.

1110. Thin fragments of retorts, flasks, and especially Florence flasks, are very useful for the evaporation of small quantities, but as these vessels are never requried to be thus cut up until they are broken, the cracks then existing may be led in advantageous directions more conveniently by other means than by the iron rings.

1111. Many pieces of glass apparatus which have become useless, such as jars, bottles, globes, and generally those with convex surfaces, may be divided along a particular line by means of a hot iron rod, and thus separated into useful pieces. The operation consists in leading a crack, either

made for the purpose or previously existing, according to the required direction. The iron rod may be nearly as thick as the little finger, and made tapering at the end for an inch or an inch and a half to a blunt point. The line of division should be decided upon, and even be marked on the glass with pen and ink; it may pass without impropriety over parts varying in thickness, but should not go suddenly from a thick to a thin part; thus it may be followed with ease round the sides of a jar or bottle, but the crack could scarcely be led down one side of a jar, across the bottom, and up the other side.

1112. It will rarely occur that a vessel is to be divided in which some previous crack or broken edge does not exist. The iron, being heated to redness, is to be brought with its point towards the crack in an opposite direction to it, and the apex is to be laid upon the sound glass just before the crack, the iron rod being at the same time retained at an angle of about 20 or 30 degrees with the, as yet uncracked, glass beneath. The crack will immediately extend itself to the part of the glass with which the hot iron is in contact; and by gradually and slowly drawing the latter along the glass before the crack, the division will follow it, and may thus be led in almost any direction. It may, when not carried too near to the edge of the glass, or to another crack, be made to turn off suddenly at right angles to its former course, or it may be led in gradually winding and curving lines. The crack should at first be led directly towards the line which marks the convenient division, and having reached it, that line is to be pursued until the separation is effected. When the rod has cooled considerably, or even when hot, if thin glass be experimented with, it is often difficult to carry the crack entirely round into the commencement or into any other division; but in such cases the small part which remains undivided easily yields to the slightest mechanical force, the crack being then continued directly into the previously divided part.

1113. The rapidity with which a division is effected depends upon the temperature of the rod. It is not desirable to perform it very quickly, and therefore when very

hot, the rod should be held at greater angles with the glass than those mentioned, that the point only may touch it. As the heat diminishes the rod should be more inclined, that the thicker part may be made to approach the glass, and by its heat and effect, compensate for the diminished temperature of the point. When still cooler it may be desirable to use the thickest part of the rod instead of the point, laying it down in contact with the glass before the crack and drawing it along, but this can only be done on convex vessels.

1114. If the direction to be followed lies but a little distance from the line of an edge, or a previous division, the operation must be performed more slowly, and with the apex rather than the line of the rod; for the crack to be led has then a tendency to fly suddenly to the edge by its side. It is not easy by this method to cut nearer to an edge than the third or fourth of an inch.

1115. If there be no crack to commence with, one must be produced in the following manner. If possible an edge is to be selected, which, being an inch or an inch and a half from the line of division, may have a crack made in it without interfering with the part of the glass intended to be preserved; if it be a recent edge, i. e. one that has been formed by fracture rather than one which, existing at first on the piece of apparatus, has been fused, it is the more advantageous. The heated iron rod is to be applied to this edge in a direction almost perpendicular to the glass, that the heat may extend to as little distance from the place as possible, and when it has been in contact for a moment, if a division has not spontaneously occurred, the hot part is to be touched with a moistened finger: a crack will immediately be occasioned, and the smaller the distance to which it runs from the edge the better; for once commenced, the smallest crack can be led as easily as the largest, and the opportunity of directing it from the commencement is secured. If the glass be thick, as that of a bottle or jar, it will usually fly by the heat alone; if it be thin, as that of a Florence flask, it will generally require the application of moisture after the heat.

1116. If the crack is to be commenced in the middle of a

plane unbroken surface, great care is required, or the fracture will extend to a considerable distance, and probably in a wrong direction. The heated point should be applied to a single spot, and being soon removed, the place should be moistened. It is better to try two or three times unavailingly, than, by heating the glass too much at first, to incur the risk of an extensive fracture. The crack should always be commenced at some distance from the important line of division, that there may be less danger of the first and uncertain separation interfering with or crossing the latter.

1117. In all divisions of this kind the glass to be cut should be supported upon a cloth, that the parts on both sides of the crack may be sustained; or, when the division approaches its completion the mere weight of one part may make the crack run in an inconvenient direction. The form of the piece of iron is by no means essential, and a furnace poker, or a pair of tongs, may, in cases of emergency, be used for these purposes. It may even be performed with a red hot pointed piece of charcoal, the ignition being heightened by blowing upon it.

1118. The edges which are exposed when glass is thus divided are very liable to fracture by slight mechanical force, by heat, or by other causes, much more so indeed than glass of which the edges have been fused or ground. Hence it is frequently advantageous either to grind them, which may be done upon a flat stone with a little sharp sand or emery and water; or to soften and fuse them, which may be effected either by the table blow-pipe, bringing all parts of the edge in succession into the flame, or by a flat charcoal fire. When the edges are not thus finished, they should have a sand-stone or a fine file passed over them to remove the linear angles, which, being sharp, are dangerous to the fingers.

1119. Jars which have been broken at the edges, may by a process of this kind be cut shorter, and then will long remain useful vessels. Bottles of which the necks or upper parts have been broken may be converted into small jars. Their stoppers should be added to those which already occupy a drawer in the laboratory (21. 1126), and from which the place of an absent one may often be supplied.

Broken test glasses may frequently be cut into useful forms; if but one half or two-thirds of the cup be removed, the remaining part with the foot will serve for many voltaic decompositions, and frequently, as a convenient insulating stand in electrical experiments. If nothing but the foot can be preserved, still there are numerous occasions for its services in the laboratory; for the body being broken away, and the stem chipped off, which is done by striking it sideways with a file or the edge of an iron spatula, a strong round glass disc remains. Such discs are very convenient as covers for the mouths of glasses containing precipitates or other substances, to exclude dust during the time the experiments are in progress.

1120. In cutting up large pieces of glass by the method described, especially if any importance be attached to the result, it is best to precede the application of the hot iron by going round the part with a diamond. The iron then merely completes what the diamond had begun, and it is seldom that the separation departs from the track thus laid down for it. But the chemist should never undertake delicate or difficult divisions; the object of the preceding directions is to enable the economical experimenter to cut up into useful forms old glass, which would otherwise be thrown away as waste. In more important cases he will, of course, transfer it into the hands of an instrument maker.

1121. Sometimes it is required that a piece of flat glass, as crown glass, should be broken into two or three smaller pieces. If this be attempted by means of a blow, the glass will usually shiver into many pieces, mostly long, with round edges and of very inconvenient forms; a piece of the desired size or shape being rarely obtained. But by contrivance a piece of such glass may be divided into two parts only, with considerable certainty, the direction of the fracture also being in some degree under government; and a long slip of glass may be divided into halves or quarters, or a piece of any form cut up into smaller parts without difficulty. Suppose it were required to divide a piece of glass four inches long and two wide, into two nearly equal portions. An angular file (three-square or four square) is to be placed with one

end against an obstacle, as the edge of a table, and the other against the breast, so that by a little pressure it may be supported with one of its edges upwards, and nearly in a horizontal line. The piece of glass is to be held with one end in each hand, and the middle of one of its long sides is to be applied to the edge of the file at that end nearest to the table or support, the glass being inclined a little upwards from the horizontal direction towards the operator. The operator is then to press with a moderate degree of force on the glass, drawing it along the file from one end to the other, and, without taking it off, to turn it as it were over, so as to incline it in the opposite direction, and then carry the glass back again with about the same pressure, to its original place on the edge. In this way there is a tendency to notch the glass on the opposite sides of the same edge and place, which is sufficient to originate a fracture there, and as the glass is returned, it generally divides in the hands by a crack, commencing at the place where it was in contact with the edge of the file, and proceeding directly across between the hands.

The degree of pressure required is quickly learnt, by a little practice on waste pieces of crown glass: it should be insufficient of itself to break the glass, but sufficient when the small fracture is commenced by the file. It is better to make it rather stronger when the glass is returned, than when drawn towards the body; the former being the most convenient time and position for the fracture to take place in. The direction of the crack is regulated chiefly by the force applied by the hands, being usually across the line of resistance to that force; and hence the opportunity afforded of giving it a direction by pressing with the hands equally on each side of the line, along which it is desired the crack should pass, at the same time making it commence at the beginning of that line, by placing it on the edge of the file.

1122. When all other means of directing a crack are absent, it may frequently be done with advantage merely by the pressure of the nail. If a Florence flask be cracked, the division may be extended by putting the thumb over it

near the end of the crack, by pressing the nail when in contact with the glass, and carrying the thumb forward. The crack will fly before it, extending on this or that side, according to the direction in which the thumb advances, or according as the pressure is on one side or the other. The flask may thus be divided into pieces, much more useful than such as would probably result from crushing or breaking it entirely at random.

1123. Pieces of glass are reduced at the edges in various ways. The corners may be removed from fragments of plate glass by running a coarse file with a light and rasping kind of motion against the edges, in a position slightly inclined to the glass. The reduction takes place, not by mere attrition and wearing away, but by the removal of successive chips of glass, each tooth of the file carrying away a small fragment, perhaps the eighth or tenth of an inch across; in fact of a diameter equal to the whole thickness of the plate. In this way the large pieces are soon brought into a round form, and serve as valves. In the same manner if, in cutting a thick tube, the aperture should not be level all round, the projecting parts may be removed piecemeal, but more care is required than with flat glass, from the tendency of cracks to form at the edge and fly up the tube.

1124. The edges of plate glass may also be removed by a pair of pliers, not by pincing off the superabundance, but by bringing it between the chops of the instrument, holding it lightly there, and then twisting the pliers slightly so as to exert a degree of pressure upon the exterior edge of the glass by one of the sides, whilst the other merely serves as a fulcrum for support to the power. The edge will be found to splinter and crumble away under a force thus applied, and the art of successfully using it is soon learned by practice. This method is not so applicable to the edges of tubes as to straight glass, but it may often be used with crown glass when the file is inapplicable.

1125. Glass may be ground on almost any flat stone with a coarse grain, by means of a little sharp sand and water, or better still, by emery and water. Thus the ends of the tubes (703. 1118), may be ground level on a piece of Yorkshire or

Purbeck stone. The operation is easy in proportion to the smallness and thickness of the tubes. It requires that the glass should be held with a steady hand, and perfectly upright, that the resulting edge may be flat. Larger vessels, as jars, &c. may be ground in a similar way, but are better trusted to the instrument maker.

1126. When a bottle requiring a stopper has been fitted with one from the stopper draw (21, 1119), it may happen that though nearly so, it is not quite true and tight. In such a case the stopper may be made to fit accurately by by being ground with a little sea sand or coarse emery and water, into the mouth of the bottle, during which operation it should be quickly inserted into and removed from its place and turned at the same time. In this manner the glass is in part worn away, and the stopper made tight, but care should be taken that during the grinding the bottle be shifted a little now and then in the hand, that different parts of the neck and the stopper may work against each other at different times, and thus mutually correct the existing inequalities.

SECTION XX.

Cleanliness and Cleansing.

1127. Much as the Chemist may soil his fingers during his experimental occupations, he will soon learn the great importance of cleanliness to the success of his experiments. The regular course of his operations causes many kinds of matter to pass in succession through his hands; and many of the substances which by mixture have exhibited the phenomena they were competent to occasion, and so far answered the purpose of the experiment, then become mere useless dirt. Their dismissal and entire removal when thus circumstanced, become necessary that they may not contaminate other bodies; and is as imperatively required, as was the care previously bestowed to prevent their contamination from extraneous matter.

1128. It is this rapid change in the character and relation of the substances with which the chemist works, that makes a constant attention to cleanliness essentially necessary. The very bodies which at one moment are carefully retained in vessels that have previously been cleansed with the most scrupulous attention, become the next in the situation of so much dirt, from which the vessels must be cleansed as perfectly and carefully, before they can be fit for another experiment, as they were for the reception of the now rejected matter. The results of numerous experiments relative to testing bodies in solution by re-agents, are, in many cases, dependent on the employing of clean vessels. For instance, a portion of water examined in glasses which have been carelessly washed, may occasion a slight precipitate with nitrate of silver or muriate of baryta, and thus seem to contain a sulphate or a muriate, when the cause of the precipitate may be nothing more than portions of salts adhering to the vessels.

1129. In the same manner the purity of an acid or a test is not unfrequently affected by the state of the bottle containing it, or by the dirty condition of glass rods dipped into it, or of the funnels through which it has been poured or filtered, or of the vessels used in its transference; and sometimes it is contaminated by laying the stopper of the bottle containing it in a dirty place. Nor is it only that kind of dirt or impurity which gives an evident tinge to what it adheres to that is to be avoided, but also numerous colourless substances, as salts, solutions, &c.; and in a word, any thing which differs from the principal substance itself, and is at the same time liable to be dissolved or mixed with it.

1130. In consequence of these liabilities, and their interference with experiments, it should be established as a general rule in the laboratory, that no apparatus, nor any vessel, (except such as may be destined to a particular use, and is as convenient when with a little previously adhering matter as if it were clean), be put away in a dirty state. All vessels or instruments when resorted to should be found fit for the nicest experiment to which they are applicable. Glass rods or stirrers should be preserved in a clean place; glasses on a

clean shelf; and stoppers when taken out of bottles, should be laid upon clean glass surfaces. These attentions and regulations will be found always useful, at times essential. They are generally more requisite and influential in minute chemistry, than in large experiments; and in trains of research, than in the processes of the manufacturer.

1131. As a part of the general system of cleanliness, the walls and ceiling of the laboratory should be lime-washed at intervals, dependent on the nature of the operations performed in it, and the state of the walls. The general light of the place will by this means be increased; and the surface thus renewed from time to time, more readily absorbs the fetid odours, animal effluvia, and acid fumes, that are occasionally disengaged during chemical operations. The tables and the filtering stands should be cleared and cleaned once a week or a month, according to the use made of them. The shelves should be periodically dusted, and the bottles upon them wiped. The laboratory drawers should also be cleared and cleaned from time to time, that the stirrers, valves, corks, and other articles in them, may be preserved in a proper state for use. All dirty glasses, and the results of experiments when done with and of no further service, should be put together into one particular place, being either a tray upon the table, or a portion of the table appointed for the purpose; and no substance should be put into this place that is not to be thrown away, nor any glass or apparatus that is not to be cleaned. A little method in these arrangements prevents mistakes and errors; very much facilitates the laboratory operations; and quickly brings every thing into a ready and available condition.

1132. When the japan or paint of the pneumatic trough is either wearing or pealing away, the trough should be emptied of water, dried, and the surface renewed. The water of the troughs, which are preserved full for constant use, should be changed every fortnight or three weeks, or oftener if any experiment has occasioned its contamination more quickly. If alkali, acid, sulphuretted hydrogen, or any extraneous substance likely to exert a chemical action

upon, or mixture with gases that may be standing over the trough, find their way into the water, it should immediately be changed. The loose iron trivets (694) for the water trough, should be varnished before they are brought into use; and also again at any future time when rust appears upon them, or if when put into the water they impart to it a yellow tinge. A coat or two of the common varnish, called Brunswick Black, is quite sufficient to prevent the contact of the water with the metal, as well as oxidation. A better coat, as being more adhesive, is formed upon the iron, by brushing linseed oil over it, when heated just below visible redness: the heat decomposes the oil, and leaves the iron when cold, covered with a fine smooth black varnish, adhering very closely, and effectually preserving the metal from contact with the water.

1133. The sink and its importance have been before briefly noticed (10): it is essential to an active laboratory. It should be supplied with a pail and a pan, or large vessel, which, being constantly full of water, is to serve in turn both for soaking and rincing operations. Several nails should be driven into the wall over the sink, upon which should hang various wires, intended to facilitate the cleansing processes. Six or eight of these should be of copper, about the eighth of an inch in thickness, from twelve to eighteen inches in length, bent into an eye at one end, and having a little tow wrapped round them at the other. The end intended to hold the tow should be roughened, by being struck with an edge, so as to have a few teeth cut in it, or by having a notch or two filed across it; that the tow may not slip off when it is pushed up and down a tube, or through a narrow aperture. The tow should be twisted round the end in such a manner as to hold by these irregularities. Some of these wires should be quite straight, others curved at the extremity, that they may reach parts unattainable by the straight wire, as the inside of a globe or retort, or that part of a bottle which is close to the neck.

1134. A similar set of wires of less thickness should be appointed for the purpose of cleaning sharp angles, narrow cavities, and small apparatus, for which the thicker wires

would be too large. These are best of iron, being stronger when of equal thickness of metal than those of copper. Some of both these kinds of wires should be retained for use when their tow terminations are wetted, others for dry tow, and others without any tow at their extremities, that they may be ready for the removal of hard adhering matter.

1135. Besides these wires, one or two wiping sticks should be provided, for the purpose of drying the inside of long jars, and other apparatus, to which the hand cannot have access. They should be of a tough but light wood, that they may have strength enough to resist considerable force, and yet not endanger the glass by a tap or slight blow. They should be about two feet in length; not round, but angular or flat at the end, that the cloth may the less easily slip off; and if the end be thinned away on one side, so as to be wedge-shaped, it is more effectual in applying the cloth with force to the angular space at the bottoms of jars or bottles.

1136. The necessary supply of dusters, cloths, and tow, should be furnished to the sink, each having its respective place both in the clean and dirty state.

1137. *Cleansing of vessels.—Glasses.* In by far the greatest number of cases glasses are dirtied by moist substances, as precipitates or solutions; it is then advantageous to cleanse them immediately upon throwing out the contents, and before the dirt can dry or harden. Rincing will usually remove the whole of the dirt; or if it adhere it is but slightly, and immediately gives way when touched by a wire with moist tow. If it should resist this application, a similar wire with wet tow, aided by a little of the wood or charcoal ashes, which are always lying at the bottom of some of the furnaces, will generally remove every thing. Sand should not be used for these purposes, as it cuts and roughens the soft flint glass, of which vessels are made in England; and at the same tim ethat it injures their transparency, it renders them improper for several particular experiments of precipitation. When by any of these methods the dirt has been removed, the glass is to be well

rinced in clean water, turned upside down for twelve hours on a side shelf or table to drain, and then wiped. The wiping should be performed with a cloth in each hand, not only because a cloth is more cleanly than the hand, but that if the glass should break the hand may be defended. The cloths should never be in a greasy, resinous, or pitchy state; but so clean that without communicating any thing, they will remove all substances that can be wiped off. Laboratory cloths when clean, should be used, first for wiping glass, then for wiping tables or dirty apparatus, and being once so used, should not be employed for clean glass again until they are washed. Especial care is required in wiping glasses that the inside be thoroughly cleansed in every part, for it is with that part of the vessel that tests and solutions come in contact.

1138. If the glasses be greasy they should not be washed, but in the first place wiped with tow to remove as much as possible of the grease, and then a dry cloth should be used, until the glass appears clean. Its surface should afterwards be washed with a little strong solution of alkali, applied by means of a wire and tow; this removes the thin film of grease remaining after the wiping, and the glass may then be rinced, drained, and wiped, as before directed. A duster should not be used at random for these greasy glasses, lest it should the next moment be applied to a clean vessel and communicate impurities to it; but one should be kept apart and appropriated for these purposes.

1139. If the glass be soiled by resin, turpentine, resinous varnishes, or similar bodies, it should in the first place be washed with a little strong solution of potash, those places where the resin adheres being rubbed by means of a wire and tow, until the alkali has softened the whole, and rendered it soluble in or moveable by water. It is then to be washed, rinced, and dried, as before. Or in place of alkali a little strong sulphuric acid may be used, and is sometimes even more advantageous: being poured into the glass or vessel, the latter should be inclined in various directions, so as to bring the acid into contact with all parts of the foul

surface : it will become very black, and after a few minutes the resin, &c. will wash off, and the glass may be cleaned in the ordinary way.

1140. Pitch and tar, when they adhere to glass, may in part be scraped off. A little strong sulphuric acid applied as above, will loosen and separate the remainder. Occasionally a little oil may be used; being rubbed on the soiled parts, it mixes with and softens these adhesive substances, so that they may be wiped off by tow, and then the glass is to be cleaned from the oil as before described.

1141. *Tubes* are cleansed generally in the same manner as glasses. Wires with tow will be found very convenient in displacing solid and adhering dirt from their insides. They should be well rinced twice or thrice, the tube being each time half filled with water, closed by the finger, and then well shaken. They may be turned upside down, and left inclining against each other in a corner to drain; after some hours they may either be wiped dry within by a cloth and stick, or what is perhaps more convenient, left with their mouths open to the air until the interior has become dry by evaporation, and then be wiped to remove any dust which may have entered. Tow is not a good substance for the removal of water from glass surfaces, and for tubes it is better to use a long slip of cloth, two or three inches wide. Having introduced a few inches in length of this slip into the tube, the wire or stick is to be inserted, and the cloth thrust up to the extremity, so as to form an accumulation there; the rest of the tube will then be occupied by the wire or stick and a part of the slip of cloth. It will thus be found easy by a very little management, and a rotatory and longitudinal motion of the tube, to wipe every part of the inside clean and dry in an expeditious and perfect manner.

1142. Long tubes open at both ends, which have become dusty, are easily wiped by pushing a loose pellet of cloth or tow, up and down them by a long stick : or a piece of string having a loop at the end into which some tow has been introduced, may be used to draw the tow through

the tube, and thus to wipe it clean. This is a very useful mode of cleaning out bent tubes open at both ends; the end of the string may be readily passed through them, by attaching a little piece of wire to it, as a weight. The piece of string must be longer than the tube to be wiped, and the portions of tow used at first, should be such as will easily pass the angles; they may be increased in size by the addition of more tow if necessary.

1143. *Air jars* require no further directions for their cleansing than is given with respect to glasses (1137). When of such narrow dimensions as not to admit the hand, the insides must be wiped in the same manner as has just been described for tubes (1142). Generally in these cases abundance of cloth should be allowed to enter the vessel before the stick, that the mass thrust up to the extremity may be large, and bear uniformly against the glass over a considerable surface.

1144. *Evaporating basins* are very easily washed. The soaking tub (1133) is useful for the softening and removing of most substances, which are likely to accumulate in them. Grease, resin, and similar bodies, may be removed by tow and damp ashes, or soft sand, or otherwise by a little strong sulphuric acid (1139). When all dirt is removed, the basins should be rinced, turned upside down to drain, and then wiped. It is advisable to clean the stock of evaporating basins belonging to the laboratory once every two or three months, with a little strong solution of alkali, both inside and outside, rejecting at such times those which have become useless.

1145. *Flasks* are not so easily cleansed as the vessels already mentioned, from the greater difficulty of access to the interior, but the bent wires referred to (1133) will overcome many obstacles. Florence flasks are frequently oily when obtained from the Italian or wine warehouses. They may be readily cleansed by putting a little strong nitric acid into each, and heating it over a lamp or sand-bath, after which every thing will wash out with water. Strong sulphuric acid may be used for the same purpose, being brought into

contact with every part of the glass, without requiring the application of heat. Either acid is better than solution of alkali. If metallic matter adhere to the inside, a little nitro-muriatic acid introduced, and heated on the place, seldom fails of separating and removing the substance. When the impurity is loose or separable by water, the flasks should be well rinced and inverted on a filtering-stand (500) or retort shelf (12), left to drain for half an hour, then well rinced out with distilled water, and again placed to drain.

1146. When the impurity within flasks, globes, or similar vessels, adheres mechanically, and is not soluble in water, it may frequently be effectually loosened and removed, by introducing some coarse brown paper torn into fragments about an inch square, with water enough to half fill the vessel, and agitating the whole well. The pieces of paper will rub or break off dirt that has resisted the action of water alone, and most sediments or deposits may be thus removed. The addition of a few wood-ashes increases the effect.

1147. Upon wiping the exterior of globular vessels, those which are thin, as Florence flasks, require care, lest they be crushed to pieces between the hands. It may be necessary to dry the interior of some of them, but others will not need it. When they are to be dried, they may be left on the retort shelf in the cupboard (11), or on the filtering-stand, with the mouth downwards, until the water within has evaporated; but as this will require some days or weeks, a more rapid method may occasionally be adopted. This is to warm the flask, so as to convert the water within into vapour, and then by introducing one end of a piece of glass tube, whilst the other is held by the hand against the nozzle of a pair of bellows, to blow out the moist air, and replace it by that which is dry. If the first warming be insufficient to convert all the water into vapour, the flask may be heated a second time; or if the flask be thick, and retain its temperature for some minutes, merely persisting in blowing air through, will gradually evaporate and remove the water from within.

1148. Instead of using the bellows, the mouth will answer every purpose; for if, when the flask is hot, the external end of the tube be put between the lips, it will be easy to throw air in from the lungs, which, though it contain moisture, is much drier than that in the flask. When the appearance of liquid within no longer exists, the moist air last introduced from the lungs is easily removed by drawing air out of the flask, through the tube, into the mouth; other portions then enter to replace it, and the vessel is left filled with an atmosphere of ordinary dryness.

1149. Six or eight Florence and other flasks should be kept ready for use on the filtering-stand; the mouths of the rest should be covered up with paper, to keep the dust out, and be put aside until wanted. In thus guarding the mouth of a flask, retort, tube, or similarly formed apparatus, it is merely necessary to roll a slip of paper round the end, so that it shall project sufficiently beyond the edge, and then to fold or double this projecting part down, in such a manner as to close the mouth, and at the same time prevent the slip from unrolling.

1150. *Retorts* may be cleaned according to the directions just given for flasks (1145) but if tubulated they require more care, because of the increased tendency to crack and fly at the junctions. When rinced they should be carefully placed, so that the water which drains may run quite out of the vessel. When warmed for drying, attention must again be paid to the tubular, that it be not suddenly heated or cooled. It is necessary too that drops of water be not allowed to run from a cool upon a hot part, as they might occasion fracture.

1151. *Bottles.* The bottles of the laboratory require constant attention and cleansing. They are liable to accidents and uses of all kinds, and are soiled by every species of matter in turn. Now and then the stoppers of bottles become fixed (701), in which case means of loosening them, successively increasing in power (but also unfortunately in danger), must be resorted to, until the stopper is removed, or giving way, is destroyed. One of the simplest methods when the unaided hands fail, is to tap the stopper alternately

on opposite sides, with a piece of wood, as the handle of a bradawl or a chissel, the other part of the tool being held loosely in one hand, whilst the bottle is retained lightly at its lower part in the other. The light alternate concussions on the opposite sides of the stopper, are often sufficient to destroy the adhesion between it and the bottle. This is indicated by the sound; for so long as the adhesion remains perfect, the noise made by the tap is as if the bottle and stopper were but one piece of matter; but the moment the stopper is loosened, however slightly, the character of the sound changes, becoming somewhat flatter and heavier, and then a few more taps complete the operation, and the stopper gives way to the hand. Before thus endeavouring to loosen the stopper, the thickness of the neck by which its upper and lower parts are connected should be observed: if that be very small, the force must be carefully applied; if strong, a little more liberty may be taken with it. If the stopper does not soon give way, this means alone will not be sufficient for its removal.

1152. Another method of removing a bottle-stopper is to insert its head into a chink, and then endeavouring to turn the bottle with the hands. This kind of force is similar to that exerted by the hand upon the stopper, but is more powerful; and if the neck of the stopper break, the hand is out of the way of danger. An upright board, such an one as supports the ends of a set of shelves, should be selected in a convenient situation in the laboratory, and a vertical slit cut through it about a foot in length, an inch in width above, but gradually decreasing in size so as to be about the third of an inch at the bottom. The top of the hole may be about the height of the breast. This aperture will in one part or another receive and retain the head of almost any stopper, and prevent it from turning with the bottle. Then by wrapping a cloth about the bottle and grasping it in both hands, the attempt to turn it round so as to move the stopper may be made, with any degree of force which it may be thought safe to exert. If the force be such as to occasion fracture, it will generally occur at the neck of the stopper, twisting the head from the plug.

It is only when the bottle is wide-mouthed, the stopper consequently having great surface of adhesion, and the neck of the stopper is also very thick, that there is any risk of the bottle breaking in the hand. But the force employed should never be carried so far as to cause fracture any where, but the attempt, if unavailing with the application of a moderate degeee, should be desisted.

1153. Another and a very successful method of removing a stopper is, to turn the bottle round, when held horizontally over the small flame (176) of a spirit-lamp or candle applied to the neck. The heat should be applied only to the part round the plug of the stopper, and in a few moments when that has become warm the stopper should be tapped with the piece of wood as before (1151). The application of the heat expands the neck of the bottle, and actually rendering it larger, permits the removal of the stopper to be effected by a force previously quite insufficient. As soon as the stopper moves by tapping it is to be taken out, and must not be replaced until the glass is cold. The application of heat in this manner must be short, and the operation altogether to be successful must be a quick one; for it is obvious that the effect depends upon the *difference* of temperature between the stopper and the neck, and if the former become heated as well as the latter no good effect can be expected, and the bottle is endangered by the application of heat to no good purpose.

If the contents of the bottle are fluid, it should be held so inclined that they may not become heated; if they are volatile, this method should be tried very carefully, lest the vapour formed within should burst the bottle. The application of heat in this way is seldom successful unless immediately so; and there is always some risk of cracking the neck of the bottle.

1154. It is often advantageous to put a little olive oil round the edge of the stopper at its insertion, allowing it to soak in for a day or two. If this be done before the heat be applied, it frequently penetrates with increased facility; by oil, heat, and tapping, very obstinate stoppers may be removed. When a stopper has been fixed by a crystalli-

zation from solution, water will sometimes set it free, and it is more advantageous in such cases than oil, because it dissolves the cement. When the cementing matter is a metallic oxide or a sub-salt, a little muriatic acid may be useful if there be no objection to its application, arising from the nature of the substance within.

1155. The preceding are all quick operations, and one or other of them will generally loosen a tight stopper, and save the bottle with its stopper and the contents. If they fail, the following method may be tried, which is particularly successful in cases where stoppers are forced inwards by atmospheric pressure, in consequence of internal absorption; the preceding methods often make such cases worse. A piece of strong twine is to be doubled, and a knot tied so as to form a loop of about four inches in length. The knot is to be brought close to the neck of the stopper, the two ends passed round, so as to meet on the opposite side, and tied there tightly, so as to fasten the string securely round the neck. The two strings are then to be tied together, so as to form a loop on that side the stopper equal in length to the first loop, or about four inches. These loops now serve as handles by which to pull at the stopper, and being on opposite sides, permit the force to be applied so as to draw the stopper directly forward out of the neck of the bottle. For this purpose they are to be passed over a fixed bar (if horizontal so much the more convenient), and are to be placed about $2\frac{1}{2}$ or 3 inches apart on the bar, that by directing the pull on the bottle a little on one side or the other, the strain upon the stopper may be equal or nearly so on the two sides. A cloth is now to be wrapped about the bottle, the hand being applied round the neck, and the bottle is to be pulled steadily. During the endeavour to separate it from the stopper, the latter must be struck gently on each side with the piece of wood as before directed (1151). The force with which the bottle is pulled must be increased until the stopper either gives way, or the power has been increased unavailingly to such a degree as to excite fear that the bottle itself may break in the effort. But generally, long before this fear need

be entertained, the stopper will leave its place, and the operation will consequently have succeeded. It is necessary to have a care that as the stopper leaves the neck and falls down suspended only by the string, it shall not swing against any thing so hard as to occasion its fracture; this is easily done by putting a cloth or duster to receive it.

1156. When stoppers become fixed in the necks of jars (701), they are generally removed with great facility by hitting them from beneath with the end of a stick, which tends directly to force them out of their places; few stoppers will resist this advantageous application of mechanical power. The stick should be a solid and rather heavy one, but not so hard as to endanger the glass. The end of the handle of a hammer answers very well for the purpose, the head of the hammer adding to the momentum and steadiness of the blow.

1157. If the stopper will not give way to any of these methods, then all that can be done is to remove it piecemeal. Large stoppers are often made hollow to diminish their weight; the heads of these may be broken off, when their plugs are easily penetrated by a pointed file, and thus may be separated without loss of the bottle. But if the stoppers are solid, it is only by grinding that they can be removed; this is the work of the glass-cutter, and the value of the bottle is seldom equal to the expense and the risk. The bottles of which the stoppers have been successfully broken out, must be refitted with others from the stopper drawer (21. 1119. 1126).

1158. All the agents and methods for cleaning glass already referred to are required occasionally for the cleansing of bottles. The stoppers should be cleaned at the same time, and when acids or alkalies are applied to the bottles, a little should be allowed to flow about the stoppers when in their places, and the latter then worked in the neck for the purpose of rubbing off the impurity and bringing it more freely into contact with the dissolving or detaching agent. When all foulness is dissolved or washed away, the bottles should be drained, rinced in distilled water, drained again, and then wiped; and if necessary dried within, by warming them and blowing air through them (1147). This must be

done with more caution than is necessary for flasks, because of the greater irregularity in thickness and form of these vessels. Finally, the stoppers are to be replaced, a little tallow or yellow wax being put round them in the manner already described (400. 701).

1159. If the laboratory be in daily use, these washings and cleansings of glass should be performed every evening, the apparatus being left to drain during the night, and then wiped on the following morning. Such a practice will be found at least very useful and convenient, and the vessels will be ready for service at all ordinary hours of experiment. The open apparatus, such as glasses, jars, &c. should be put by in their respective places, with their mouths downwards, to exclude dust.

1160. When oxidized and foul copper, such as wires, plates, &c. are rubbed clean by sand-paper, a subtle cupreous dust is diffused through the air, which is exceedingly unpleasant in its effects upon the mouth and nostrils. It is better in such cases to use a little water with the sand-paper; the copper is more readily cleaned, and all unpleasant effects are prevented. Foul copper-plates may be cleaned also by putting them into the furnace and heating them to redness for five minutes, with access of air, so as to allow the formation of a coat of oxide upon them, and then plunging them in water. The oxide scales off, or may easily be separated by bending the plate, and leaves the latter clean and metallic.

1161. When a platina crucible has become tarnished and dirty by use, in consequence of the adhesion of substances, it is perhaps best cleaned by making it red hot in a charcoal fire, after it has been covered with a paste, made by mixing pulverized glass of borax or fused borax, with water. The borax fuses over the surface of the platina, and dissolves most earthy or metallic impurities, so that when, after ignition for a quarter of an hour, the crucible is thrown into water and left there, the borax dissolves and removes all impurity with it. It is assumed that the crucible has been used fairly, and is soiled only by a little adhering oxide of iron or other substance. If metal has by any means come in

contact with the platina, the ignition will only do harm by making the alloy of the metal and the platina more complete. In such case, if the injury, i. e. the contact of the extraneous metal with the platina be slight, it may be well to dissolve the former by a little nitric acid and heat; but if heat has been long applied, and the alloy be formed to a considerable extent, nothing remains but to use the crucible for the few purposes to which it may yet be applicable until it becomes unserviceable.

1162. Porcelain and other mortars should be kept in good and clean condition; dry pulverizations frequently fill the minute irregularities of the inner surfaces with the substance pulverized, so that even after careful washing, portions still remain behind. This may readily be observed with coloured bodies, as oxide of iron, Prussian blue, vegetable substances, &c. A little sand and water put into the mortar and rubbed with the pestle over all the contaminated parts, cleans them and the pestle itself so far, that the affusion of water is sufficient to wash off all impurities. In some cases, sulphuric or nitric acid, or solution of alkali, must be used; their action is always facilitated by rubbing a little sharp sand in the mortar with the pestle.

1163. There is one apparatus which has not as yet been mentioned in this chapter, but which requires frequent attention relative to its state of cleanliness. This is the mercurial trough. It should be covered when out of use, that dirt and dust may not get into it. If these be allowed access they do not merely collect upon the surface of the metal, but by the mechanical motions to which the mass is subjected, are often carried beneath, and are lodged and retained between the mercury and the trough even at the very bottom of the bath. For this reason when a trough has been exposed to dirt and dust, it is not sufficient to clean only the surface with a card; but the mercury should be poured out, the trough well wiped and cleaned in every part, and the metal restored, after it also has been cleaned and purified.

1164. The mercury may require to be cleansed both from mechanical and chemical impurities; and indeed the ordi-

nary operations of the pneumatic trough tend to confer both these contaminations. The processes to be adopted for the removal of these extraneous matters must therefore be varied, and several very different in principle have been devised.

1165. Adhering dirt and dust, as well as the thin films of oxide and other impurities which attach to mercury, may be removed in several ways. A very common method is to fold a piece of paper into a cone, so as to make it nearly tight at the apex, and to pass the mercury through it as through a funnel. The aperture at the bottom may be made larger or smaller by a little management of the paper: when the inward fold is pulled upwards, it increases the aperture below, whilst pulling the outer fold upwards a little, tends to close it. The aperture may also be opened or closed more or less by applying the finger to it. The mercury as it runs through should be received in a glass or other proper vessel, and the last portions reserved in the cone; they will be found to abound with scum and other impurities, a portion of which might pass out with the metal. It is better to put these latter portions by themselves, and when they have accumulated, to purify them altogether. This method of cleansing mercury is a ready and sufficient one in numerous cases where it is only the adhering dirt that is to be removed.

1166. Mr. Millington recommends that the mercury should be cleansed from mechanical dirt by being filtered through the pores of a piece of hazel wood by means of atmospheric pressure. Others squeeze it through a piece of shamois leather. But when cleaned by any of these methods, a film still generally adheres to its surface; and the metal when agitated has a scum formed upon it, especially when chemically foul. Much assistance in removing this exterior scum and dirt is gained by pulverizing some loaf sugar, putting it into a bottle with the mercury to be cleansed, and agitating them well together. The sugar should be damped, which may be done by breathing into the bottle two or three times; by agitation it then adheres to the dirt with the mercury, and the latter being removed by passing it through a paper funnel, is obtained in a state of great comparative cleanliness.

1167. The *chemical impurities* of mercury consist of certain metals, such as lead, tin, zinc, &c. These interfere chemically when the metal is to be used in forming combinations; and from the rapidity with which they oxidate and produce films on the surface, interfere mechanically in its uses in the bath, in certain electro-magnetic experiments, and in the construction of thermometers and barometers. Mercury which is chemically impure will soon acquire adhesive films on its surface, even when cleansed of mechanical impurities, and with a rapidity dependent on the agitation of the metal or extension of its surface.

1168. The first method of purifying mercury from these metals is by distillation. The operation should be performed in an iron retort, a portion of clean iron and copper filings having been introduced with the mercury, which should be condensed and received in clean water. Although this is an excellent process generally, yet it is by no means unobjectionable, for both zinc and arsenic will pass over, and these metals are not uncommonly introduced in experiments at the mercurial trough.

1169. A very useful method of cleaning considerable quantities of trough mercury is to put from half an inch to an inch in depth into a large earthenware pan (the pneumatic trough before referred to (693) answers very well for this purpose), and to pour over it sulphuric acid diluted with twice its weight of water. The surface of contact, and consequently of depuration, is thus rendered very large. The substances should be left together for a week or two at common temperatures, being frequently agitated. At the end of that time the metal and the acid are to be separated, the latter preserved for a similar operation at some future period, and the former washed, dried, and cleansed mechanically, as already described. The sulphuric acid acts more readily if a little sulphate of mercury be added to it; the residue of a process for the preparation of sulphurous acid from sulphuric acid and mercury may be used for the purpose without farther preparation. This residue is not an uncommon one in the laboratory (415), and being put altogether into the

pan, the mercury, the sulphuric acid, and the sulphate of mercury, will each be economically and usefully disposed of.

1170. An acid solution of nitrate of mercury left upon the trough metal in a manner similar to that just described, will also cleanse it to a great extent from other metals. The solution need not be very strong or in large quantity; a week or two at common temperature is sufficient for the purpose. The solution when poured off should be reserved apart from other nitrate of mercury, for this particular use; the impurities which it has received from the metal, and for which it has rendered up an equivalent portion of mercury, rendering it unfit for any other than very ordinary purposes.

1171. These chemical cleansings of the trough-mercury are intended to destroy the disposition which exists in impure mercury to form films upon its surface. The films are produced by the oxidation of a very minute portion of the impure metal; they do not consist of oxide alone, but of metallic matter adhering to it, which being enveloped by the film of oxide, is prevented from coalescing with the fluid metal beneath, and is equally injurious in its effect as if it were also extraneous matter. Whenever the surface of filmy mercury is extended or removed, the film from the neighbouring parts rapidly expands over the newly exposed portion, just as a drop of oil extends and expands itself over the surface of water. This may be observed and understood by moving a card over the surface of such mercury from one side to the other: the film will be collected on the one side of the card, and the recent surface on the other will become covered by an extension of that which is on the metal immediately in its neighbourhood. If the operation be repeated, still the renewed surface will be re-covered, and thus a large quantity of film may be collected, which if examined appears to consist for the greater part of metallic mercury. And though after many operations of this kind the surface of the metal will be much cleaner than at first, yet exposure to the air for a while, especially if aided by agitation, will soon bring the surface into its first dirty condition, and this will continue so long as the mercury contains metallic impurities.

1172. The manner in which these films interfere with experiments made over the mercurial trough, is principally by preventing contact between the metal and the jars or other vessels used. If a jar be dipped into the mercury, it does not break through the film and come into contact with the pure metal beneath, but the film expands between the glass and the metal, and from its solid and rigid nature, entirely prevents that close contact which would occur between pure mercury and the glass. Or if the jar be laid with its side upon the mercury, every particle of the thick and wrinkled film that is included between the glass and the metal, will retain its place upon the sides of the jar, whatever may be the depth or position in which it may afterwards be placed under the surface of the mercury. The consequence, when a jar thus circumstanced contains gas, of which a portion is required to be transfered into another vessel is that, as soon as the jar is so inclined as to cause the gas to approach its edge, it escapes (741); for instead of passing out in bubbles, and ascending through the metal into the vessel above, it tends to pass up the side of the jar, between the glass and the film, into the air. This is the consequence of want of continuity, or at least of close contact there; and though the gravity of the mercury around the gas passing from the edge of a jar, is a force generally sufficient to enable it to overcome and break through the cohesion of mercury when clean, and to occasion it to rise in distinct bubbles through the metal, it is not sufficient to do so when the cohesion of the film is added to that of the metal; and when from the interference of the film between the metal and the glass, a passage upwards, although in a somewhat inclined position, is already opened for it.

1173. In the same manner when the beak of a retort is dipped into such mercury for the purpose of delivering the gas, instead of passing out in bubbles it will frequently creep round the edge of the glass and ascend between the neck and the mercury into the air (742); and this takes place with greater facility as the mercury is more impure and filmy; as the inclination of the beak approaches to the perpendicular; and as the gas evolved, tends by its action on

the metal or otherwise, to favour the formation of films. Such gases as euchlorine, muriatic acid, ammonia, &c. are more apt to do this than oxygen, hydrogen, nitrogen, &c.

1174. Small quantities of mercury, as for instance a pound or two, may be purified upon particular occasions by very ready and simple processes. Dr. Priestley's † method is a most excellent one, and highly worthy of attention. So much foul mercury is to be put into a ten or twelve ounce stoppered bottle as will occupy about a fourth part of its capacity, the stopper to be put in, the bottle inverted, and being held in both hands is to be shaken violently, the hand that supports it being generally struck against the thigh. After twenty or thirty strokes the stopper is to be taken out, and the air in the phial changed for fresh air by blowing into it with a pair of bellows. The mercury will soon become black, and a quantity of the upper part will appear as if it were coagulated, so as to be easily separable from the rest; the phial is then to be inverted, and the mouth being covered with the finger, all the metal that will flow easily is to be poured out, and the black coagulated part put into a cup by itself; by pressure with the finger this may easily be separated into running mercury and black powder, the former, with the rest of the metal, is then to be returned to the bottle and agitated as before. This process is to be repeated till no more black matter separates, and it is not a little remarkable that the operator will be at no loss to know when that is the case, because the whole of the mercury becomes pure at once; and Dr. Priestly observes, that "whereas, while the lead was in the mercury, it felt, as I may say, like soft clay, the moment the lead is separated from it it begins to rattle as it is shaken, so that any person in the room may perceive when it has been agitated enough." Mercury purposely rendered impure by lead and tin was found to be perfectly purified by this process.

1175. Another method is to put the mercury to be cleaned into a bottle, to add a little nitrate of mercury or a small

† Experiments and Observations on Air, vol. iv. Section xvi.; or abridged edition, iii. 439.

quantity of diluted nitric acid, to agitate well for a minute or two, then to wash off the soluble parts with any portion of yellow powder formed, and to dry the mercury with a cloth. If any difficulty should occur from the separation of the mercury into an infinity of globules, which may proceed so far at last as, with the intervening water, to give the whole a soft solid appearance, it is easily overcome by drying the mercury after it is well washed, in a Wedgwood basin by heat. As the water evaporates, the globules of mercury will run together, and the metal will be obtained in its clean and pure state.

1176. After any of these processes, the adhering dust should be removed by passing the metal through a paper cone or funnel (1165).

1177. The tests of the purity and cleanliness of mercury are, the absence of all film or powder when a portion is shaken quickly for a moment in a clean tube or bottle; the freedom of its motions upon the surface when agitated; the extreme mobility of its globules when a little is poured into a clean dish and broken into small parts; the perfect rotundity of form at the receding edge when a portion is made to flow from side to side of a glass dish or other clean vessel; the largeness of the depression which exists, when it is put into a dry bottle, between the sides of the glass and the metal at the surface of the mercury; and the ready pointing of a small magnetic sewing needle when laid upon its surface out of the magnetic meridian.

1178. When mercury has been purified and cleansed for very particular experiments, as those relating to the barometer and thermometer, extreme care is required that its surface be not soiled by any portion of dirt from the hands or the vessels used. The smallest quantity of greasy matter, or of deliquescent, or animal, or vegetable substances soluble in water, is enough to render it improper for these uses: it is rapidly diffused by motion over the whole surface of the metal, and even a touch with the finger is sufficient to communicate so much impurity as to render the mercury inapplicable in the construction of accurate instruments.

1179. A glass should always be appointed and kept in one

particular place to receive any residual portions of mercury that may be left in an impure state after experiments, or gathered from the table in a dirty condition. They are thus saved and accumulated, and when in considerable quantity may be freed from mechanical impurity by washing (324), and then be purified by any one of the methods described, which may be most applicable (1167). In this manner a continual saving of metal is effected to a great extent; the quantity thus returned to the trough in an active laboratory in the course of a year being very considerable.

SECTION XXI.

General Rules for young Experimenters.

1180. Besides the numerous directions which occur throughout the preceding pages there are certain general precepts and rules, the observance of which will be found of great service not only to those who are commencing the practice of experimental enquiries in chemistry, but likewise to such as, having made some progress, have indulged themselves in irregular habits. They all relate to *method*, that great source of facility and readiness which is equally influential in the performance of the most common and the most difficult processes. Such as are given in this section have been proved by long trial: it is not supposed that they include all that are advantageous, but they are all that suggest themselves to the mind of the author as worthy to be classed together for their general usefulness. Those who may add to them will deserve the thanks of the practical chemist.

1181. A particular and convenient part of the laboratory tables should be appointed for all general operations of experiment. It should be considered as a place intended for working only, and should not be encumbered by things carelessly laid upon it: it should be understood that every article placed there by the experimenter is sacred for the time; that no apparently dirty glass or useless bottle is to be removed, nor any arrangement upon it disturbed by others

who may be in the laboratory, but that all is to be left until the experimenter himself has disposed of them or given special directions to that purport. It is desirable in a long course of experiments that this place should be cleared as much as possible every evening, that it may be ready the next day for further progress, but unless this be done by the experimenter, or under his particular directions, it should be left untouched.

1182. By the side of this portion of the table should be another, appointed to receive apparatus, bottles, and other articles that are done with. The putting of a thing here should be considered as a direction that it may be cleansed and restored to its proper place. The experimenter will do well to disembarrass his part of the table during his pursuits by moving his dirty glasses, waste precipitates and mixtures, and every thing for which he has no further present use, to this place, that they may be taken away. It is convenient that a wooden tray should remain on the spot, which, when filled with dismissed apparatus, may be at once removed towards the sink and replaced by another.

1183. The laboratory note book, intended to receive the account of the results of experiments, should always be at hand, as should also pen and ink. All the results worthy of record should be entered at the time the experiments are made, whilst the things themselves are under the eye, and can be re-examined if doubt or difficulty arise. The practice of delaying to note until the end of a train of experiments or to the conclusion of the day, is a bad one, as it then becomes difficult accurately to remember the succession of events. There is a probability also that some important point which may suggest itself during the writing, cannot then be ascertained by reference to experiment, because of its occurrence to the mind at too late a period.

1184. The account of the days' experiments should always be prefaced by noting down in the book the day, month, and year; and if the experiments relate to gaseous manipulation, the height of the barometer, and the temperature of the laboratory.

1185. On commencing the examination of a substance of

unknown nature, the experimenter should first proceed to the most general and instructive experiments, and then to those which are more particular. He should therefore apply heat to the substance contained in a tube, and remark whether it fuse or volatilize; he should then heat it in the air upon platina foil, observing whether it will burn or not, whether it will evolve fumes, &c. Afterwards it should be heated in water in a tube, and observed whether it be soluble; and then trials should be made to ascertain if it be sapid, if it be soluble in alcohol, &c. These general examinations will soon indicate to what class of bodies the substance belongs, and will point out the particular train of investigation it may require; after which the substance may be dissolved by acids or alkalies, or any other proper solvent, and its properties more minutely ascertained.

1186. When a substance has been brought into solution, and its relation to various tests and re-agents is to be considered, it will be proper to proceed methodically in examining the different substances eliminated by their action, and not to wander from one to another. The examination of the first product or educt should be completed before proceeding to that of a second, unless indeed it be expected that a particular trial of one will throw light upon the nature of another. Generally speaking it is best to pursue the precipitates, reserving the remaining solution until these are examined. Thus if an ore be dissolved in an acid, and the solution be precipitated by potassa, the precipitate should in this method be examined before the remaining solution. If this precipitate require solution in an acid, and precipitation by peculiar tests, the first precipitate it affords should be examined and decided upon, and then the solution containing the remainder resumed, and its nature made out. This done, and consequently the whole of the original precipitate dismissed, the solution which remained when it was thrown down by the potassa is to be resumed, and treated with other agents. Perhaps carbonate of ammonia may be applied, and cause a second precipitate from it, which is as before to be examined previously to the solution yielding it.

1187. On other occasions, the solutions may be investigated before the precipitates. This plan indeed may be followed generally, and possesses the advantage of supplying the experimenter with occupation in the solution whilst his precipitates are washing. The rule intended to be impressed is, that the one or the other of these plans should be adopted as a constant practice; a deviation from which is to be resorted to only when it is considered as offering peculiar advantages.

1188. A plan of this kind renders the notes of the experiments also more methodical. The different solutions and precipitates may be referred to by letters, as is usual in describing analytical process. Thus in the instance quoted, the original solution may be called *a*; the precipitate by potassa, *b*; the remaining solution, *c*; the solution of the precipitate, *d*; the precipitate from it, *e*; and the solution with the rest of the precipitate *b*, *f*. The solution *c* being then resumed, the precipitate by carbonate of ammonia, will be *g*, and the solution remaining, *h*.

1189. When the substance to be examined is small in quantity and rare, those experiments must be first made that will not prevent the performance of others. The action of heat, of water, and of alcohol, upon a substance may be observed, and still leave it in a proper state for other experiments, as those of solution and precipitation. The same portion of water which has been tested for sulphuric acid by nitrate of baryta, may after filtration be tested for muriatic acid, by nitrate of silver; whereas if muriate of baryta had been used in the first place, the second trial would have been impossible.

1190. New, important, and uncertain or unexpected results, are to be repeated once or twice, that no doubt may exist at a future period, as to the accuracy of the notes which have been made at the time of observation.

1191. Upon making a particular experiment, as of heating a substance in some peculiar gas, or the decomposition of a body by voltaic electricity, all the articles that are likely to be wanted should be previously prepared and close at hand, that no hesitation may occur in the performance of

the experiment, or the attention be called off from observing the results, by the necessity of supplying some important omission.

1192. When a long series of experiments with the spirit-lamp is in progress, a candle or lamp continually burning should be at hand.

1193. On examining a mineral water by precipitants, the glasses used should be placed in a row, each before the precipitant which has been added to the water it contains: and they should remain for half-an-hour, that any ulterior indication of the test may not be overlooked, and without risk of mistaking one glass for another.

1194. Every substance or glass that is entirely done with, should be dismissed, and placed at once on the tray of dirty articles (1182).

1195. Besides the working place (1181) another unconnected with the busy part of the laboratory, should be appointed, from which nothing is to be moved without the experimenter's direction. There are many occasions on which experiments or solutions are to be placed aside for a week or two, to be again resumed. These should be labelled, and put into a place which, from previous appointment, is considered as containing nothing that may be disturbed. In this way the experimenter will often avoid the disagreeable circumstance, of finding that what he intended to reserve for future examination, has been dismissed to the sink or the dust-hole. A third place of this kind may be appointed in a cupboard, out of the way, for the reception of experiments that require weeks or months for their performance, or for things that cannot be resumed before long periods have elapsed.

1196. All products, educts, precipitates, or solutions, that are set aside for some time, should be labelled, and referred to by their names or marks in the note-book. Thus the precipitates and solutions before spoken of (1188) should have labels, *a*, *b*, *c*, &c. on the glasses or bottles containing them. When the products are new and important this should be done immediately, that no possibility of mistake from delay may be allowed to occur. The use of gummed or

pasted paper (1029. 1231) removes all trouble from this operation.

1197. Finally, the general rules for cleanliness and order so often inculcated, are to be attended to. This Section cannot be better closed than by the very excellent observations of Macquer on this subject He says, " A persuasion must exist that arrangement, order, and cleanliness, are essentially necessary in a chemical laboratory. Every vessel and utensil ought to be well cleansed as often as it is used, and put again into its place : labels ought to be attached to all the substances, mixtures, and products of operations which are preserved in bottles or otherwise ; these should be examined and cleansed from time to time, and the lables renewed when required. These cares, although they seem to be trifling, are notwithstanding the most fatiguing and tedious, but the most important and often the least observed. When a person is keenly engaged, experiments succeed each other quickly ; some seem nearly to decide the matter, and others suggest new ideas ; he cannot but proceed to them immediately, and he is led from one to another ; he thinks he shall easily know again the products of his first experiments, and therefore he does not take time to put them in order ; he prosecutes with eagerness the experiments which he has last thought of, and in the mean time the vessels employed, the glasses and bottles filled, so accumulate that he cannot any longer distinguish them ; or at least he is uncertain concerning many of his former products. This evil is increased, if a new series of operations succeed, and occupy all the laboratory ; or if he be obliged to quit the place for some time, every thing then goes into confusion. Hence it frequently happens that he loses the fruits of much labour, and that he must throw away almost all the products of his experiments.

" The only method of avoiding these inconveniences is to employ the cares and attentions above mentioned. It is indeed unpleasant and very difficult continually to stop in the midst of the most interesting researches, and to employ much valuable time in cleaning and arranging vessels and attaching labels. These employments are capable of cooling and retarding the progress of genius, and are tedious and disgust-

ing: but they are nevertheless necessary. Those persons whose fortunes enable them to have an assistant operator, on whose accuracy and intelligence they can depend, avoid many of these disagreeable circumstances; but they ought nevertheless to attend to the execution of these things. We cannot depend too much on ourselves in these matters however minute, on account of their consequences. This becomes even indispensable when the experiments are to be kept secret, at least for a time, which is very common and often necessary in chemistry.

"When new researches and enquiries are made, the mixtures, results, and products of all the operations ought to be kept a long time well ticketed and noted. It frequently happens that at the end of some time these things present very singular phenomena, which would never have been suspected. There are many beautiful discoveries in chemistry which were made in this manner, and certainly a much greater number which have been lost because the products have been thrown away too hastily, or because they could not be recognised after the changes which happened to them." *

SECTION XXII.

Uses of Equivalents. Wollaston's Scale.

1198. There is a small instrument, the invention of Dr. Wollaston, which though not directly concerned in the actual performance of chemical operation, is of great and constant use in the laboratory, either in supplying the information requisite previous to an experiment, or afterwards in interpreting and extending its results: it would therefore be improper to pass it by unnoticed in a work the very object of which is to point out to the unexperienced those practices and contrivances which facilitate the acquisition of experimental evidence. The instrument is called a

* Dictionnaire de Chimie par Macquer. ii. 486.

Synoptic scale of Chemical Equivalents, or more usually *Wollaston's Scale*. The paper, by its author, describing the nature of the scale and the manner of ascertaining the numbers appropriated to the different substances upon it, is inserted in the Philosophical Transactions for 1814. The scale itself, as purchased of the instrument-maker, consists of a moveable slider with a series of numbers upon it, from 10 to 320, on each side of which and on the fixed part of the scale, are set down the names of various chemical substances.

1199. It is not the object of this volume to teach the principles of chemistry, and they are at no time entered into farther than is necessary to make the student acquainted with so much of the nature of the matter spoken of as is necessary for his clear comprehension. It will be sufficient therefore to state that the scale is founded on three important points,—the constancy of composition in chemical compounds; the equivalent power of the quantities that enter into combination; and the properties of a logometric scale of numbers: and to explain briefly how these contribute to the formation of the instrument.

1200. The same compound body is always of the same composition; no variation in the proportion of its elements can by any possibility take place. 48 parts of potassa combine with 54 parts of nitric acid to produce 102 parts of nitre; no method of putting the substances together, as by causing an excess of the one or the other, or abstracting one from a previous state of combination, or allowing other substances to be present, can cause any change in these proportions. Nor is this confined to the numbers 48, 54, and 102, but whatever may be the quantity of these elements in combination, or of the nitre produced, the proportions will be the same.

Hence the composition of a substance being once accurately ascertained, it requires no further investigation; for whenever that substance re-occurs, whatever may be its quantity, the proportions of the elements existing in it may be deduced from the former determination; and whether nitre be produced by combining together pure nitric acid and potassa, or by using nitric acid with carbonate of potassa,

or precipitating a nitrate of copper by potassa, or in any other manner, still it will contain the above proportions of potassa and nitric acid: whatever its quantity, yet $\frac{48}{102}$ parts of it will be potassa, and $\frac{54}{102}$ nitric acid. It is but another form of this natural law to say that the same quantity of an element always requires the same quantity of another element to form the same resulting compound.

1201. The second point, or the equivalent power of the quantities which enter into combination is not so evident as the former; but it is abundantly confirmed by experiment. If a quantity of sulphate of soda in solution be poured into a solution of nitrate of baryta, the latter being in excess, a quantity of sulphate of baryta will precipitate, and nitrate of soda will remain in solution with the excess of nitrate of baryta. So much of the nitrate of baryta will be decomposed as is sufficient to supply the necessary quantity of baryta to combine with the whole of the sulphuric acid in the sulphate of soda, and to form sulphate of baryta with it; but the point now particularly to be observed is, that the quantity of nitric acid which leaves the baryta, will be exactly that required to combine with the soda separated from the sulphate of soda, to form with it the neutral salt, nitrate of soda; for the two solutions, after mixture and chemical change, will be found as neutral as before.

It is evident from the result of this experiment, that the nitric acid is exactly equivalent in combining and saturating power with the sulphuric acid; for they have both equally neutralized the portion of soda in the solution, and what is more, they have also both equally neutralized the portion of baryta, which has changed acids during the experiment. Upon very slight consideration it will be perceived too that, the baryta in the sulphate, and the whole of the soda, are similarly circumstanced with respect to each other; for they have both during the experiment exactly neutralized the active portions of the two acids. The excess of nitrate of baryta undergoes no change during the experiment, and is merely considered as present to ensure the total decomposition of the sulphate of soda. If the quantity of dry nitrate of baryta has been 132 parts, and the quantity of dry sulphate

of soda 72, then the whole of the acids and bases present will have changed places in the manner just described.

1202. Similar phenomena are presented by all other neutral saline bodies: the reciprocity of saturating power, is found to exist as above described whenever chemical change takes place, and is therefore dependant upon no particular body, but belongs to all. Hence a correct notion may be formed of the meaning of the term *equivalent* as applied to bodies acting chemically. The quantities of substances which by combining together saturate each other, are *equivalent* in their power of combination; thus 40 parts of sulphuric acid are equivalent to the saturation of 78 parts of baryta. The quantities of two or more substances which combine with and saturate an equal quantity of the same substance, are *equivalent* to each other in their saturating power; thus 40 parts of sulphuric acid and 54 parts of nitric acid are equivalents, for both are competent to combine with and neutralize 32 parts of soda or 78 parts of baryta (1201); and the latter are equivalents for the same reason. Also the quantities of compound bodies which mutually act upon each other are *equivalents*, because the same proportional quantities are always necessary and always sufficient.

1203. The term *chemical equivalent* may therefore be used to imply that proportion of a body which is necessary to act upon another body, the circumstances of chemical affinity being such as to permit action to take place; and it has been found that the proportions are the same for one body, whatever other body it be compared with. So that if a particular number be arbitrarily taken to represent the quantity of any one substance competent to enter into combination, and be called its *equivalent*, then all the equivalents of other substances may be set down in numbers, those numbers being in the same proportion to the first number, that the combining quantities of the bodies they represent are, to the combining quantity of the substance to which that first number belongs. Thus in the change between nitrate of baryta and sulphate of soda (1201), suppose the number 40 to be assumed as the equivalent number of the sulphuric acid present, then 32 will be the equivalent of the soda, for so

much is combined with the 40 of sulphuric acid; and 54 will be the equivalent of the nitric acid, for so much will combine with the 32 of soda, and 78 will be the equivalent of the baryta; 118 will be the equivalent of the sulphate of baryta, 72 of the sulphate of soda, 132 of the nitrate of baryta, and 86 of the nitrate of soda.

1204. The determination of these *equivalents*, or *equivalent numbers*, is purely a matter of experiment. Any errors which we may adopt with regard to their value, depends entirely upon the errors of our experiments, or our mistaken interpretation of them, and not upon a possible change of their real value, under any circumstances. So that once well ascertained, they become a safe and invaluable source of information to the chemist; which he may refer to and use with the utmost facility, by means of Dr. Wollaston's scale.

1205. The third point necessary to the scale is the logometric line of numbers; or, as it is termed, the common Gunter's line of numbers. It will be found that the numbers are so arranged in this line, that at equal intervals they bear the same proportion to each other. The student will easily observe and understand this, by measuring a few distances upon the scale with a pair of compasses, or even a piece of paper. If his paper extend from 10 to 20, it will also extend from 20 to 40, or from 55 to 110, or from 160 to 320. Whatever number is at the upper edge of the paper will be doubled at the lower. If any other distance be taken, the same effect will be observed. If, for instance, the paper extends from 10 to 14, then any other two numbers found at its upper and lower edge will be in the same proportion as these two numbers 10 and 14. Thus make the upper number 100, and the lower number will be 140.

1206. Now supposing that the paper were cut of such a width that, one of its edges being applied upon the scale to the number representing the equivalent of one body, the other should coincide with the number of the equivalent of a second body; then upon moving the paper, wherever it was placed over the numbers, those at its upper and lower edges would still represent the corresponding proportional quantities of the two bodies as accurately as at first, because the

numbers at equal distances on the scale are proportional to each other. Thus suppose the upper edge were made to coincide with 40 and the lower with 78, then the upper edge might be called sulphuric acid, and the lower baryta; and this width once ascertained, the paper wherever applied upon the scale, would shew at its lower edge the quantity of baryta necessary to combine with the quantity of sulphuric acid indicated by its upper edge.

1207. It is evidently of no consequence whether the paper be moved up and down over the scale, or the line of numbers be moved higher and lower, to bring its different parts to the edges of the paper. And supposing the piece of paper just described to be pasted upon the side of the scale, then by moving the latter any of the numbers might be made to coincide with the upper or lower edge at pleasure, and consequently the quantity of sulphuric acid necessary to combine with any quantity of baryta, and vice versa, ascertained by mere adjustment and inspection of the scale. Or if, instead of referring to the separate piece of paper, marks were to be made on the side of the scale at 40 and 78, and named sulphuric acid and baryta, the same object would be attained, and the same method of inquiry rendered available.

1208. Other substances are to be put down upon the scale exactly in the same manner. Thus the scale being adjusted until the number 40 coincides with the sulphuric acid already marked, then sulphate of baryta is to be written at 118, and thus its place is ascertained; nitrate of baryta at 132; soda at 32; sulphate of soda at 72; and a similar process is to be adopted with every substance, the number of which has been ascertained by experiment. The instrument, which in this state merely represents the actual numbers supplied by experiment, will faithfully preserve the proportions thus set down, whatever the variation of the position of the slider may be. It is therefore competent to change all the numerical expressions to any degree required, the knowledge of one only being sufficient first by adjustment, and then by inspection to lead to the rest.

1209. A few illustrations of the powers and uses of this scale will be sufficient to make the student perfect master of

its nature and applications. Suppose that in analysing a mineral water, the sulphates in a pint of it have been decomposed by the addition of muriate of baryta, and the resulting sulphate of baryta washed, dried, and weighed: from its quantity may be deduced the exact quantity of sulphuric acid previously existing in the mineral water. Thus, if the sulphate of baryta amount to 43.4 grains, the slider is to be moved until that number is opposite to *sulphate of baryta*, and then at *sulphuric acid* will be found the quantity required, namely 14.7 grains. In the same manner the scale will give information of the quantity of any substance contained in a given weight of any of its compounds; these having previously been deduced from experiment, and accurately set down on the table in the manner just explained (1208).

1210. If it be desired to know how much of one substance must be used in an experiment to act upon another, it is evident that the equivalent must be taken, and this may be learned from the scale. Suppose that a pound of sulphate of baryta has been mixed with charcoal, and well heated, to convert it into a sulphuret, and that by the addition of nitric acid it is to be converted into nitrate of baryta. The quantity of acid which will probably be required may be learned by bringing 100 to sulphate of baryta, and then by looking for the number opposite nitric acid: it will be found to be 46. But this represents the quantity of dry acid; casting the eye therefore lower down, upon liquid nitric acid of a specific gravity of 1.50, it will be found that 61 lbs. or a little more, is the equivalent for 100 lbs. and consequently that 61 hundredth parts, or somewhat above six-tenths of a pound of such acid, will be sufficient for the pound of sulphate of baryta operated with.

1211. If a certain weight of carbonate of baryta be required in that moist and finely divided state, in which it is obtained by precipitation, and in which it cannot be weighed, the accuracy of the quantity may be insured by taking the equivalent of dry muriate, or nitrate of baryta, precipitating it by an excess of carbonate of potassa, and then washing off the salts which remain in solution. Suppose

100 grains of the carbonate were required; by bringing that number to carbonate of baryta, it will be found that the quantity of dry muriate necessary will be 105.8 parts, and the quantity of nitrate 133.4; and if the quantity of carbonate of potassa necessary for this purpose be also required, it will be found opposite the name of that substance on the scale, to be a little less than 70 parts, so that 5 or 10 parts more will ensure a satisfactory excess.

1212. The second paragraph of Dr. Wollaston's description of this scale may be transcribed, as a further illustration of the powers of the instrument. "If, for instance, the salt under examination be the common blue vitriol, or crystallized sulphate of copper, the first obvious questions are—(1) How much sulphuric acid does it contain? (2) How much oxide of copper? (3) How much water? He [the analytic chemist] may not be satisfied with these first steps in the analysis, but may desire to know further the quantities (4) of sulphur, (5) of copper, (6) of oxygen, (7) of hydrogen. As means of gaining this information, he naturally considers the quantity of various re-agents that may be employed for discovering the quantity of sulphuric acid (8), how much barytes, (9) carbonate of barytes, or (10) nitrate of barytes, would be requisite for this purpose? (11) How much lead is to be used in the form of (12) nitrate of lead; and when the precipitate of (13) sulphate of barytes, or (14) sulphate of lead are obtained, it will be necessary that he should also know the proportion which either of them contains of dry sulphuric acid. He may also endeavour to ascertain the same point by means of (15) the quantity of pure potash, or (16) of carbonate of potash requisite for the precipitation of the copper. He might also use (17) zinc, or (18) iron, for the same purpose, and he may wish to know the quantities of (19) sulphate of zinc, or (20) sulphate of iron, that will then remain in the solution."

1213. All these questions and points are answered by moving the slider until the number expressing the quantity operated with coincides with *sulphate of copper crystallized.* 5, *Water.* Let it for instance be 100: this being brought opposite crystallized sulphate of copper, the information

relative to all the above points, except the sixth and seventh, is supplied by mere inspection. The sixth may be supplied by subtracting (5) the quantity of copper from (2) the quantity of oxide of copper, or by halving the quantity at 2 oxygen, or taking the third of that at 3 oxygen. The seventh relates to the quantity of hydrogen in the 5 water present in the salt; this quantity of hydrogen does not come within the line of numbers, but may easily be obtained by doubling the quantity of water, or doubling the quantity of the salt used, which will then bring 10 hydrogen into the scale, and the half of this is to be taken as the quantity in 5 water, or in 100 grains of the salt. Putting therefore 200 to sulphate of copper, 10 hydrogen, is indicated as 17 parts nearly, when of course the half of this, or 8.5 parts, is the quantity in 100 grains of the crystallized salt of copper.

1214. Whenever it thus happens that the number known or the number sought for is out of the scale, then some convenient multiplier of the numbers may be used. The most convenient method is to use the tens or the hundreds as units, or what is the same thing, to consider for the time that decimal points are inserted between the units and the tens, or between the tens and the hundreds of all the numbers on the scale. Thus if it were required to ascertain how much magnesia and sulphuric acid were contained in a pound of crystallized sulphate of magnesia, no 1 exists upon the scale, and of course no fractions or small parts of 1; but imagine decimal points between the tens and the hundreds, then 10 upon the scale become one-tenth, 22 twenty-two hundredths, 100 one, 220 two and two-tenths and so on. Bringing therefore 100 to crystallize sulphate of magnesia, it represents the 1 pound, and by inspection it will be found that it contains 16 hundredths of a pound of magnesia, and $32\frac{1}{2}$ hundredths of a pound of sulphuric acid.

As another illustration; suppose that the quantity of magnesia in 50 lbs. of crystallized Epsom salt were required; upon bringing 50 opposite the name of the salt, the quantity of magnesia will be found smaller than any quantity expressed upon the scale: but all that is necessary to obtain

the answer is, to double the quantity of the salt, and then to halve the quantity of magnesia indicated; in which way it will be found that the 50 lbs. contain about 8 lbs. of the earth.

1215. These *Synoptic scales* are generally constructed of paper or wood. Those on paper are first laid down accurately upon copper, are then engraved, impressions worked off upon paper, and these impressions pasted upon a wooden frame and slider prepared for them. It is almost impossible that these scales should be accurate, because of the extension and contraction of paper when it is damped, and again dried, and the facility with which it yields to mechanical impressions, and may be stretched when in a moistened state. When the paper is pasted to make it adhere to the wood, it extends considerably in all directions; and though this extension, as caused merely by dampness, would not very much surpass that which had taken place in the paper when damped previous to its receiving the ink from the copper plate, it is seriously increased by the rubbing and other mechanical action employed, both in applying the paste from a brush, and in afterwards bringing the paper into close contact at every part with the wood. These scales should never therefore be considered as accurate when they first come from the instrument maker. They may be examined by a pair of compasses or a piece of paper, as before described (1205), to ascertain how nearly, equal intervals on the scale of numbers, accord with equal proportions between the numbers at the extremities of those intervals, and thus the degree of error in them, and the part where it exist to the greatest extent may be observed: but it will be useless to do so with the view of finding one so accurate as to dispense with calculation in exact analytical experiments.

Those scales, which are laid down directly upon wood, though not liable to the same sources of error as the paper scales, are still seldom, if ever, so accurate as to compete with calculation.

1216. The errors just referred to relate to the accuracy of the scale of numbers, and its proportional value in every part. Others relate to the imperfect and inaccurate results of the experiments, by which the numbers representing

the equivalent or combining quantities of bodies are obtained. If an inaccurate result be mistaken for a correct one, and the proportional number of a body be entered erroneously upon the scale, it is evident that all estimations of substances including that body, which are given by the scale, must involve this original inaccuracy. Whenever therefore a more accurate determination of the number of a body is obtained than was before possessed, its place on the scale should be corrected; and as the equivalent numbers of substances, previously undetermined, are satisfactorily ascertained, the substances themselves should be put upon the scale in their proper situations, as before described (1207—8).

1217. In consequence of the unavoidable errors in the scale of numbers, which, however small, still interfere in the investigation of complicated cases, and the determination of accurate conclusions, the instrument should only be used in those instances where accuracy within a certain degree is sufficient for the purpose. All nicer results should be obtained by calculation from a *table* of equivalents: if, for instance, the quantity of sulphuric acid in 64.7 grains of sulphate of baryta were required to two or three places of decimals, it would be better to take the equivalent numbers of sulphate of baryta and sulphuric acid from such a table, and to say, as the first number is to the second, so is 64.7 to the quantity of sulphuric acid it contains, than to work with the scale. The present determination of the sulphate of baryta is 118, and that of sulphuric acid 40, hydrogen being 1 or unity, and as 118 is to 40, so is 64.7 to 21,932 very nearly. It will be impossible to ascertain this last number accurately on an ordinary scale, or to observe how far it differs from 22.

There are numerous tables of equivalents published in different chemical works. Whichever may be adopted should be examined from time to time, and the numbers affixed to bodies on it corrected, whenever they are more accurately determined.

1218. It has been shewn by Gay Lussac and others, that all gases and all volatile substances when in the state of vapour, combine or act chemically in volumes, which have

very simple relations to each other. Thus a volume of hydrogen combines with half a volume of oxygen to form a quantity of water, which, if raised into vapour, and corrected for temperature, &c. is equal in bulk to the volume of hydrogen used. A volume of hydrogen combines with a volume of chlorine, to form two volumes of muriatic acid; and with a volume of the vapour of iodine to form two volumes of hydriodic acid. Three volumes of hydrogen combine with one volume of nitrogen to form two volumes of ammonia; and half a volume of oxygen on combining with carbon to form carbonic oxide, becomes a whole volume.

Relations of this simple kind have been found to exist in the case of every volatile body, which has been particularly examined in reference to this point. These volumes once ascertained, may be considered in the relation of equivalents, and their proportions are so simple, as to be remembered without the least difficulty: it is therefore highly advantageous in all tables of chemical equivalents, to place small diagrams by the sides of the substances and their numbers, which may represent the volumes of the equivalents when brought into the state of gas or vapour. For it requires no great power of discernment to perceive that, if bodies combine in definite weights (1200), and also in simple ratios of volumes, these volumes so combining must contain the weights previously found to be definite: for whether two substances which combine to form a third, are observed by weight or volume, still they combine only in one proportion.

1219. So arranged, the table will have an appearance of the following kind:

Hydrogen	1	
Oxygen	8	
Chlorine	36	
Iodine	125	
Water	9	
Muriatic acid	37	
Hydriodic acid	126	
Ammonia	17	

and will be found very useful when referred to for gaseous or vaporous substances. The proportions of these volumes are much more easily remembered than the proportions of their equivalent numbers; which, added to the facility with which the bulk of gases or vapours are ascertained, may often properly induce the chemist to dispense with the determination of weights, and work with volumes only.

SECT. XXIII.

MISCELLANEA.

1. *Uses of Corks.*

1220. The cork drawer (21) and some of the uses of corks, have been already referred to, whilst speaking of the facility of their conversion into stands for vessels (58), and handles for hot tubes (854). Their cheapness and general qualities place them in constant requisition in the laboratory. They make excellent wedges at the joints of glass apparatus, or between glass and other substances, yielding in consequence of their elasticity and softness, and adapting themselves to the form of the glass over a considerable surface. Their use as stoppers for bottles and jars is very common. When cut from good cork, they may be employed even in closing the apertures of pneumatic apparatus attached to the air-pump; and notwithstanding that, when so employed, they are subjected to the air's pressure, they will remain perfectly tight for an hour or more, if their surface has been rubbed over with a little soft cement (1037). They are very convenient as stoppers for jars, globes, and other experimental apparatus, because of their ready admission of a sharp point, and other modes of attachment (781, 782). The wires of deflagrating spoons may be passed through them (700). Tubes for voltaic decomposition may be prepared by closing their ends with a cork, through which a wire has been passed (961). A fine wire passed through a

cork, will serve to give motion to apparatus within a vessel closed by the latter, without permitting any appreciable portion of air or gas to pass; and in this manner wire and cork may occasionally be made to supply the place of a sliding rod, passing through an air-tight stuffing box. Sometimes corks may be strengthened, when used as stoppers, by passing through them a wire attached to a metallic button at the lower surface, and terminated above in a ring or handle, somewhat in the manner of decanter corks.

1221. Corks being very bad conductors of heat, are formed into ready and excellent handles for the support of hot rods and wires, and for the insulation of hot pipes. They serve equally well for the support of cold apparatus, and three or four corks or bungs make excellent feet to a vessel containing a refrigerating mixture, which is to be preserved in a cold state for as long a time as possible. A long cork makes a ready and good handle for the pole of a powerful voltaic battery (959), and prevents the unpleasant effects of an accidental discharge of the battery, through the arms of the operator.

Those which are supplied for laboratory use, should be both elastic and compact. When to be used as wedges between glass, or inserted into apertures, they may be softened, either by pressure between the fingers, by rolling them under a weighted board, or by heat.

2. *Uses of Paper.*

1222. Paper will often supply the persevering chemist with a substitute for numerous vessels, when his ardour urges him to pursue a subject under circumstances of great deprivation, as regards his usual means. Good wove and hot-pressed writing paper is the most desirable, but any that is sized may be made to answer the same purposes. By folding the edges of triangular or square pieces, little vessels may be constructed, which are water tight, and in which precipitations may be made, and the action of reagents observed. On such occasions, the water or solution should not be put into the paper vessel until the

precipitant is ready to be added, and the result should be immediately observed; the short time which then elapses will not be sufficient to communicate any sensible impurity to the fluid from the paper. Or if the paper be such as has been imbued with wax, a much longer time may be allowed before any impurity communicated from it to the water need be suspected. Coloured precipitates are observed in such vessels with great advantage. Dr. Paris long since pointed out this use of paper as applicable to the detection of arsenic by nitrate of silver. Even heat may be applied to water in paper vessels, and though it is not often that the experimenter is likely to be driven to such extremities as to have occasion to resort to such resources, it is proper that he should be acquainted with them. A pint or more of water may be boiled with perfect safety in a paper vessel made out of half a sheet of good cartridge paper, placed over a chemical lamp (189).

Waxed paper may be purchased of Messrs. Fisher and Toller, of Conduit-street, Bond-street; or it may be readily made by laying the paper upon a clean hot plate (577), and rubbing it over with a piece of wax tied up in muslin or cloth.

1223. The use of paper in forming tubes (225, 249, 786, 903), has been already referred to: the elasticity of writing paper is such, that a tube constructed of three or four convolutions, being tied round with thread or twine, and preserved from rough treatment, may be considered as tight at low pressures. It is not intended to say that no gas will pass out of it in any length of time, except at the extremities, but that the quantity is so small that such a tube may be used upon urgent occasions for the conveyance of hot air, carbonic acid gas, or coal gas, or in any other experiment on gases, where exact quantities are not necessary. Those who have suddenly had occasion to collect gas from natural or unanticipated sources, such as the blowers of coal mines, the fissures of the earth, the flues of furnaces, or brewer's fermenting vessels, will fully appreciate the use of these and similarly rough but ready instruments.

1224. When the edges of the paper are pasted, the tightness is more permanently insured. If the whole of one side

of the paper be pasted before it be rolled up, the tube will be still tighter and stronger, and being then varnished or covered with a coat of drying oil, will serve for the conveyance of steam and water, as well as of gases. It may be strengthened if there be occasion by passing twine round it (249). Waxed paper also makes excellent tubes for the conduction of fluids, vapours, and gases.

1225. When the tubes are intended for the conveyance of inflammable gas, they may be made of paper which has previously been washed with a saline solution (903), so as to render it incapable of taking fire and burning with flame. The tubes which are pasted or cemented together, are easily made by folding them upon a round ruler or wooden rod, or upon a wire, a piece of loose paper having been first put upon the ruler or wire, to permit of its ready removal when the tube is finished.

1226. Round discs of thick writing or cartridge paper, or of card, answer the purposes of glass valves, (1234, 1119), for covering glasses at common temperatures, and excluding impurity.

1227. Waxed paper is very useful when bottles or tubes cannot be obtained, for wrapping up deliquescent or changeable substances, so as to preserve them from water and air. Solid bodies, like crystals, which are to be transported to some distance, and would be injured by being folded up carelessly in flat paper, may be secured occasionally in little tubes of the same material, closed by a cork at each end, the tube being tied round with thread or twine upon the cork.

1228. Paper funnels are of continual service, especially if made of waxed or oiled paper. They may be formed either by rolling the sheet into a cone, the apex of the cone being in the middle of one of the sides of the paper, as in a grocer's envelope for sugar, or by wrapping up the pieces of paper in the manner of a simple filter (505), and piercing the point. The first kind are the strongest, if the external fold be made fast by a little paste, or a piece of soft cement (1035), and may be made more or less inclined in the side. Fluids, even acids, may be poured through these funnels, especially if of

waxed paper: they also serve for filtering funnels; for conducting gas into jars and bottles; for collecting the gas of stagnant waters; and for numerous other purposes.

1229. Similar cones of paper, but of a larger size, are useful for keeping hot or cold materials from exposure to the air (515), to retard their change of temperature. If a glass containing a frigorific mixture be applied to freeze a substance inclosed in a tube or wrapped up in foil, the powers of the mixture would diminish much more rapidly by the free contact of the air than by the matter experimented upon; and in the course of an hour its low temperature and consequent efficacy would probably be gone. But being supported on two or three corks, and covered over by a paper cone, the contact of air and other substances is prevented, and the glass will remain at a very low temperature for many hours. In the same manner paper jackets, or loose sheets of paper, tied round apparatus which are to be retained in a hot (392. 407. 439. 668. 875), or a cold (424) state, are very serviceable in preventing the diffusion or the reception of heat by the access of air.

1230. Similar small cones of paper held together and finished by folding the edge of the base inwards all round, serve as stoppers to flasks, bottles, tubes, &c. and are often useful in closing the apertures of vessels, especially such as are used for processes of sublimation.

1231. Paper, on one side of which a coat of gum, paste, or any other cementing matter has been applied which may be brought into an adhesive state by water, has been already referred to as supplying ready labels (1029. 1196). It is equally useful for the instantaneous manner in which it serves to form tubes, funnels and cones, and to join fractures temporarily, or wheresoever adhesion is suddenly required.

1232. Tough paper may even be made to answer the purposes of string. A slip of whited brown paper, about two-thirds of an inch in width, being rolled together between the fingers into the resemblance of twine, has considerable strength. Parcels packed up in this manner have arrived safely in this country from China.

3. *Uses of Copper wire.*

1233. Copper wire, when annealed, is, on account of its flexibility, the best kind of wire that can be ordinarily used in the laboratory for binding apparatus together. This service it has to perform very frequently. It is also very useful in forming temporary supports for tapers, tubes, or arranged apparatus; as also in assisting in the formation of apparatus itself, especially such as is intended for electro-magnetical experiments. It is the best kind of wire for the poles and connections of voltaic and electric batteries, not only for its flexibility, but also for its high conducting power as respects electricity. When old or useless, it should be wrapped together, or cut into pieces of about an inch in length, and reserved for the purpose of making nitrous gas. Two sizes of copper wire at least will be required in the laboratory; the one about one-twentieth, and the other one-fifth of an inch in diameter.

4. *Uses of Glass plates or valves.*

1234. The glass plates mentioned formerly (353. 536. 547. 559.) are made by clipping fragments of plate glass (1123, 1124) into circular discs, from one inch to three or four in diameter, and are applicable to numerous purposes. Being perfectly plane on both surfaces, they are often used to close the apertures of jars, of which the ends are ground, and are frequently more convenient than basins for the transference of jars containing gas, especially from shallow portions of fluid or in confined situations. They serve as covers to glasses and jars; as vessels for the evaporation and crystallization of small portions of fluids or solutions (547), and as insulators in electrical or electro-chemical arrangements. In the latter, drops of the fluids to be decomposed should be put upon them (962), or the metallic vessel containing the fluid should be placed on the glass plate. They are often very valuable in testing minute quantities; the smallest quantity of a reagent may be added to a drop of a solution placed on such a plate, and from the trans-

parency of the plate, and the different positions in which the tested matter may be held, the appearances may be observed to the greatest advantage.

5. *Uses of Leaf and Sheet metals.*

1235. *Tin foil* is very useful in the laboratory as a conductor of electricity for the purpose of establishing a metallic communication between the different apparatus standing upon it, and for the purpose of forming metallic linings and coatings to those which, like the Leyden jar, require them. It may readily be cut with scissors or a knife, and is easily applied by means of paste and rubbing of it with the hand, as in the case of pasting paper. It is highly useful upon certain occasions of refrigeration, particularly when a solid substance requires immersion in the mixture. The metal leaf should be wrapped so closely round the substance to be frozen, as to prevent the penetration of the frigorific mixture, and being a good conductor of heat, the circumstances are then the most favourable for rapid and great diminution of temperature. It is often useful also when wrapped round tubes to darken a certain point, or to cool that part more rapidly. It is a very manageable leaf metal, but should not be handled carelessly, lest it become full of holes, when it is of course no longer a water-tight wrapper.

1236. *Lead leaf* has similar uses. *Sheet lead* is of considerable service in supplying counterpoises for the balance (33), being readily cut by a knife or scissors. It is of service in heating and cooling bodies by contact; and from the facility with which it yields under the hammer or pressure, may easily be formed into dishes or basins when those of metal are necessary for particular purposes, or into vessels for freezing, and into other temporary apparatus, when better cannot be had.

1237. *Copper plate* is of great service as an electromotor, and in conjunction with the metal zinc, is of continual use in voltaic electricity. Slips of it are required also in the laboratory for the precipitation of certain metals. It is soft

when annealed, and is then easily bent into temporary metallic vessels. *Copper foil* has been already referred to as of the greatest service when wrapped round glass tubes (678), both in strengthening and conducting the heat more uniformly over them. It is often used in the same manner on a smaller scale to tubes closed at one end and held by the hand. *Copper leaf*, as it is usually called, is a particular kind of brass, which being extended very greatly, answers well for observing in a general manner the effect of agents upon a metal in a finely divided state.

1238. *Zinc plate and leaf.* Zinc rendered malleable and rolled out into plate and leaf, is very useful in both forms. Plate or sheet zinc is a powerful electromotor, and with sheet copper, as above mentioned, enters into the construction of voltaic apparatus. A temporary instrument may be formed in a few minutes with these two metals and a few discs of flannel. Plates of sheet zinc are often required for the precipitation of metals. The *foil* being thinner than the plate, answers for similar occasions when a smaller quantity of metal than that in the sheet is required, and being lighter, has on that account partial superiority. From its thinness also, it is highly advantageous in exhibiting chemical action, mechanical separation being carried in it to a considerable extent. It always comes from the rolling mills covered with a coat of oil, from which it should be freed by washing with a little soap or alkali, before it is used in chemical experiments.

1239. *Platina foil.* Many of the services of this substance have already been referred to (181. 954. 963. 966). In all experiments in which it is used to support other substances at high temperatures, the fusible metals, or even their oxides, sulphurets, and other compounds, when mixed with carbonaceous matters, should be kept from contact with it; for the metal alloying with the platina forms a fusible combination, and the foil is destroyed or rendered impure. It is very useful as an electromotor. A piece of zinc and a piece of platina foil in contact, when put into a solution, will separate many metals from it if present: the metal passes to the platina, and may afterwards easily be removed. An

application of this kind, made by Dr. Wollaston, has been already referred to (485. 979). It is not difficult upon occasions of necessity so to fold up a piece of platina foil as to make a vessel of it capable of retaining fluids, and in that state it may serve the purpose of a platina crucible so far as to allow the performance of an analysis, which could not otherwise have been effected.

6. *Uses of Soft or Windsor brick.*

1240. This brick is easily cut by a jagged knife or saw into numerous useful forms. It assists by juxta-position in building up small charcoal furnaces, allowing of the formation of apertures through the brick itself. It is easily shaped into stoppers for furnace apertures (145), or into covers, plugs, and supports for crucibles; or into wedges, to be applied where necessary about furnaces or rigid apparatus. Its softness, in which it much surpasses ordinary brick or stone, is a considerable advantage, especially when it is used in contact with glass. These bricks are also very useful as supports upon the tables for hot apparatus. Furnaces, red-hot crucibles, or heated iron plates may be supported on them very well and steadily, the heat transmitted through the brick being insufficient to do injury (174). They were first brought into notice for these uses I believe by Mr. C. Aikin.

7. *Conduction of heat.*

1241. Heat may frequently be conducted by means of a solid mass of metal, to places into which it could not so conveniently have been introduced by other means, and the chemist will sometimes find his operations facilitated by such a contrivance. Sir Everard Home wished to coagulate the blood within an aneurismal tumour without disturbing the tumour or the neighbouring parts. This he effected by passing a needle through the place, and then heating it on the exterior; the heat conducted to the fluid within was sufficient to cause its coagulation. A similar instance is now very common in the structure of certain lamps; in which cocoa-nut

oil in a reservoir is preserved in the fluid state by a metallic rod, one end of which enters the oil, whilst the other projects over a flame several inches off.

1242. In operations with a tube and a spirit lamp, particular parts of the former may be heated and cooled very conveniently by means of the conducting power of metals. The manner in which uniformity of temperature may be insured at the lower part of a tube when heated in the flame, by enveloping it in copper foil, has been already described (1237). If on the contrary it be required to cool a particular portion of the upper part of a tube, for the purpose of more effectually condensing the vapour at that place, the tube may be wrapped round with metal foil, which is to be placed in contact with thicker metal, as sheet lead, or cooled by touching it with wetted paper. The envelope of foil may be moistened and cooled, when, if the glass itself were similarly treated, it would immediately fly to pieces. A heated basin, which, with its contents, requires to be cooled rapidly, may be placed in water, or upon the mercury of the pneumatic trough: the heat will be rapidly abstracted. When the end of a tube in which a substance has been submitted to heat will ultimately require to be broken for examination; whilst hot, it may be cooled and broken at the same moment by plunging it into the mercury of the trough.

1243. A very useful indication of the conducting power possessed by different substances for heat, is obtained, by putting them in contact with the upper lip, or that part of the cheek which is near to the mouth. These places are highly sensible to changes of temperature; and as the substance which conducts best abstracts the largest quantity of heat in a given time, it will of course feel the coldest, i. e. supposing all the substances are at the same temperature, and several degrees below the temperature of the skin. In this way many differences of conducting power may be observed. Another method is to hold one end or side of a piece of the substance between the fingers and to apply the other to a flame: the difference between wires of silver and platina is thus easily distinguished, and also that between

various stones, diamond, and glass. The substance which best conducts heat, will first feel hot to the fingers.

8. *Uses of reflective and receptive powers.*

1244. Clean polished metallic surfaces receive heat by means of radiation (i. e. from a hot body not in contact with them, but at a distance), with great difficulty; and if made hot, it is with equal difficulty that they throw off their heat by radiation into space or to other bodies. Hence if a bright metallic vessel be placed before a strong fire, it will receive heat but slowly; or if it be filled with any hot substance and set in a cool place, it will be a long time before it will become cold by mere radiation. On the contrary, if the surface of the vessel be covered with a thin coat of lamp-black, varnish, paper, or any substance not metallic, its power of receiving and sending off radiant heat is greatly increased. Such a vessel will soon become hot before a fire, or if heated, will soon cool to common temperatures by radiation. These are facts which the student will gain from the most elementary treatises on Chemistry, and may frequently be applied with facility to useful purposes. If a crucible furnace (143) require to be placed so near the sides of the pneumatic trough, or any other piece of apparatus, as to endanger its injury by the heat radiating from it, a bright tin plate should be interposed, when the wood work will be perfectly safe (173). But as metallic bodies are excellent conductors of heat, such a shield should not be placed in contact with the hot furnace; or if it must necessarily bear against and be supported by it, a piece of brick, or tile, or stony matter, should intervene.

1245. When it is necessary to prevent change of temperature in a very hot or very cold substance for a long time together, it may be placed with advantage in a clean metallic vessel, the radiation or the reception of heat by the surface being thus prevented. The contact of air which would carry off or communicate heat by conduction is to be retarded by paper cones (515. 1229), or by flannel wrappers. Clean tin foil is often useful in thus supplying a

metallic cover. If, for instance, part of the neck of a retort were to be preserved in a hot state, in order that the vapours may be prevented from condensing too soon, the object would often be attainable by a wrapper of tin foil when the application of flannel, paper, or other means, might be inconvenient or inadequate.

1246. If whilst heating a flask over a chemical lamp (189. 359) the sides of the vessel have become blackened by the smokiness of the flame, the deposition should be immediately removed, for otherwise, by its radiating power, it causes considerable dispersion of the heat which has been previously communicated by the lamp.

1247. On the contrary, when the object, in place of preserving the temperature constant, is to bring it rapidly up or down to that of the neighbouring bodies, the vessels should be covered with a surface that will radiate or receive heat with facility. On such occasions metallic vessels, such as cannisters, tubes, the envelopes of foil applied to the necks of retorts, &c. should be blackened or closely coated with a good radiator of heat.

9. *Writing on Glass.*

1248. When, in the progress of active and earnest experimental enquiry, various bottles, jars, glasses, &c. containing different products and preparations, require to be marked or labelled (1197), it is advantageous that this be done with as little interruption to the general course of the thoughts and occupations as possible. It is often therefore convenient to write upon the glass of the vessel with a common pen and ink, with the intention of substituting a proper label afterwards. There is no difficulty in writing with great distinctness upon glass provided it be wiped perfectly dry, the last rub being given with a clean part of the cloth, and also with a slow motion to remove any electricity that may have been excited on the surface of warm or very dry glass by the previous quick action. The pen should contain plenty of ink, the letters be large and written quickly, and the pen held nearly perpendicular to the glass.—

Jars containing particular gases over the pneumatic trough, or bottles of gas required for temporary purposes, may be sufficiently distinguished by such inscriptions.

1249. If it be required that the writing should remain for some time, and should resist the action of the damp vapours or acid fumes that are continually afloat in the laboratory, it is convenient to prepare an ink by diluting black varnish, such as Brunswick black, with its bulk of oil of turpentine, and keeping the mixture, with a pen, in a bottle for this particular purpose. For certain stock bottles, and jars or bottles of gas which are put by in damp or un-aired places, this method of labelling surpasses paper and ink. The writing soon dries, and though pale, it is very distinct and legible. If in the course of five or ten minutes, or after any greater lapse of time, a little lamp-black be rubbed over it with cotton or tow, the writing immediately becomes as black as that of common ink, and then will resist rubbing or wiping with either wet or dry cloths for a long time.

10. *Smelling by a Tube.*

1250. It is desirable in certain experiments to increase in every possible way the means of perceiving whether a substance possesses odour: whether for instance ammonia, when reduced to very low temperatures, affects the olfactory nerves or not. At such times a tube six or seven inches long, applied in the following manner is of great use. One extremity is to be put into the vessel containing the substance, and placed in contact with it; the other extremity is to be applied to one of the nostrils, the other being closed, and then air is to be inhaled through the tube. This air will pass by the substance before it enters the nostril, and if it affords any odour it may then be perceived. In this manner substances inclosed within vessels, or at the bottom of tubes which are subjected to very low temperatures, may be examined; but when thus operating, the end of the tube must be allowed to become as cold as the substance, *before* it is placed in contact with it.

11. *Engraving on glass.*

1251. This is an amusing and sometimes a useful experiment, and as involving also a little serviceable practical manipulation, is worthy of description. Suppose the object be to engrave a design on a piece of flat glass; common crown glass will be found the best for the purpose, and a pane of this substance should be procured of such dimensions that a circle may be described upon it large enough to include the intended drawing. The glass is then to be warmed over a spirit-lamp, sand-bath, or other convenient source of heat, and rubbed with yellow bees-wax; this will melt, and by using such a quantity of it as will flow readily upon the glass when hot, a uniform coat may be applied. If when cold it prove to be not quite uniform, still if every part of the surface to be engraved be perfectly covered, it will suffice. The design is then to be traced upon the waxed side with a coarse point, every mark being made to penetrate the wax. The point may be that of a knife, or a piece of wire, or a brad-awl; if made flat at the end in one direction, but round in another, so as to resemble a minute round-edged chissel, no difficulty will be found in making lines through the wax, finer or coarser, according to the relative position of the edge or end of the tool and the line which it is describing. If the design be previously drawn upon paper with ink, it may be easily seen and traced through the wax.

1252. An evaporating basin, either of earthenware or metal (344. 1236), is to be selected of a diameter that will include the whole of the design when the glass plate is inverted over its mouth. Coarsely bruised fluor spar, in quantity equal to about two ounces for a pint basin, is to be put into the basin with a sufficient quantity of strong oil of vitriol to make it into a thin paste; the two substances are to be stirred together with a wire, and the waxed plate put over the mouth of the basin with the design downwards. A moderate heat is then to be applied to the bottom of the basin, which is best done by means of the sand-bath; it soon causes the evolution of fumes in abundance from the mixture, but should never be allowed to increase so as to melt the wax on any part of

the glass; a temperature of 140° or 160° is sufficient. The basin and its contents, being warmed, should be removed to a cooler part of the sand-bath, and left for half an hour. The etching is known to proceed well when, upon raising one edge of the plate, vapours are visible within. At the end of the half hour the glass plate should be rinced with water to wash off the adhering acid, and the wax removed either by scraping it with the edge of a flat case knife, or otherwise. The design will generally be found perfectly engraved upon the glass, and may be rendered still more evident by lightly rubbing over it a little finely powdered vermillion with a ball of cotton.

1253. If the glass to be etched or engraved be so formed as not to close the mouth of a basin or capsule, it must be waxed all over, which may be done by dipping it into the melted substance; and after the design is drawn upon it, it must be put with the mixture of fluor spar and sulphuric acid into a vessel sufficiently long and deep to include the whole of the glass to be etched. The mixture of fluor spar and sulphuric acid is to be placed at the bottom, and the glass supported over it upon corks or wires, or suspended so as to be out of contact with the mixture. The vessel is then to be covered over, that the vapours which rise may be retained and surround the glass on every side. Evaporating basins, metallic dishes, or other metallic vessels, not having sufficient depth, may be made to answer the purpose by a paper cap or cone put over the edge rather tightly: the upper part of such a cone serves the purpose of a chamber for the reception of the glass to be engraved, and the vapours that are to act upon it.

12. *Small Air-guages.*

1254. The air-guages by which the pressure of the vapour of liquefied gases (892) were measured, may be made in the following manner. Some capillary tubes must be drawn (1079), not of equal diameter throughout, but much smaller at one extremity than the other. Their lengths may be from 8 to 12 inches; each tube being formed as it were of two or

three portions, successively diminishing in size from one end to the other, so that a volume of mercury at the narrow end shall occupy a length, eight or ten times greater than at the wider end. Many of these tubes being drawn, those are to be selected for further preparation in which the proportions of the different parts are such as to make them most advantageously applicable.

1255. The selected tubes should be graduated into parts of equal capacity in the following manner. The widest extremity of the tube to be graduated, which is open at both ends, is to be dipped into mercury, and, when a portion of the metal has entered, raised into a horizontal position. The mercury may easily be brought to any required part of the tube by inclining it one way or the other, and at the same time slightly tapping the hand retaining it; either surface of the included column of metal may thus be made to coincide accurately with any given mark on the glass. The mercury, being brought into the narrow part of the tube, will be very much extended in length, and so much should be allowed to run out as to leave a portion not more than an inch in extent, which is to be reserved in the tube and considered as the measure of each degree upon the scale of the guage to be formed. Being moved in the manner above described a little way towards the wider part of the tube, search is to be made for that portion of the narrow part which, being nearly of equal diameter, or rather of equal capacity for an inch or an inch and a half in length, is also nearest to the wider part. This place in the tube, if it exist, will be easily found, for the mercury will not undergo any change in length in different parts of it. So soon as a portion of the narrow part of the tube of the required regularity has been discovered, the column of mercury is to be brought to the middle of it, and the tube marked with ink (1248) at the places where it coincides with the ends of the cylinder of metal: thus the *first* degree will be fixed. Other degrees must then be marked off in a direction towards the wider part of the tube; the column of mercury being moved forwards for each degree until its posterior surface coincides with the mark which has pre-

viously been made at its anterior extremity, which in this new situation will point out the place where the mark for a new degree is to be made.

1256. On proceeding from the narrow part of the tube to the wider, the included portion of mercury will soon become very much shortened, and increased in diameter. When its length is less than one half what it was at first, it must no longer be used as a measure; but, being returned towards the narrow part of the tube, may be employed to mark off equal spaces or degrees beyond the first, these degrees being only for a temporary purpose and extending to the end of the tube. This mercury is then to be thrown out, and a fresh portion taken in and adjusted in the manner already described, until it is equal in bulk to two or three, or even four degrees. It is then to be used to divide the wider part of the guage-tube, and an account is to be preserved of the value of these degrees on a piece of paper marked with the same intervals, and at the same time, as the tube. The paper scale is easily made, by laying the guage-tube upon it and making lines coincident with the degrees upon the guage.

1257. By this mode the tube will be divided into a number of equal or proportionate parts. So much of the mercury may then be rejected, as to leave a quantity sufficient to form a column in the wide part about one-third or one half of an inch in length. The end of the column towards the narrow part of the tube is to be made to coincide with one of the graduations on the wide part, so that a certain number of degrees, 20 or 30 for instance, may be included between it and the extremity of the *first* degree marked down on the narrow part of the tube. Now, by employing a small spirit-lamp flame it will be easy to draw off and seal the narrow part of the tube at the extreme end of the first degree, or rather, a little farther towards the end than the exact spot. This may be done by heating so small a proportion of the tube, or of the air within, that it may be considered as an unimportant quantity when compared with the whole bulk of air in the guage. Even this may be in part compensated for by sealing the tube a little *beyond* the extremity of the first degree, and when sealed, applying the heat so far up

the tube as to fuse the glass together exactly to the mark indicating the degree. Supposing for a moment that by this method a little too much air, as for instance, a quantity equal to the twentieth part of a degree, has been included, it is only a four hundredth or a six hundredth part of the whole of the air in the guage, which is of no consequence; but it is of essential importance that the glass should afterwards be made to coalesce to the line of the *first* degree, that the scale may accurately commence from that line, and that the divisions reckoned from it may be equal.

1258. When the guage has been so far advanced, the glass should generally be softened at the distance of about an inch on the outside of the little column of mercury and drawn off (1071), a small hole only being left at the extremity, for the entrance of the air which is to press upon the mercury.

1259. These guages are to be introduced into the tubes in which the compression of the gases is to be effected (892). The gas tubes should be formed of greater length than for cases of simple condensation, and bent twice instead of once, so as to form three straight portions separated by two angles, the guage being in one of the long limbs. If, during the lapse of time, the graduation of the guage disappear, still the paper scale being preserved, may be placed on the outside of the tube, and its termination made to coincide with the end of the guage; in which position it will indicate the compression with sufficient accuracy.

The compression is estimated of course in the same manner as by other similar guages. If there are at first thirty degrees included between the mercury and the closed end of the guage, and in the course of an experiment the metal is forced up to the fifteenth degree, then the pressure exerted is equal to two atmospheres; if it stands at the third degree it is equal to ten atmospheres: if at the end of one degree, it is equal to thirty atmospheres. In consequence of the great length of the first degree, it is easy by such a guage to read off to above a hundred atmospheres; Marriotte's law, as supported by the late experiments of Oersted, being considered as correct. These guages, however thin, are perfectly safe, being subjected to the same pressure within

and without; and for that reason no inaccuracy resulting from unequal pressure is likely to arise.

1260. Such guages are of similar use in the repetition of M. Cagniard de la Tour's experiments: and in many others where gases or vapours are subjected to pressure, either by mechanical or chemical means.

13. *Screens and Masks for the eyes and face.*

1261. It is worse than thoughtless to neglect the proper means of preserving the eyes, when experiments on dangerous or explosive substances, as chloride of nitrogen, or on gases under great pressure in glass vessels, are in progress; and hence the use and necessity of masks in the laboratory. A very excellent mask for the defence of the eyes and face, may be made of a piece of wire gauze, sufficiently large to cover the visage. It may be attached at the upper edge to a spring band, which, passing round the head, will retain it in its place. This mask is flexible, consequently not liable to be shattered like one of glass, and is free from the inconvenience of producing dimness, which is often occasioned by masks of glass, owing to the condensation of moisture from the breath. But it is objectionable for all experiments which require close observation, because of the interference of the wire gauze with perfect distinctness of vision; and as it allows the passage of fluids through its meshes it is inefficient in explosive experiments, made with corrosive liquids, as for instance, those upon the chloride of nitrogen by acids.

1262. An excellent mask may be formed of a piece of plate or even crown glass, guarded on the side towards the eyes with a sheet of mica, both being bored at their upper edges, and made fast to a piece of wood which, being curved and attached to a band, will admit of adaptation to, and support from, the head. The glass, if broken by an explosion, is prevented from doing harm to the eyes or face by the mica, and the latter being flexible and tough, is not likely to be shattered to pieces. Mica alone would scarcely answer the purpose, unless of such thickness as would colour

the transmitted light, when it occasions a dimness before the eyes; for there is not much of this mineral found which, being large and thick, is yet so clear as to allow the passage of light through it as freely as through glass. Mica too, undefended by glass, would soon become rough and dull from scratches and slight injuries. A mask of glass and mica need not descend far below the eyes, for all beneath the nostrils to the chin may be defended by wire gauze, and thus dimness from the moisture of the breath will be avoided.

1263. A pair of spectacles, with side as well as front glasses, afford sufficient protection in many experiments; the glasses should be large and of thick plate glass. The spectacles should fit close to the eye-brows and cheek bones, and the eyes being thus secured the rest of the face will incur the risks of the hands and other parts of the body.

14. *Silvering Glass.*

1264. The advantage of being able to silver a small surface of glass for experiments on light having been experienced, it is assumed that the student may have occasion to perform the same operation: and as regards the manner in which he may coat one side of a glass valve (1234) with a bright metallic surface, and thus convert it occasionally into a reflector, he will find no difficulty by proceeding according to the following directions. Having prepared the glass, a piece of clean, smooth tin foil, free from holes, (1235) is to be cut to the same size, and is to be laid upon a couple of sheets of filtering (501) or blotting paper, folded into quarters. A little mercury is to be placed on the foil, and rubbed over it with a hare's foot, or with a ball of cotton slightly greased with tallow, until the whole of the upper surface of the leaf be amalgamated and bright. More mercury is then to be added, until the quantity is such as to float over the tin foil. A piece of clean writing paper with smooth edges, is to be laid upon the mercury, and then the glass surface, previously well cleaned, is to be applied to the paper. The paper is then to be drawn out from between the mercury and the glass, whilst a slight but

steady pressure is to be applied to the latter. As the paper recedes, it carries all air with it from between the glass and the metal, which come into perfect contact.

The mirror is now made, and may be used for an experiment, but there is still much more mercury present than is required to make the definite and hard amalgam of tin constituting the usual reflecting surface. If it be desired to remove this excess, the newly formed mirror must be put on its edge for some days, when the superabundance of fluid metal will drain to the bottom; or it may be put under the pressure of a flat board, in a slightly-inclined position, and loaded with weights.

1265. The mercury used for silvering should be free from other metals: and such as has been used in the manner above described, should be kept apart from the rest of the laboratory stock, because of the tin it may contain, or before being added to it, should be purified in some of the methods described (1174 &c.).

15. *Phosphorescence.*

1266. There are many substances which, when heated, become more or less luminous; but in numerous cases, the light evolved is so feeble as to require the most favourable circumstances to render it visible. A usual and very good method of producing the effect in ordinary cases, is to heat a thick plate of iron to a temperature at which it is barely visible in the dark, to place it on a brick, and after carrying it into a dark place, to sprinkle the substances to be tried upon it. It is better to heat the iron more at one part than another, so that when the former is just visible, the latter, being at an inferior temperature, is not sensible to the sight; trials may then be made on both parts with the same substance. A substance often emits so little light, as not to yield any appearances on the part of the iron visibly hot, while it is distinctly phosphorescent on the other part, where there is no light to blend with that evolved.

1267. The substance should not be altogether in fine powder; it is better to experiment with a mixture of coarse and fine parts. If the fine particles or the mixture does not seem

to become phosphorescent, a few small fragments should be tried unmixed with smaller portions. Their form becomes faintly visible, and may be distinguished on the black iron, when the light of an indiscriminate and general sprinkling cannot be certainly ascertained. Occasionally a fragment is more advantageous, because of the different temperatures of its parts at different moments, a faint light appearing to pass gradually over it as its parts acquire the necessary temperature.

1268. It is much better to place the substance at once upon a hot body, from which it may quickly receive the heat it may require, than upon platina foil, or in a crucible, and to heat both it and the vessel at the same time. The operation is then slower, because of the larger mass to be heated, and the eye in certain cases becomes accustomed to such a degree, to the gradual change of light, as not to notice it. The quicker the phosphorescence occurs, the more distinctly is it recognised. The eye should not be directed towards luminous or enlightened bodies immediately previous to the observation, but towards darkness, that it may be rendered more sensible to the impression of light.

1269. Dr. Brewster, in giving an account of some experiments, by which he recognized this property in so many bodies, as to nearly quadruple the number previously known to be phosphorescent, says, "I never reduced the body to powder, but always placed a fragment of it upon a thick mass of hot iron, carried into a dark room. When the phosphorescence was not readily perceived by this method, I took a pistol barrel, and having shut up the touch-hole, I introduced the mineral into the breech, and placed the bottom of the barrel in the fire. Before a red heat was produced, phosphorescence was distinctly seen by looking into the barrel, which I sometimes did through a plate of glass, to keep the heated air from the eye, and sometimes through a small telescope, adjusted to distinct vision at the bottom of the barrel. At other times the mineral was not introduced into the barrel till it was taken out of the fire, and till the red heat had entirely disappeared."*

* Edinburgh Philosophical Journal, i. 385.

16. *Media for exhibiting the direction of light.*

1270. If animal charcoal, i. e. such as is used by the sugar bakers, and prepared by carbonizing bones, be boiled in alcohol, and the latter, when cold, either poured off or agitated and filtered, a minute quantity of solid matter passes with it in a state of such extreme division, as to remain for days and even weeks suspended in the fluid. Its presence is perceptible, not by any dark tinge which it confers upon the alcohol, but by a peculiar tint and reflection at the edges and other parts, and a degree of opalescence through the whole. When a ray of light is passed through this fluid, its course is shewn in the most beautiful manner by the illuminated solid particles, and nothing can equal the delicacy of the form and appearance of the cone of light, when the rays from a lens are thus made visible, or the interest of the appearance when the rays of a solar spectrum are exhibited in it.

1271. A solution of quinia in alcohol, when precipitated by water, or a solution of the sulphate or any salt of that substance precipitated by alkali, produces a similar medium. A small quantity of the body is sufficient to bring a large quantity of water into this state. These fluids are of considerable use in illustrating and demonstrating the course of the rays of light.

17. *Uses of Solar Radiant Matter.*

1272. The rays of the sun when concentrated in a focus, have not unfrequently been used in heating bodies placed in the middle of glass vessels, to which heat could not otherwise be communicated. Thus the Florentine Academicians, and Sir Humphry Davy, heated the diamond in oxygen gas.

1273. Their influence in occasioning chemical change in a manner unlike that of any other agent, is such as to make their application in the laboratory highly important, and it is to be regretted that chemists generally are not more in the habit of trying their powers over bodies which as yet have not been submitted to them. Chloro-carbonic acid is always

formed by their means, so also is one of the hydriodides of carbon; and the chlorides of carbon, cannot be produced in any other way so advantageously as by their assistance: chlorine will decompose water when exposed to them, which it can scarcely do without their aid; and having these strong evidences of a peculiar and very effectual power, there is no reason why we should not hope to find, that even solid bodies exposed to solar light when in contact with gases and vapours, and also with fluids, exerts an action quite independent of the powers of heat, and adequate to the production of new results.

18. *Magnetism.*

1274. Though magnetism may be thought to form no part of chemical science, yet from its extraordinary developement by electricity, and its equally extraordinary residence in some of the metals, it cannot but press upon the attention of the chemist. The present notice will principally relate to the use of the magnetic needle as a test of the presence of magnetism in minerals or substances containing iron, or of its developement by electro-chemical arrangements.

1275. When a magnetic needle of the ordinary kind is used, its point of suspension should be very fine and delicate, that no serious retardation of its motion may be occasioned by friction, and the agate, glass, or other cap which supports the needle, should be clean and smooth within. The magnetic state of the needle may be judged of from the freedom and readiness with which it vibrates when disturbed from its natural position. It may be appreciated also by dipping the points into iron filings: the brush of filings sustained should be considerable, and quite at the end of the needle, and no part towards the middle of the needle ought to shew attractive powers sufficient to lift up any particles of the iron.

1276. When the needle is used as a test of the magnetic powers of a body, as an ore of iron, or other mineral, it should be allowed to take its state of rest, when the body should be approximated to one side of either extremity or pole: the

attraction or disturbance of the needle will indicate the magnetic state of the substance, and the magnetism may be considered of a strength proportionate to the distance to which the substance attracts the needle, or that at which it first acts.

If the magnetism be very weak, its effects may be rendered more evident by the following management. Suppose the substance to be a piece of iron ore applied on the right side of the pole, and capable of deflecting the needle only a very small distance from its original position: if the substance be removed sideways, and the needle allowed to return, it will, if freely suspended, pass beyond its position of rest to a distance on the left side, nearly equal to that to which it had been deflected on the right side of the magnetic meridian, and will regain its state of rest only after several oscillations. But in place of allowing it thus to regain its state of rest after it has swung to the left side, and is in the act of returning to the right by the attraction of the earth, and the mere momentum of its parts, the iron ore should be again brought near to it on the same side, to conjoin its attractive force with the forces before mentioned, and thus to draw it as far as possible towards the right side. The ore is then to be withdrawn from the needle as before, and when the latter has passed to the left side, is to be again applied whilst it is returning to the right side; this is to be done repeatedly, the oscillations of the needle in *one direction* being favoured by superadding the attractive powers of the ore each time. This will be found very easy of performance by an alternate movement of the hand to and from the pole of the needle on the right side; the object being to hold the ore as near to the pole as possible, while the latter is passing from left to right, and to remove it so as to leave the needle quite uninfluenced by it, as the same pole moves from right to left. In this manner a new impulse is added to the pole or needle at each oscillation, the amplitude becomes gradually increased, and deflections, which at first were scarcely visible, become extended to a very considerable degree.

1277. If it be a weak repulsive power that is thus to be rendered evident, the substance tried must be made to follow

the pole closely as it recedes, and is to be withdrawn to a distance as it returns in the oscillation: but it is better in such a case to use the attractive force of the substance on the *other* pole; for no mistake can arise as to any tendency of the substance to *draw* the pole, through the mere motion of the air, though such a mistake might occur as to repulsion; the effect supposed to be repulsion, being nothing more than motion communicated mechanically through the air by the approximated body, driving, as it were, the air and needle before it.

1278. M. Haüy has instructed us that, under the combined influence of the earth and a magnetic bar, a needle may be made a much more delicate test of the presence of small magnetic attractions, than when under the earth's influence alone. The power which is required to deflect a needle from its natural position, is least when the deflection is smallest, and greatest when the deflection is 90°. It increases therefore from 0 to 90°, and then decreases again; but the increase is in a decreasing ratio, and the decrease in an increasing ratio, so that it requires a much greater magnetic force to move it from 0° to 10°, than to move it from 80° to 90°. To take advantage of this circumstance, the needle is to be allowed to acquire a state of rest when under the earth's influence only; then if the south pole of a bar magnet be approached towards the south pole of the needle, the bar being in a line with the needle, a repulsion will take place, and the needle will deviate until the repelling power of the bar and the attractive force of the earth on it, are equal to each other. This may have brought the needle to an angle of 30° with the magnetic meridian, but by approximating the bar the effect may be increased, and the angle rendered greater. In this way the distance of the bar is to be diminished, until the needle is very nearly at right angles with its first direction, and will scarcely retain that position, but on the slightest further degree of motion passing through another quarter of a revolution, or even more. It is thus placed in the most favourable position as a test of magnetism; for an attractive power, many times smaller than that which would sensibly deflect it, when in the mag-

netic meridian, will now be sufficient to make it pass through the few remaining degrees to 90°, and then entirely invert its position.

1279. When a bar of iron is examined for magnetism by the needle, the method is, to observe whether both ends attract both poles at all distances, or whether in any case a repulsion on either pole can be observed. This repulsion is a proof of magnetism in the bar, but in such cases it is necessary to hold the bar in a horizontal position, and perpendicular to the direction of the needle; for in any other position a bar of soft iron without previous magnetism, will seem to be magnetic and to possess poles, solely in consequence of its relative position to the earth. Whilst in a plane perpendicular to the dip of the needle, it will not shew this effect, but when out of that plane the end below acts as a north pole to the needle, and the end above as a south pole. Although it has just been said that when in such a plane it shews no effect of this kind, the assertion is not strictly true; for such a plane being considered as passing through the thickness of the bar, all that is above will seem to have the one effect on the needle, and all that is below the other; but the power is so slight in a bar having this position, as to be scarcely perceptible under ordinary circumstances.

1280. An iron bar may also be examined for magnetism by bringing it near fine iron filings; if it have poles they will attract the filings, but the test is not so delicate as the needle. Iron filings afford ready indications of the power of bar magnets; the bulk of the brush taken up being in proportion to the attractive power of the bar.

1281. Small temporary and very delicate magnetic needles may be made by magnetising a common sewing needle, and then either floating it upon water on a small piece of cork, or suspending it by a single fibre of silk. For this latter purpose a small ball of soft cement (1035) is to be attached to each end of a piece of the fibre, about a foot or two in length. One of these being pressed against any convenient place from which the needle may be suspended, will adhere with a force quite sufficient to support the needle. The latter having previously been magnetised, is to be pressed

against the other ball of cement, and adjusted until it balances in a horizontal position. Being left to itself it will take its natural position in the magnetic meridian, and during suspension will be more delicate, and more readily obey impulses exerted upon it, than a needle supported on a point.

1282. The needles are easily magnetised in the usual way by an ordinary magnet. If such be not at hand, a steel bar may be rendered powerfully magnetic, as Mr. Scoresby has shewn, by placing it in the magnetic dip, i. e. with one end pointing about $24\frac{1}{2}$ degrees west of north, and downwards, so as to make an angle of $72\frac{1}{2}$ degrees with the horizon. When the bar is held in this position, with one end on a large kitchen poker in the same position, and the other end struck three or four times with a heavy hammer, it will become a good magnet, and quite sufficient for the preparation of small magnetic needles.

SECTION XXIV.

A course of Inductive and Instructive Practices.

The Chemical student must not expect that, by reading this book, he will find himself ready and expert in the application of the various methods and contrivances which it describes. No valuable experimental knowledge can be obtained at so cheap a rate. Practice is essential to that facility, without which nothing dependant upon the hands can be done well. With the view therefore of expediting the acquirement of the necessary habits, the present Section will contain a number of practices, arranged either as single experiments, or in sets; the performance of which, whilst it will confer considerable experimental readiness, will convey instruction relative to numerous important points of chemical science, and teach the applications and powers of the contrivances described, when they are afterwards to be applied in trains of new and original research. All the expe-

riments are accompanied by references to the previous paragraphs of the book, that the information necessary for their successful performance, may be found at the moment it is wanted: and thus, at the same time that the instruction given, directs the practical manipulation, it is itself illustrated and rendered more forcible by the performance of the experiment.

II. *Balance, Weighing, &c.*

1. Observe the equality and readiness of oscillation in the balance (37) when the scales are empty, and also when they are equally loaded with, first, a fourth, and then one half of what they ought to carry (38). Remark the difference, if any, in the time of the oscillation when the pans are empty and when they are loaded.

2. Load the balance with the full weight it is intended to carry, then observe whether it sets or not (38). If it set, diminish the weights in the scale, until the charge with which it first begins to set be ascertained.

3. Try the different weights of the balance against each other (43) in various ways.

4. Examine the old brass weights belonging to the balance, by counterpoising them with new and accurate weights (43); during the trial put all the weights to be tried on one side, and the ascertained weights on the other (52).

5. Counterpoise the balance by weights equal to about one half of what it should carry (29); and when in equilibrium, change the weights from pan to pan, and observe whether the balance still remains equipoised (42, 52).

6. Weigh two pieces of solid substance together (45, 49), to the hundredth of a grain; then weigh the two separately, and observe whether the sum of their weights make the first weight.

7. Balance two pieces of writing paper in the pans (53) by as few cuts with the scissors as possible. Put these papers successively into the same pan; weigh 300 grains of sand into each (54, 52), and then ascertain whether the weighed portions equipoise each other.

8. Counterpoise a piece of smooth writing paper (53), weigh 50 grains of magnesia on it (54); then pour off the magnesia and ascertain whether the portion which adheres to the paper has rendered it sensibly heavier. Do the same with a fine heavy powder, as carbonate of baryta. In this way an idea of the quantity of powder which will adhere to paper may be acquired.

9. Weigh 49.7 grains of carbonate of lime in fine powder (53, 54), weigh a second portion of 49.7 grains, then put them together, and try if they weigh accurately 99.4 grains; if not, ascertain whether the rest of the weight is on the paper, or what has occasioned the apparent inconsistency in the results.

10. Weigh a piece of glass or metal of about 400 or 500 grains (45), cool it well (421, 1235), then hold it for a few minutes in a glass containing a little water at the bottom, but so as not to touch the fluid; afterwards ascertain if the weight of the cold body has been increased by moisture condensed upon its surface.

11. Counterpoise a cold platina crucible (55), make it hot, and putting it into the pan in that state, observe the quantity by which the weight appears to be diminished (51).

12. Counterpoise a tube supported on a cork (55, 58), then accurately weigh a hundred grains of water into the tube (60), taking particular care that none pass to the outside.

13. Counterpoise a glass (55) and weigh 127 grains of mercury into it (117, 118).

14. Counterpoise a bulb or little flask, supported on a cork ring (55, 58), weigh into it 150 grains of strong sulphuric acid (60), adjusting the quantity by a rod (61).

15. Counterpoise a little evaporating basin or capsule (55) and weigh into it 130 grains of Venice turpentine in a cleanly manner (61), adjusting the quantity by the tip of a wire or rod.

16. Counterpoise a small glass (55), weigh 300 grains of water into it (60); fuse some chloride of calcium in an earthen crucible to dissipate all the water (608, 633, 634) pour it upon a cold metallic or stone surface, and as soon as

it is solid break it into pieces and introduce two or three fragments, together exceeding 100 grains in weight, into the water, before the chloride can have increased in weight, by absorbing moisture from the air (63). Ascertain the increase of weight; then stir up the solution carefully with a glass rod until it is perfectly uniform (477), and afterwards remove so much of it (60, 62) as to leave exactly 100 grains of chloride of calcium behind, i. e. if 110 grains of the compound has been added, making 410 grains of solution, remove an eleventh part of it, by which 10 grains of the chloride will be withdrawn, and 100 grains left for analysis, or for experiments.

17. Balance a green glass tube closed at one extremity (55, 57), weigh into it 60 grains of crystallized muriate of baryta in a dry state (44), heat the tube so as to drive off the water and fuse the muriate (669); when cold, re-weigh it and ascertain the diminution occasioned by the dissipation of water (52). It should equal 8.71 grains. Ascertain how many proportions of water this accords with, either by the scale of equivalents (1209), or by calculation (1217).

18. Weigh two or three portions of solid matter by a Black's balance (100), or an unadjusted instrument, applying the weights and the substances on the same side (52); then compare the weights so obtained with such as may be obtained by weighing the same portions of matter in a good balance.

19. Weigh a glass flask (56), or a tube (57), attaching it by a wire to the bottom of the pan.

20. Take the specific gravity of a smooth solid body, as a piece of glass (71, 74). Take also the specific gravity of a piece of solid matter in the rough state, for example, a fragment of zinc or antimony (74).

21. Ascertain the specific gravity of alcohol, of ether, of sulphuric acid, and of water, by the bottle (80).

22. Make a number of small weights (103); ascertain their truth by trying them against correct weights (43).

23. Make a Black's balance (100); compare its results with those obtained by a good balance (52, &c.)

24. Take the specific gravity of water and beer by the hydrometer (91), and compare the results with those obtained by the bottle and balance (81).

III. *Measures. Measuring, &c.*

25. Measure out a pint of water (107. 108), avoiding the formation of bubbles near the graduation. Whilst measuring out the fluid pour it slowly into the measure, that the exact quantity may be observed and ascertained at once.

26. Pour a quantity of water into an ungraduated glass or jar; then measure it (107, 108); afterward pour mercury into the first vessel, to the same height (108), and measure it by a graduated vessel (105), to verify the first result.

27. Counterpoise a graduated measure in the balance (55); pour a certain measure of distilled water into it, four ounces for instance (105), then weigh it (58), and ascertain whether the weight is what it ought to be, or 1750 grains, at the temperature of 62° F. (104). Remove the first portion of water, and measure in the same quantity a second time (107). See if its weight be the same as the weight of the first, or to what extent it differs. It ought to be the same; and the nearer the results approach in weight, the more reason has the operator to be satisfied with the accuracy of his eye and habit of measuring.

28. Measure half a cubical inch of mercury (108, 122) and then ascertain its weight (113).

29. Mark a line down a glass tube (116). Make a mark across it with a file (119), beginning either at the line, or extending on both sides at pleasure; divide a space about an inch in length, first into two, then four, and then eight equal parts by the eye (130); ascertain the accuracy or inaccuracy of these divisions, by weighing mercury into them, (113).

30. Graduate a tube into tenths of a cubical inch by weighing water into it (56. 114. 62. 113. 116. &c.)

31. Graduate a tube into hundredths of a cubical inch by weighing mercury into it (56. 113. 116, &c.)

IV. *Management of heat.*

32. Convert a blue pot or large earthenware crucible into a furnace (142, &c). Then put some chalk into an earthenware crucible (608), and by heating it in this furnace (634), convert it into quick lime. Try whether it has become quick lime, for which purpose put a small piece into water, and add muriatic acid; no effervescence should occur (341).

33. Melt some cast iron in a Hessian crucible (609), in the same furnace (143).

34. Heat some zinc in a Hessian crucible in the same furnace (143), until it burn freely upon agitation and exposure to air.

35. Boil some water in a Florence flask (356), on the furnace sand-bath (155); observe the temperature of the steam that passes off (256. 262) and also of the water. Introduce some iron-filings into the flask, and again observe the temperature of the steam and of the water beneath (408).

36. Diffuse 1 oz. of starch through a pint of cold water, allow it to settle (521), pour off a little of the water, and evaporate it to dryness (563); observe if any thing remain; then heat the mixture of starch and water (354, &c.) and observe the solution of the starch; allow the fluid to stand twelve hours, then decant a portion (522), and evaporate it to dryness (571) by a bath of water covered with oil, and observe how much starch is left, and in what state.

37. Heat a little starch in a tube (848. 869) to 500° by means of a metallic bath (242), allow it to cool, and then upon adding water it will dissolve without heat: on evaporating the solution in a basin over a chemical lamp (562. 189), the same results as in the former experiment will be obtained.

38. Evaporate a portion of the above solution of starch to dryness by a steam heat (248. 251).

39. Evaporate a quarter of a pint of mineral water to dryness over the chemical lamp (564. 189), add a drop of water to the residue, and observe whether it be alkaline by turmeric paper (591). All the deep well-waters of London yield alkaline matter.

40. Heat a piece of wood on platina foil (1239. 181) by the spirit-lamp (176); observe the odour, the production of flame, the carbonaceous residue, and its combustion by a continuance of the heat. Heat also a piece of isinglass or cheese in the same manner; remark the fetid ammoniacal smell, the flame, the fusion, the difference between its coal and the former, and the greater difficulty of incineration.

41. Fuse common salt in a platina crucible (619) by the heat of a spirit-lamp and jacket (183. 631. 632).

42. Attain the highest possible ignition of a platina wire by a spirit-lamp or candle (176. 210) and the mouth blow-pipe (196). Try the same experiment with platina foil (181), holding the foil vertically, or directing the flame from below upwards, or from above downwards (211. 213) upon the metal; observe the circumstances of the most intense heat (215).

43. Endeavour to fuse the extremities of a film of asbestus by the mouth blow-pipe and a candle (196. 210. 212.)

44. Melt 30 grains of bi-carbonate of soda in a platina-foil crucible (1239), until they fuse freely, and become fluid dry carbonate of soda, using the mouth blow-pipe and spirit-lamp for the purpose (213).

45. Melt a globule of tin on charcoal (212) by the mouth blow-pipe and a candle (207. 210), keeping it perfectly metallic and bright for one or two minutes together.

46. Heat, melt, and burn a small fragment of a cast-iron sparable, on a piece of charcoal (219) by a mouth blow-pipe and a candle (211. 212).

47. Heat a globule of antimony on charcoal (219) by the mouth blow-pipe and candle-flame (210); when hot remove it from the flame, and still forcibly urging a stream of air upon it, observe how it continues to burn until nearly the whole is consumed.

48. Heat a globule of antimony as just described, then drop it from a height of five or six feet, upon a sheet of paper, and observe its brilliant combustion, and the trains of oxide it leaves on the paper. Heat another globule, and when in full combustion throw it through the air against a wall; remark its combustion in the air before and after it is broken.

49. Heat a small platina crucible (619) red hot, by a lamp (213) and mouth blow-pipe (215).

50. Make a spirit-lamp according to Mr. Phillips's method (185), and complete the apparatus by making a temporary blow-pipe from a piece of glass tube (201).

51. Fuse platina on charcoal (219) by means of the oxy-alcohol blow-pipe (229). Burn a cast-iron sparable in the same manner.

52. Compare two thermometers at high and at low temperatures (257. 262).

53. Cool a thermometer in ice and water (420. 421), quickly wipe it, and then immerse it in a jar of water at common temperature, to ascertain it; and observe the time required (263). Again, cool the thermometer, and wiping it quickly as before, ascertain the temperature of the air above the water, and noticing the time required, remark how much longer it is than in the first experiment. Hence learn to be cautious with respect to the time allowed for a thermometer to acquire its proper temperature in different situations (262).

V. *Comminution.*

54. Break a flint in the hand, supporting it upon a cloth or glove. Break a small pebble on the anvil (291).

55. Heat flints red hot, and quench them in water (308); then reduce a portion to an impalpable powder (298. 305).

56. Break a piece of flint-glass in a mortar (290); reduce it to small fragments or a coarse powder (296); then pulverize a small portion *very finely* (298. 305); afterwards place it on turmeric paper, and moistening it, render the alkali evident (591)).*

57. Rub a piece of white marble of about 400 grains in weight into an impalpable powder (304. 305); reduce half as much muriate of ammonia also to fine powder (294 298); mix the two well together (301), for exp. 101.

58. Make an intimate mixture (302) of equal parts by weight of muriate of ammonia and quick lime; observe the

* An experiment suggested by Mr. Griffiths. Quar. Jour. xx. p. 259.

ammonia evolved even at common temperatures (591. 593); then use it in exp. 203.

59. Break and pulverize some charcoal (308) for experiments 176, 183, 185.

60. Pulverize a brittle metallic ore, as sulphuret of copper, or of lead, or native oxide of iron (296. 298), and weigh 100 grains (53) for analysis.

61. Before fusing the common salt of exp. 41, pulverize it (315) to prevent decrepitation.

62. Weigh 200 grains of white marble in lumps (45); pulverize it very finely (298. 305); then collect it together (310), and again weigh it (53), and ascertain how much is lost by dispersion or adhesion to the mortar. The loss ought to be very small.

63. Pulverize (308. 296. (298) and levigate (319) a piece of felspar or slate, so as to obtain an uniformly fine powder.

64. Rub and wash crude platina (319. 324), for the purpose of separating the black particles from those which are bright and metallic.

65. Dissolve a silver coin in nitric acid (347. 354), dilute the solution, and precipitate the metal in a finely divided state (331) by a plate of copper.

66. Dissolve the washed platina of exp. 64 in nitro-muriatic acid (347. 356), precipitate the solution by muriate of ammonia (472), wash and dry the precipitate (525. 510. 572); then decompose a part of it by heat (634) in an earthenware crucible (608), so as to produce platina in a spongy state (331). Test its state of division and lightness, by throwing a jet of hydrogen upon it (769); although perfectly cold it will become hot, causing the ignition of the gas: the readiness with which this will take place will depend on the sponginess and lightness of the platina.

67. Granulate some zinc (327), that it may be ready for the preparation of hydrogen gas in future experiments. If the heat of the fused zinc be moderate, the resulting pieces of metal will be thicker than if the heat be much higher. Granulate some thus raised to a high heat and almost ready to burn, the metal will be almost in films; dry it (562), and

then break it down in a mortar (290. 296), for the purpose of preparing carbonic oxide gas in future experiments.

VI. *Solution. Digestion. Infusion.*

68. Examine the solubility of crystals of sulphate of potassa, sulphate of soda, borax, and sugar (336). The first is difficultly soluble: observe the effects in all, and note the absence of similar effects when an insoluble substance is immersed in the fluid.

69. Examine corrosive sublimate as to its solubility in water (336); then dissolve some common salt or muriate of ammonia in the water, and again examine the solubility of the corrosive sublimate (336); the difference occasioned by the salt will be very considerable.

70. Make a saturated solution of nitre in water without heat (349) by trituration in a mortar. Then to each pint add about four ounces of crystallized nitre, dissolve it by the application of heat (344. 355), and set the solution aside to crystallize as in experiment 129.

71. Dissolve common salt in common water in a tube, for the purpose of obtaining evidence that air is expelled during the solution (341).

72. Mix together nearly equal quantities of sugar, starch, marble, and sand, in a mortar (302). Take about an ounce of the mixture, and by means of cold water, dissolve out the sugar (343. 348); collect the washed residue (510), which need not be dried, and mixing it with water in a basin, heat it to 212° (354); the starch will now be dissolved, and by washing, (525), may be removed from the insoluble part. Now subject the remaining powder to the action of a little diluted muriatic acid, to dissolve the carbonate of lime (346. 378); and having removed the solution formed by washing (511, &c.), nothing but the sand will remain. A separation and imperfect analysis of the mixture will thus be made.

73. Dissolve a crystallized and clean carbonate of baryta in pure muriatic acid in an evaporating basin (355. 378), containing excess of the carbonate, so that the solution shall be

neutral (591); pour off the solution formed (369), and add fresh acid, and proceed in this manner until the carbonate be nearly all dissolved; filter the solution (508), pour it into a clean bottle by a rod (370) or funnel (403), and preserve it for use as a test.

74. Boil a few fragments of gum mastic in a tube with alcohol (374) under pressure (87. 855). When this solution is diluted with more alcohol, so as to diminish the quantity of mastic to 70 grains in half a pint, it forms an excellent wash, as Mr. Hatchett has shewn, for fixing chalk and pencil drawings.

75. Weigh 100 grains of pure dry white marble in small fragments (45. 53), put them into a Florence flask (367. 402), with four or five ounce measures of water. Put about one-third of an ounce measure of strong muriatic acid into a test-glass, and adding its bulk of water, stir them well together: then counterpoise (55. 56) the test-glass and the Florence flask with their contents, putting both into the scale at once, the flask on the glass. This done, pour the diluted acid into the flask (369), using no funnel, rod or other means, but taking care that no acid escape down the outside of the vessel. It is not requisite that *all* should be poured out of the glass, but that *none* should be lost to these vessels. Attend to the effervescence, that no liquid be thrown off (368): when all the solid matter is dissolved, expel the atmosphere of carbonic acid by blowing in air through a tube, and again weigh the vessels, observing the loss of weight due to the expulsion of the carbonic acid (52). It should be 44 grains.

76. Dissolve pulverized sulphuret of iron (298) in nitro-muriatic acid (378. 382) under a hood (363, &c.), that the fumes may be carried away. When dissolved, examine small portions of the solution (371. 469) by ammonia to shew the presence of oxide of iron, and by the muriate of baryta of exp. 73, to shew the sulphuric acid formed during the action.

77. After observing the precipitation of the oxide of iron from the above solution by ammonia, take another portion of the solution, add tartaric acid to it (381), and then, on

adding the ammonia, it will be found that no precipitate will take place.

78. Put a solution of chromate of potassa into a flask, and add a portion of sulphuric acid; the colour will be very much deepened and rendered almost red; add a little alcohol and apply heat (383. 359), when on a sudden the colour will change to green. Upon examination it will be found that the chromic acid has lost oxygen, has become chromic oxide, and has formed a sulphate with the acid present.

79. Dissolve caustic lime in water in a close vessel (346), evaporate a certain volume of the solution to dryness (568), and note the quantity of earth left. Then make a similar solution of lime in a vessel with water, containing one half its weight of white sugar (381); take the same volume of this solution as before, evaporate to dryness, and burn off the sugar (619. 631) in a crucible; ascertain the weight of lime left, and observe how much it surpasses the former quantity, in consequence of the solubility conferred by the sugar.

80. Digest some pale Peruvian bark in four times its weight of water (344. 384); after the infusion has stood some time pour off the clear part (369), and when cold, test it by tincture of galls and by carbonate of potassa (470). The precipitate will be proportionate to the quantity of cinchona in the bark.

81. Make a strong infusion (386) of bruised nut galls, and set it aside in covered jars (539) for a month or two (1195); at the end of that time a quantity of crystalline matter will be observed at the bottom of the fluid, which may be collected (521), purified by crystallization, &c. (536. 537), and will be nearly pure gallic acid.

82. Pour water or a solution by means of a rod (369) without spilling. Pour out exactly one ounce measure of muriatic acid in the same way (107. 370), so steadily as to make the fluid coincide with the mark on the measure at once, and without addition or abstraction. Add this acid carefully to the carbonate of baryta in exp. 73, washing out the last portions from the measure by water (372). In this way acquire the facility of apportioning exact quan-

tities, and of adding every particle of them to other substances when required.

VII. *Distillation, Sublimation, &c.*

83. Distil common water in a metal still (391), or in a glass retort (395. 405), condensing, if requisite, by a funnel and paper (432), or using a globe of sufficient capacity (414) to condense all the vapour. Apply the heat of a lamp (189. 359), or hot air (246), or a small charcoal fire (143. 359.)

84. Distil half a pint of wine in a glass retort (432), until three-fourths of the fluid has passed over. Change the receiver or flask (433) when about an eighth has been distilled, for the purpose of keeping apart the first strong spirit. Introduce a few slips of platina foil, and a piece or two of cork (408), to facilitate the formation of vapour. Use any of the sources of heat mentioned in the last experiment.

85. Distil nitric acid from nitre and sulphuric acid in a glass retort (440). Introduce the acid in a neat manner (403); apply heat by means of a sand-bath (156), and condense in the manner already described (441).

86. Distil dry nitrate of lead in a glass retort (430) by the heat of a crucible furnace (360), condense the products in small dry flasks (428), tubes (863), or bottles (428,) cooled by a refrigerating mixture (421). Nitrous acid will pass over and be procured in the fluid state.

87. Rectify some sulphuric acid in a glass retort (396, 406) over a sand-bath (156), or crucible furnace (143). Use platina foil to facilitate the evolution of vapour (411). Condense the vapour in a flask (414), supported in the open air (447), and not purposely cooled by ice or freezing mixtures.

88. Put two ounces of acetate of potash into a retort (402) with its weight of strong sulphuric acid; distil, using a flask as a receiver (413), containing one ounce of diluted water. Heat the retort by a chemical lamp (189), and cool the flask by a basin of water (414). A solution of pure acetic acid will be obtained.

89. Distil sulphurous acid as already described (415). Heat the retort by a chemical lamp (189); cool the little tube receivers (863) in a well prepared refrigerating mixture (421), and ultimately seal them up (1090).

90. Distil a portion of muriatic acid from common salt, mixed with nearly its weight of sulphuric acid, previously diluted with an equal weight of water (440). Apply heat by a sand-bath or low charcoal fire (147), and use the tube of safety (443) to prevent absorption. Receive the products into vessels containing a little water. Test the acid, which will thus be prepared, by muriate of baryta (470), to ascertain whether any sulphuric acid have passed over or not.

91. Distil a little isinglass or horn, or even slips of leather, in a small coated glass retort (453) by a crucible furnace fire (454). Receive the products in successive portions, using glass flasks as condensers (413), employing a little water at first in them to dissolve the ammonia formed. Observe the production of water, ammonia, fetid gas, tar, and empyreumatic matter, and heat the retort to redness (454), so that when cold and broken, the charcoal within may be well formed. Remark its peculiar appearances, its cellular state, its lustre, great hardness, &c. and its difficult incineration in the air (181).

92. Mix the finely divided zinc of experiment 67 with thrice its weight of powdered marble (298), and heat the mixture in an iron (457) or an earthenware retort (455), for the production of carbonic oxide, (exp. 209); a dull red heat will be required, and may be obtained either by means of the table-furnace (458) or the crucible-furnace, according to the size of the retort (454). The gas, if inflamed as it issues from the mouth of the retort, will burn with a fine blue colour.

93. Prepare phosphorus according to the direction contained in elementary works; or make chloride of antimony, distilling in coated glass retorts (453. 454).

94. Put some ether into a tube, close the mouth of the tube by the finger (723, 87), and heat the ether until it is ready to boil upon opening the aperture (855, 856); remove the tube from the heat, and displace the finger so as to allow

ebullition, until the temperature is so low as to occasion its cessation ; then suddenly drop in a chip of dry wood (411), and remark how powerfully the ebullition is renewed by it.

95. Make a freezing mixture of ice and salt (421), put it into a glass, and ascertain whether its temperature is, as it ought to be, at 0° Fahr. (262). Put a little water into a thin glass tube (848), and stir the mixture by means of it (421, 424). The water will be frozen solid in the course of two or three minutes.

96. Introduce a little metallic arsenic into a tube (459, 848), apply the heat of a spirit-lamp (176), and sublime the metal so as to form bright metallic films or crusts of crystals at pleasure (869) ; observe the temperature at which it sublimes, and the degree of rapidity with which it condenses on parts more or less heated. Sublime it up and down the tube, so as to obtain command of it, and the power of condensing it in this or that part of the tube at pleasure (870).

97. Introduce some naphthaline into a large flask or globe (459), place it on a warm part of the sand-bath (153), and allow it to sublime slowly ; close the mouth of the vessel with paper (1149). When a sufficient quantity has sublimed, remove the vessel carefully on one side till all is cold, then shake out the crystals and examine the beauty of their forms.

98. Sublime iodine in the same manner (459), both quickly and slowly ; observe the beauty of the forms obtained in the latter case.

99. Put a portion of calomel into a Florence flask (459), and sublime it into the upper part by placing the bottom in sand (461) on a hot part of the bath (153) ; nearly a red heat is required. When sublimed allow the vessel to cool : cut it by an iron ring (1109), and examine the sublimed mass.

100. Sublime a little indigo in the manner described (463). It will be obtained in very minute but beautiful crystals.

101. Take the mixture made in experiment 57, put it into a Florence flask, and sublime it by a sand-bath or chemical lamp (359). Incline the flask and pass its neck through a cork (432) into a cool receiver (459), or into the

end of a wide tube that may be cooled by the air (461), or if necessary by water (434). Carbonate of ammonia will be obtained.

VIII. *Precipitation.*

102. Neutralize the solution left by experiment 75 with ammonia (595), adding a slight excess of the alkali, then add carbonate of ammonia until all the lime be precipitated (476); collect it together (483), wash it (525), dry it (526. 572), and weigh it. It should be exactly 100 grains, or the quantity at first dissolved.

103. Select a marle or a lias limestone, pulverize it (298), weigh a given quantity (53), act upon it by diluted muriatic or acetic acid at ordinary temperature (349) until all effervescence ceases; wash off (525) and preserve the solution as well as the insoluble portion; dry the latter (572), and weigh it (55. 45). Precipitate the solution by ammonia and carbonate of ammonia (483) as above, and having washed (525) the carbonate of lime formed, dry and weigh it (55. 646, &c.). Its quantity is the same as the quantity of carbonate of lime in the marle, and with the quantity of residue should make up the whole weight of the marle used. An analysis of the marle will thus be effected.

104. Precipitate a portion of muriate of baryta in solution by sulphate of soda (472. 476. 481), wash the precipitate well (511), dry it and heat it red hot (631) in a platina crucible.

105. Weigh out 50 grains (44) of crystallized muriate of baryta, dissolve it in distilled water (343), precipitate the acid by nitrate of silver (476. 480), and after separating all the soluble matter from the insoluble by repeated washing (525), dry (573) and weigh the latter which is chloride of silver, it ought to amount to 58.87 grains (1209). Then proceed to precipitate the soluble portion by sulphate of soda (476. 481) to separate the baryta as a sulphate; wash (525, 528), dry, and heat this substance to redness (631), then weigh it (44, 646), it ought to be 47.42 grains (1209.)

106. Dissolve a silver coin (346, 354), precipitate the

silver by adding a solution of common salt (476, 480), wash and dry the pure chloride of silver thus formed, and use it hereafter in exp. 182, for the preparation of pure silver.

107. Precipitate the muriates from a mineral water by adding solution of nitrate of silver (480, 477), wash, dry, and weigh the precipitate (44, 55), and estimate the quantity of muriatic acid present in a given quantity of the water by referring to the scale of equivalents (1209).

108. Take a portion of the ferruginous solution of experiment 76, or any other solution of iron, and throw down the oxide of iron by ammonia (472, 595); wash, dry, heat to redness (634), and weigh the oxide obtained. If the iron in the solution be not in the state of peroxide, first render it so (382) by a little nitric acid and heat.

109. Take a small portion of the same ferruginous solution and precipitate it by the ferro-prussiate of potassa (472, 482). A blue precipitate will be obtained, which is then to be repeatedly washed (525). As long as much of the soluble matter remains, the washing water and the precipitate will easily separate (482), but as the washing approaches completion it will be found that the pure water added dissolves the blue precipitate. Remark this effect, and then add a little pure muriatic acid (528), this will immediately cause as complete a separation of the prussian blue as before, and the washing fluid will become nearly colourless.

110. Dissolve 100 grains of crystallized sulphate of copper in water (349), immerse a clean plate of soft iron to precipitate the copper in the metallic state (484); when the precipitation is completed collect the metal, wash, dry, and weigh it (525, 573, 44), its weight should be 25.6 grains. Then dissolve it carefully in nitric acid. Precipitate the solution by excess of caustic potassa, applying heat at the same time (479), till the precipitate becomes a dense black powder. Then wash and dry it, and heat it to 300° or 400° (242), afterwards weigh it; it ought to equal 32 grains (1212).

111. Test a weak solution of potassa by muriate of platina (470).

112. Examine the distilled water of the laboratory by various precipitating tests. Previously evaporate three or four

pints to half a pint (566, 569), to render any salts that may be present more sensible to the action of the reagents.

IX. *Filtration, Decantation, Washing.*

113. Burn 400 grains of the filtering paper in use in the laboratory (502) and ascertain the quantity by weight of the ashes left (503). Wash them well with water (513), dry the insoluble portion (577), and ascertain its amount.

114. Pass a quarter of a pint of distilled water several times in succession through the same double filter of paper (509) so as to wash out every thing soluble (513); evaporate the water to a fourth its bulk (563), then test it for different substances, the presence of which has been suspected in the paper, as sulphates, muriates, &c. (468).

115. Filter some foul or turbid water through a folded filter (506, 508), remarking that it pass through perfectly clear.

116. Filter a turbid solution (510), as that obtained from the marle or lias limestone in experiment 103, washing out all the soluble matter from the filter (513).

117. Separate a precipitate of oxide of iron by filtration, experiment 108, or one of sulphate of baryta, experiment 104, (511), washing it in the filter until the water that will pass in the first case contains no trace of muriatic acid (468) or other soluble matter, and in the second case no trace of sulphuric acid resulting from the excess of sulphate of soda used (470).

118. Wash carbonate of lime precipitated as in experiment 103, or in any other way (483), until all traces of soluble matter are removed (511), stirring up the carbonate by the bottle (512, 372) or the washer (518).

119. Dissolve four ounces of crystallized Glauber's salt in two ounces of water by heat (354) in a flask, filter the solution whilst hot (515) to avoid crystallization in the pores of the paper, and cover the whole up with a glass vessel or paper cover (1229).

120. Filter a portion of heated hog's lard or tallow through paper (515).

121. Mix up equal measures of oil and water; separate these bodies one from the other by filtration of the water (514) through a wet paper filter.

122. Dissolve five grains of carbonate of baryta by means of a little muriatic acid in a small evaporating dish (344), pass the solution through a small filter without a funnel (517), test the baryta on a glass plate (1234), using but little of the solution. Precipitate the rest by carbonate of ammonia in a tube (849), separate the carbonate on a small paper filter (517), wash it on the filter by the dropping bottle till pure (373, 518), then dry it (577), and ascertain with how small a loss the whole has been effected (44, 52).

123. Dilute an ounce of port wine with three ounces of water; set aside a small quantity of it, and boil the rest (359) with an ounce of animal charcoal (53) for 10 minutes, filter it (510, 514), and by comparing the colour with that of the retained portion, observe how powerfully the charcoal has acted in removing it.

124. Collect some charcoal ashes from the crucible furnace (143) and lixiviate them (387). Examine the solution for alkali (591) and other substances.

125. Precipitate a solution of two ounces of alum in water by potassa (468, 595); wash the precipitate in much water (525), mixing it up well with a tube (477); when settled, *decant* off the fluid (369, 521), and wash the precipitate again (525); when subsidence has taken place, remove the fluid by a *syphon* (522), and thus proceed till no trace of alkali or sulphuric acid exist in the washing fluid.

126. Put water, oil, and mercury into the same glass. Separate them by the funnel (530) as accurately as possible, receiving them into different vessels.

127. Mix a little oil of turpentine and water together in a tube (848), then separate them by the little vessel before described (532).

128. Put some globules of mercury at the bottom of some water or sulphuric acid, and remove them by means of the mouth and a pointed tube (531), or by the use of a little glass syringe (533), and transfer them in a clean dry state into a separate vessel. In the same manner remove a few drops of water from the bottom of some oil.

X. *Crystallization.*

129. Make a solution of crude or common nitre on the sand-bath, (exp. 70), of such strength as to crystallize when cold (353); filter it (515); then set it aside in a deep basin (537) to crystallize slowly.

130. In the same manner crystallize warm solutions of alum, and of Glauber's salt (537), previously trying the proper strength of the solutions on a glass plate (353); cover the solutions with paper cones (1229) or flannel.

131. Crystallize acetate of lead (536) by cooling a hot solution.

132. Crystallize muriate of soda (538) by the slow evaporation of a cold saturated solution (352).

133. Prepare a solution of alum for crystallization by diminution of temperature (352. 536); hang a thread across it, or leave in it a glass rod with a thread wound round it, and observe the greater tendency to deposition on the one substance than the other.

134. Dissolve a little sulphate of magnesia in water in a capsule (547); evaporate drops of it slowly on a glass plate (1234), and examine the crystals (547. 552). Do the same with alum, nitre, Glauber's salt, phosphate of soda, and common salt; and observe with what facility the crystals of these salts may be obtained from small quantities of solutions, and examined, so as to determine their characters and the nature of the substance crystallized.

135. Transform several small crystals of sulphate of nickel into a large one (542).

136. Crystallize sulphur, bismuth, or lead (550) in a crucible, by fusion, and partial solidification.

137. Crystallize naphthaline by sublimation in a globe or flask (551).

XI. *Evaporation. Desiccation.*

138. Evaporate a solution of common salt gradually to dryness (555, 538), covering the vessel containing it with paper (539) to keep out the dirt.

139. Evaporate a solution of sulphate of copper, so that it shall crystallize on cooling (353, 537), make it thus give successive crops of crystals by successive processes, till all the salt is separated.

140. Procure some spring water, as the deep well water of London; evaporate a portion to dryness, in a basin (344), on the sand-bath (570,355) or otherwise, (562) and then test the residue by a little water and turmeric paper for free alkali (591), or by other agents for the detection of other substances.

141. Evaporate some of the same water by boiling it away in a Florence flask (566), until reduced to a very small quantity; then test the remaining portion (468).

142. Evaporate a part of the same water in a platina crucible (569), and heat the residue (631) to ascertain whether it be changeable by such treatment or not.

143. Evaporate an infusion of a vegetable substance to dryness (386), so as to obtain the extract uninjured by heat (571).

144. Dissolve an impure carbonate of baryta in muriatic acid added until in slight excess (344, 591); evaporate the solution to dryness (568) to dissipate the excess of acid, stirring the product when it becomes thick or solid (564), to prevent its dispersion.

145. Heat crystallized Glauber's salts in a basin (572) to drive off all the water (573), and reduce the substance to an anhydrous state. Stir the melted salts with a rod, until they become nearly solid (564), and then rub them with a pestle, that all parts may be pulverized and dry (564).

146. Evaporate the moisture from washed carbonate of lime (483), in a basin (344), covering the substance with another basin, (568) during the operation, to keep out the dirt. Test the dryness of the carbonate by a cold glass plate (573).

147. Dry a little pulverized black oxide of manganese on the sand-bath (155), or over a lamp (189); test the dryness by a glass plate (573).

148. Evaporate a solution of sugar in water (349), by Leslie's process (555), until it be as dry as possible.

149. Freeze water by evaporation by means of Leslie's process (555).

150. Dry a part of the vegetable solution of exp. 143, by sulphuric acid or other bodies (561) under a receiver, no exhaustion being made.

151. Dry a filter and its contained precipitate, as that of exp. 103, on a tin plate (577) over a lamp or sand-bath.

152. Dissolve 2 grains of carbonate of soda in water in a watch glass (371); add excess of muriatic acid, evaporate to dryness (574); re-dissolve and re-evaporate, so as to obtain small well-formed crystals in the glass (541); observe their forms (552), which will be those of chloride of sodium.

153. Dry some precipitates on filters (513), in a box (576) or air jar, into which heated air is thrown from a lamp (247) or by some other arrangement (246).

154. Drain the crystals of exp. 129 or 130, in a funnel (581), aiding the desiccation by a current of air.

XII. *Coloured tests. Neutralization.*

155. Dilute 10 grains (58, 44) of strong sulphuric acid until it will scarcely affect litmus paper (591), comparing it with water (592); observe and estimate the quantity of water required for the dilution.

156. Try the effects of different acids (582) on the blue test solution (583).

157. Try alkalies and carbonated alkalies on turmeric (591) or reddened litmus paper (593); remark how little of these substances produces a sensible effect. Try lime and baryta water in the same manner, but notice the restoration of the colour on the turmeric paper as the earth becomes carbonated by contact of the air.

158. Test the air of the laboratory for acid fumes by litmus paper (586, 590).

159. Try the effect of boracic acid on turmeric paper (596), and afterwards the effects of other acids on the same places. Try the effect of a mixture of boracic acid and other acids upon turmeric paper (596), and compare it with the effects of the pure acids.

160. Test ammonia, either in solution or in vapour, by

turmeric paper (589, 591), and observe the transient effect produced by this alkali.

161. Heat a piece of isinglass in a small tube (848, 885), and test the vapours given off at the mouth of the tube by turmeric paper, for ammonia (589).

162. Render a portion of diluted sulphuric acid neutral by the addition of a solution of carbonate of potassa, applying heat during the operation (594), and ascertaining the state of the solution by litmus and turmeric papers (591, 592).

163. Dilute some sulphuric acid to a given strength (599).

164. Lixiviate half a pound of wood or charcoal ashes (142, 387), and ascertain by the diluted sulphuric acid (599) and alkalimeter tube (598) how much alkali they contain (600).

165. Try an impure alkali, as barilla or kelp, in the same manner (600, 604).

166. Precipitate a solution of the persulphate of iron by carbonate of ammonia in an evaporating basin (344), applying heat and adding the alkali only to neutralization (594, 595). Then examine the solution, and it will be found that all the iron will have been separated (468).

167. Make a solution of the common ore of manganese in dilute sulphuric acid (354); filter (510); add a little nitric acid, and apply heat (382) to peroxidize the iron that has been dissolved; then gradually add solution of carbonate of ammonia to the hot solution (594), until the latter is neutral (591, 592); by this process all the iron will be precipitated, but all the manganese remain in solution.

168. Try the strength of a specimen of common vinegar by a piece of marble (605). Try the strength of a diluted pure acetic acid, or a specimen of distilled vinegar in the same manner.

169. Ascertain the strength of diluted muriatic acid by a similar process (606), and also of diluted nitric acid (606), applying heat in all these cases to expedite the action (594), and to render the point of neutralization distinct (591).

XIII. *Crucible operations.*

170. Heat some flints to redness in a Hessian crucible (609, 634), and quench them in water (308), to prepare them for pulverization.

171. Convert some carbonate of lime into quick lime in an earthenware crucible (608), by means of a crucible furnace (143, 634), and flue (148).

172. Fuse a portion of lead in an earthenware crucible (614, 627), heated in a crucible furnace (634). After concluding that experiment, fuse a portion of copper in another crucible in the same furnace (634, 148): and ultimately, if possible, a portion of cast-iron in a third crucible, raising the heat for this purpose to the highest degree (635, 151). Remark the difference of temperature required for these operations, and also the powers of the furnace when assisted by the flue (148), &c.

173. Fuse 400 grains of copper in an earthenware crucible (609) heated in the crucible furnace (143, 634), and cover the metal with a few pieces of charcoal (647). When well melted, add 100 grains of zinc in fragments, and mix it with the copper, either by one of the pieces of charcoal or an iron rod (647). The result will be brass, and may either be poured into a mould, or be allowed to cool in the crucible.

174. Fuse a portion of steel in an earthenware crucible (609) in the blast-furnace (163, 637), being careful to keep the carbonaceous matter from contact with the steel (638, &c).

175. Fuse a portion of pure iron, as horse-shoe nails, in the same manner in the blast-furnace (643). When the crucible is cold, examine the button of iron by nitric acid, to ascertain the absence of carbonaceous matter; for this purpose the surface of the button must be brightened on one part, and a drop of dilute nitric acid placed on the spot. Being wiped off a few minutes afterwards, it should leave no black stain, but the metallic iron should appear pure and untarnished.

176. Mix two ounces of red-lead with about two drams of pulverized charcoal, and one ounce of common salt (648); heat the mixture in a Hessian crucible (609, 634) in the crucible furnace (143), that the lead may be reduced. If the experiment be properly performed, metallic lead, equivalent to the red-lead used, will be obtained at the bottom of the crucible.

177. Pulverize a native oxide of tin (298), mix it with one-eighth its weight of pulverized charcoal and half its weight of borax (308), put the mixture into a crucible with a few pieces of charcoal over it, and heat it (633, 634) to reduce the metal. The tin will ultimately be obtained at the bottom of the crucible.

178. Melt carbonate of soda in a platina crucible (619, 627) in the crucible furnace (143, 634). Afterwards melt green glass in the platina crucible in the same furnace (634).

179. Melt borax in the platina crucible over a large spirit-lamp (182, 631), or oil-lamp (189, 632).

180. Mix together three parts by weight of bi-carbonate of potash, and one part of pulverized flints, see exp. 170; fuse the mixture in a platina crucible (619, 627), by means of the crucible furnace (634); pour out the result upon a clean cold stone or a metallic surface, and disolve it in water.

181. Carefully melt a mixture of caustic alkali and siliceous matter in a silver crucible (622), using the crucible furnace (143, 634).

182. Take the silver obtained by reducing the chloride of exp. 106, by means of zinc and a little sulphuric acid, and fuse it in a Hessian crucible with a little carbonated alkali (649).

183. Mix an ounce of oxide of copper with one-twelfth its weight of pulverized charcoal (308, 658), adding oil enough to make the whole into a paste (659); put it into a crucible with one-fourth of an ounce of borax, and ignite it in a wind-furnace (633), or a crucible furnace if it can be made to afford sufficient heat (151, 634). The oxide will be reduced, and a button of metallic copper obtained.

184. Line a crucible with charcoal (618); place some

oxide of copper in it (658); then add more charcoal, and close it with a cover nearly tight (640). Apply a temperature sufficient to melt copper for half an hour; the metal will be reduced.

185. Introduce some dry pulverized (298) oxide of iron, as for instance clean scales, into a crucible lined in a similar manner (618); cover it and heat it for an hour at a high temperature (637); the oxide will be reduced throughout, and leave the iron in a spongy and extremely divided state.*

186. Put some sulphate of potash into a similar crucible (618); place some charcoal over it, and then lute on a cover (640); heat the crucible highly for an hour, after which take it out of the furnace and allow it to cool; when cold, the sulphate will be found converted into a pure sulphuret of potassium.†

187. Take the oxide of iron separated in experiment 108, and when washed, and also dried as much as possible by the heat of the bath or a hot plate (153, 577), introduce it into a platina crucible (619), and raise the temperature to dull redness over the chemical or spirit-lamp (631) to dissipate the last portions of water. If the crucible be large, or the lamp alone ineffectual, use the jacket (632), for the purpose of increasing the power.

188. Put 50 grains of dry hydrate of lime into a counterpoised platina crucible (619, 646); carefully heat the crucible and its contents to redness for a quarter of an hour (632); then weigh and ascertain the loss (44, 646): again heat for five minutes, to ascertain whether any further loss will be occasioned (51, 52, 646). In this manner the water may be driven off, and the composition of the hydrate of lime ascertained. The loss should be 12.16 grains.

XIV. *Furnace tube operations.*

189. Send steam (668, 666) through an iron tube (662) containing iron turnings (683), heated to redness (659) in a furnace. The water will be decomposed, and a mix-

* Berthier. Annales de Chimie, xxvii. 24. † Journal des Mines, vii. 421.

ture of hydrogen gas and steam evolved, or even gas alone if the operation be slow; this may be burnt at the end of the tube, or received in jars over a pneumatic trough (666, 706).

190. Decompose ammonia by passing it through a red-hot iron tube (681, 662). The ammonia may be liberated from a retort containing the usual mixture of quick lime and sal ammoniac; and the gases evolved may be received into jars (706, 710) over the pneumatic trough. The ammonia will in this manner be resolved into a mixture of three parts by volume of hydrogen, and one part of nitrogen, which upon trial will be found to be combustible.

191. Pass ammonia in the same manner over black oxide of manganese (686) heated to redness in a tube either of iron (662), glass, or earthenware (665). The vapours, if thrown into a globe or large flask, will be found to produce red fumes, from the presence of nitrous acid; the alkali being decomposed in this experiment and occasioning the production of an acid body.

192. Pass oil through an iron tube heated to redness (662, 670) in a furnace. The fluid will be decomposed, and a quantity of oil gas produced that will burn at the farther end of the tube with a brilliant flame, or that may be received and preserved in jars (706) over water.

193. Decompose alcohol (668) by passing its vapour gradually through a glass tube (665) containing rock crystals (680), heated at the lamp (672); collect the gas (706), and observe its combustibility and other properties. Ether may be decomposed in the same manner: the deposition of carbon will be far more abundant than when alcohol is employed.

194. When chlorine is passed over crystals of metallic titanium in a glass tube heated by the lamp (672), combination takes place, and a chloride of titanium is deposited in the cool part of the tube (689).*

195. In the same manner chlorine passed over arsenical ores combines with the arsenic, sulphur, and other sub-

* Mr. Georges Annals of Philosophy, N. S.

stances present, and carries them onwards (689). For a complicated but excellent process of this kind, see Berzelius on the Analysis of Arsenical ore.†

196. Put peroxide of manganese into a green glass tube (665), apply heat by means of Cooper's lamp (672), and then pass hydrogen over it (686). The peroxide will become protoxide, and the manner in which the change proceeds will be observed through the glass.

197. Send naphthaline (660) through a tube heated to redness by the ordinary oil-lamp (671), that the effect of heat upon the substance may be observed.

198. Select a green glass tube about one third of an inch in diameter (665), and counterpoise it (56). Introduce some pure baryta in fragments, so as loosely to occupy the length of six inches (680, 687); weigh it, and ascertain the quantity of earth introduced (52). Then heat the tube and its contents to dull redness, either by Cooper's lamp furnace (672), or any other convenient means (669), and pass oxygen (666) over the earth, until, from the abundance which issues at the open extremity of the tube (687), it is evident that no more will be absorbed. Allow the tube to cool (51), closing the extremities (890, 1149) to prevent the free access of air. Then weigh it again (52), and ascertain how much oxygen has been absorbed to convert the baryta introduced into peroxide of barium.

199. Make a similar experiment with lime, except that instead of oxygen, pass chlorine over the earth (689). It will be found, if the gases be collected (706), that oxygen is evolved during the experiment, the lime being decomposed, and its metallic base, calcium, combined with the chlorine to form a chloride. The quantity of oxygen set free may be ascertained by collecting all the gas (709), and absorbing the excess of chlorine. The quantity of lime experimented with may be ascertained also, as well as the quantity of chloride of calcium produced (56, 52), and in this manner the composition of the oxide and the chloride of calcium may be ascertained, not only as to the elements they contain, but as to their actual quantities.

† Annales de Chimie, xvii. p. 113.

200. By putting some spongy platina into a glass tube (665), and heating it over an oil (189, 671) or spirit-lamp (182), and then passing mixtures of gases through the tube, the power of the platina (682) to facilitate chemical changes may be easily observed. Thus a mixture of carbonic oxide and oxygen is readily converted into carbonic acid at comparatively low temperatures and without explosion.

XV. *Pneumatic Manipulation.*

201. Put about one ounce of granulated zinc (327) into a pint retort (395, 402); dilute half an ounce (105) by measure of oil of vitriol, with four or five measured ounces of water, add the mixture to the zinc in the retort (403), and collect the gas evolved (706) in jars (699), over the pneumatic water trough (691). When two or three jars of gas (710) have been received, remove the retort, and proceed to manipulate with the gas. Transfer (717) a portion from one of the jars into a lipped glass (343, 718), then transfer a little from the glass (719, 722) into a tube (703), using a funnel (723) for the purpose, and filling the tube for about two inches in length with gas; close the end of the tube by the finger (723), and then apply a lighted taper to the gas (884) to prove its combustible nature. Refill the tube with water (720), and transfer a second portion of gas into it from the glass (722), not using the funnel but the fingers only (721). Transfer a part of the gas from this tube to a smaller (721), not using a funnel but the fingers, as already directed.

Fill a transfer jar (702) with water (714) over the trough, and decant some of the hydrogen gas from the jars into it (717); depress the transfer jar in the water of the trough (714), so as to cause a jet of gas to issue at the aperture of the stop-cock (776) as soon as the latter is opened; do this gradually, and apply a light to the issuing jet of hydrogen, so as to inflame it and shew its combustibility.

Fill a small jar or a large glass (343) with water at the trough (710), and throw part of the remaining hydrogen gas into it (717), until the jar or glass is full. Raise it care-

fully from the water into the air, still keeping the mouth horizontal and downwards. It will be found that after the lapse of a minute nearly, still a light applied to the air in the glass, will cause slight explosion from the ignition of the hydrogen gas remaining in it. Refill the jar or glass in the trough with hydrogen (717), cover its mouth with a valve (699, 1234), set the glass upright, mouth upwards, and then remove the valve. If after the lapse of two or three seconds only, a light be applied to the contents of the glass no inflammation will take place, the hydrogen gas having now escaped, in consequence of its lightness, and the position of the vessel.

202. Put some fragments of marble (290) into a gas bottle (706), and pour upon them muriatic acid, diluted with thrice its bulk of water; carbonic acid gas will be evolved, which is to be received in jars (699) over the water trough (691). Transfer a portion of it (718) into a small jar (699), filling the latter and then closing its mouth with a valve (713, 1234); take it out of the trough and set it upright, with the mouth upwards. Remove the valve and apply a lighted taper to the gas; the taper will be extinguished as soon as it descends in the jar below the level of the edge. Leave the jar thus open for a minute or two, the air about it being undisturbed, and then on applying the taper, it will be observed to be extinguished as readily as before. Such is the weight of this gas, that after four or five minutes, still enough will be left in the jar to extinguish the taper.

Refill the jar with carbonic acid gas over the trough from the portion originally received (710, 717); put a lighted taper fastened to a wire at the bottom of a similar jar standing on the table, and containing air; it will burn freely; bring the mouth of the jar containing the carbonic acid gas to the mouth of that inclosing the taper, and pour the carbonic acid gas into the latter jar; the gas will descend and extinguish the flame as effectually as so much water. Remove the taper and test the presence of the gas by another method, namely, by lime water; for which purpose pour a little lime water into the jar and agitate it, it will immediately become turbid from the formation of carbonate of lime. On doing

this do not bring the mouth of the lime water bottle near the jar containing the carbonic acid, but pour the lime water required into a glass, and from that into the jar; otherwise all the lime water in the bottle will become turbid, from a little carbonic acid gas thus introduced.

Transfer a portion of carbonic acid gas at the water trough into a tube (720), of a size that may be closed by the finger (723), then quickly introduce a piece of potassa through the water into the tube; close the tube by the finger, and shake it to dissolve the potassa, then open its aperture by removing the finger under water, observe the absorption of the gas by the alkaline solution; the whole of the carbonic acid gas will be absorbed, and thus its purity may be ascertained.

203. Mix one volume of good alcohol with two volumes of oil of vitriol carefully (403), because of the heat liberated. Distil the mixture in a glass retort (395), applying the heat of an oil lamp (189, 359), and receive the gas into jars over water (710); it will be olefiant gas, and should burn with a brilliant flame. Receive small portions into tubes (703), and observe whether it burns with a bright flame when lighted (884, 708); do not collect the gas to be preserved until that be the case. During the progress of the operation, test the gas that is passing over in the same manner, and when its flame decreases in brightness, preserve that which is afterwards collected apart, as inferior and impure. Allow the gas to stand over water (710, 712), or agitate it with water to wash out the sulphurous acid. Transfer a jar filled with it into an evaporating basin (712), and add some quick-lime to the water in which it stands, for the purpose of more effectually separating the carbonic and sulphurous acid gases.

Half fill a tall cylindrical jar (699) with chlorine (693) over the pneumatic trough (710), and then throw up an equal volume of the olefiant gas. Immediately transfer the jar into a large basin (344, 712), and observe the gradual combination and disappearance of the gaseous fluids, and the production of a liquid in drops, insoluble in water, and so heavy as to fall through it; the liquid will communicate a very aromatic sweet taste to it, and is itself powerfully sweet and sapid. Into a similar jar (699) throw chlorine, until it

be two-thirds full, and fill the remaining third with olefiant gas. Close the mouth of the jar with a valve (1234), remove it from the trough, invert it two or three times (799), to mix the contents, and removing the valve, immediately apply a light to the mouth of the vessel; the gases will combine with inflammation, the flame slowly passing through the jar, and rendering it opaque from the great quantity of carbon suddenly evolved.

Burn a jet of olefiant gas from the stop-cock of a transfer jar (702, 714) in the manner described in experiment 201, and remark the brilliancy and beauty of the flame. Pass a bladder full of it (769) through a heated glass tube, as in the practices of Section xiv. and observe both the deposition of carbon in the tube (685), and the diminished intensity of the flame produced by the gas, after the operation.

204. Put some fragments of sal ammoniac into a small dry gas bottle (706), retort (396), or flask (346, 706), and add strong sulphuric acid; muriatic acid gas will be evolved. Receive it into jars (699, 737), over the mercurial trough (696, 736), applying the heat of a spirit-lamp to the retort if necessary (176, 406,) and shaking the vessel to break the bubbles. When several jars are filled with the gas, close the mouth of one of them by a valve, and place it upright with the mouth upwards, on the table (699, 737). Remove the valve, and observe the fumes produced by the gas in the air, and the heat which becomes sensible when the finger is dipped into the gas. Apply a lighted taper, and observe its instant extinction. Pour a little water into the jar, remark the increase of fumes within, and by a little agitation their final absorption. Test the acidity of the solution by litmus paper (591, 584) or cabbage liquor (583), and test the acidity of the fumes also by litmus paper (593).

Transfer a little tube full of water into another jar of the gas as it stands over the mercury (736); observe the immediate absorption, and ultimately the entire disappearance of the gas. Remove the jar from the trough by means of a valve (699, 737), and examine the solution (591, &c.); it

will be found to be the same substance as ordinary solution of muriatic acid.

Transfer a portion of the muriatic acid gas into a tube (703), under the mercury (740, 746), then close the mouth of the tube by the finger (723), transfer it into an evaporating basin containing water (693), remove the finger and observe how instantaneously the gas is absorbed by the water.

205. Make a mixture to evolve ammonia, as in experiment 58. Put it into a small retort (396, 405); heat it by the large spirit-lamp (182), and receive the ammoniacal gas which will be liberated into jars (699) over the mercurial trough (696). Throw up a little water into a jar of the gas, and observe its solubility, and the alkaline nature (591) of the solution produced. Take two jars, one containing ammoniacal gas, and the other muriatic acid gas of the last experiment, observe their volumes in the jars (750), and then pass up the ammoniacal gas gradually into the muriatic acid gas (740); dense fumes will be produced, and condensation will take place. By degrees the whole of one of the gases will disappear with an equal volume of the other, and in their places will remain a solid muriate of ammonia. Estimate the quantities of the two gases used (750), and practically verify the statement just made, that equal volumes of the two condense each other.

206. Make muriatic acid gas (775) and ammoniacal gas (774), and receive them in clean dry bottles (773), without the aid of a mercurial trough.

207. Make chlorine in a glass retort (395), from a mixture of eight parts of salt with three parts of black oxide of manganese, to which has been added six parts of sulphuric acid, diluted with four times its bulk of water, and allowed to become cold. Heat the retort gradually by an oil-lamp (189), removing the lamp if the evolution of gas become quick, or the mixture froths over into the neck of the retort. Receive the gas when good into stoppered bottles (773), in a trough containing warm water (693), close the bottles well (773), and preserve them inverted in a dark place, with their stoppers and necks immersed in water. To test the goodness of

the chlorine, fill a tube with water, and receive a few bubbles of the gas into it, then remove the tube to a trough containing cold water, agitate it with the gas (723), and observe whether the absorption be entire; any residue is impurity. This trial should be repeated until not more than a fourteenth part remains unabsorbed, and then the chlorine may be received.

208. Make an aqueous solution of the gas contained in one of these bottles (773, 798). Then remark its bleaching powers as shewn upon a little finely divided indigo, or upon writing or printed calicoes, &c.

209. Make some carbonic oxide, as in experiment 92; receive it into jars over water (707, 716). Wash it well over water, or lime and water, as in experiment 203 with olefiant gas, or even over alkaline solutions. Mix (717, 799) a portion of the pure gas with half its volume of oxygen in a glass (343, 469); transfer a little of the mixture into a tube (719), and applying a taper to it, examine its combustibility; it will be found to explode. Transfer a small quantity of the mixture into a detonating tube (919), pass the electric spark through it (913, 918), explosion will take place and the bulk of the gas will be diminished. By agitation the remaining gas will now be absorbed; or if a little piece of potassa be introduced and agitated with it, the effect will proceed more rapidly, the resulting gas being carbonic acid.

Transfer a portion of the detonating mixture into a dry tube, over *mercury* (744, 746), and from that transfer a small quantity into a dry eudiometer tube, also over mercury (919). Observe the volume of gas to be detonated (750), and when the explosion has taken place (921), again remark the volume; the diminution will be found equal to one-third of the original bulk. Throw up a tube full of lime-water into the eudiometer: the opacity thereby occasioned, and the condensation of the gas, will sufficiently prove that carbonic acid gas has been the result.

210. Make a little oxygen in a tube retort (859) from chlorate of potassa, by the heat of a large spirit-lamp (182), and receive the gas in tubes (114) and phials over water,

contained in an evaporating basin (880). Try portions of this oxygen in the tubes (723). Introduce a glowing taper, or the ignited end of a splinter of wood, into a tube containing some of it, and observe the increased combustion at the moment. Twist together five or six folds of steel harpsicord wire, fasten a little piece of wood to one end of the bundle, light it and then plunge it into the oxygen gas contained in one of the phials. The steel wire will burn brilliantly.

211. Transfer a little of the oxygen of the preceding experiment into a dry tube (744, 745) over mercury, or make a little oxygen from the tube retort (859) directly into dry tubes or jars, over the mercurial trough (697). Mix a portion of it with twice its volume of dry hydrogen, transfer a part of the mixture into a dry eudiometer tube (919), using Pepys's instrument for the purpose (746), and detonate it by the electric spark (913). If pure, the gases will entirely disappear, and only a minute quantity of water will remain.

212. Make some nitric oxide gas in a glass retort, by acting on copper clippings, with a mixture of two parts water and one part nitric acid. The action, which is often tardy at first, very frequently increases on a sudden and becomes powerful; hence attention and watchfulness is required. The gas should be received into glasses (703) or jars (699) over water, and after standing an hour or two, will be sufficiently washed from acid fumes. Mix a portion of this gas in a glass (703, 717), with some of the oxygen of experiment 210. Observe the deep orange colour produced, and the rapid disappearance of the gases in consequence of the solubility of the product in the water.

213. Measure equal volumes of common air and nitric oxide (732), mix them together in a tube (114) over water, and observe the diminution (735).

214. Mix equal volumes of dry air and hydrogen over mercury (750), introduce a portion of the mixture into a tube, and observe its detonation by the application of a lighted taper. Introduce a portion of the mixture into an eudiometer tube (919), observe its volume accurately (752),

detonate it by the electric spark (919), and then remark the diminution in bulk (752). One third of the diminution will be the quantity of oxygen existing in the common air used, the latter amounting to half the bulk of the mixture detonated.

215. Take any one of the jars of the preceding experiments containing gas standing over water, and measure the gas in it (728). In doing this be careful to level the surfaces accurately (725), to mark the place of the gas before transferring it (724), and to verify the measurement (726), in the manner described. Note also the temperature and pressure (735, 729). Then measure a given quantity of gas into a graduated jar, or up to a certain mark in a jar (730), adjusting the quantity accurately (731). Measure out also a given number of parts into a graduated tube (114), as eight or ten (734), carefully adjusting the quantity by the use of the finger (731). Make use of a standard measure (732) in mixing together two parts of hydrogen with one of oxygen by volume, for experiments like those of 214.

216. Transfer the remaining oxygen, chlorine, hydrogen, or any other valuable gas of the preceding experiments that may be unused, into bottles (718), being careful to close their mouths accurately with stoppers (773).

217. Measure half a cubical inch, or any small quantity of oxygen, hydrogen, or common air, in a tube (114) over mercury (750); then transfer the tube to a basin of water (723), allow the mercury to escape, and again observe the volume of gas now that it stands over water (725), the level being in both cases attended to (724). In this way the effect produced by the different curvatures of mercury and water in the tube (122), may be valued and appreciated.

218. Cement a cap, tightly, (780), upon the mouth of a clean dry retort (396) attach a stop-cock (776), and by an air-pump (784, 800) or syringe (803), examine whether the arrangement be air-tight. Exhaust the retort (800, 807), attach it to a graduated transferring jar (702, 782), containing common air, and allowing the air to enter (810), observe how much is required to fill the retort. Exhaust the retort again (800), and attaching it to a graduated

transfer jar (702) containing nitric oxide (experiment 212), allow so much to enter (810) as is equal to two-thirds of its capacity; then remove and attach it to another graduated transfer jar (702), containing oxygen, open the stop-cock, and allow so much to enter (810) as is equivalent to one-third in bulk of the contents of the retort: then close the stop-cock. The two gases will combine, and form a deep red gaseous product, which is nitrous acid, but great condensation will at the same time occur. To measure the extent to which this proceeds, allow the vessel to cool, that the heat evolved may not tend to expand the gases, and then attach it to a graduated transfer jar (702), containing hydrogen or nitrogen, or some gas dissimilar to those which have been used. Open the communication (810), and observe how much gas will enter to fill the retort, at a pressure equal to that of the atmosphere (729, 724). This quantity will be nearly one half the capacity of the vessel. Then upon dipping the stop-cock into water, opening it, and cooling the retort slightly (414), water will enter; and dissolving the red gaseous nitrous acid, will shew by the quantity of unabsorbed air or gas left, how much of the mixed contents of the flask were soluble in that fluid.

219. Fix a cap and stop-cock upon a retort as before (780), introduce a little litharge, and exhaust the air from the vessel (800). Afterwards, fill it with muriatic acid gas (810) from a transfer jar over mercury (702, 736, 760); leave the communication open, and heat the litharge (807); the latter will change colour and water will appear, and after some time the gas will be observed to rise in the receiver beneath, to a considerable degree, partly in consequence of the actual decomposition of a portion of the gas by the elements of the oxide of lead with the consequent formation of water, and partly of the absorption of gas by the water so produced.

220. Fill a transfer jar (702) with water, over the trough, by the mouth (714). Put some copper leaf (328, 1237) into a capped retort (780, 807), attach a stop-cock to it, and exhaust the air from within (810); screw the retort upon the transfer jar, and then pass chlorine (717) which has been stored and set aside in bottles (773), into the latter, in suffi-

cient quantities to fill the retort. Admit the chlorine to the metal leaf (811); the latter will instantly inflame and become converted into a metallic chloride.

221. Partly fill a gas-holder (762) with oxygen (707), or in the absence of oxygen with air. Fill a transfer jar or a glass with the gas, at the trough on the top of the instrument (764). Exhaust a flask (809), and fill it from the gas-holder (810, 764). Fill a bladder with the gas from the holder (764). Attach a flexible tube (786) and a blow-pipe jet (199), to the stop-cock (766), and throw a stream of the gas upon burning charcoal (229). If the gas be oxygen, and the metals be silver, lead, iron, copper, or tin, they may easily be burned in this manner with brilliant phenomena. In the same way oxygen may be sent through the tube in the baryta experiment 198; caoutchouc connecting pieces (416) being used at the different junctions.

Now transfer the gas in the bladder (769) into the gas-holder again (765), and removing the transfer jar above mentioned into a deep trough (712), transfer the gas in it first into a bladder, and then back into the gas-holder (765).

222. Fill a gas-holder with coal or oil gas, see experiment 192 (762), and then screwing on a jet (766), burn it gradually, as in the applications of such gases to artificial illumination.

223. Compress the oxygen contained in the air-holder (764, 766), experiment 220, into a caoutchouc bottle (771), by means of a syringe (800). Then use the latter with a spirit-lamp as an oxygen blow-pipe (230).

224. Send muriatic acid gas, or ammoniacal gas, through a series of Woulfe's bottles containing water (788), to form a solution (798); use a safety tube (791), and connect the joints where necessary by caoutchouc connecters (418).

225. Weigh a portion of air, of carbonic acid, and of oxygen (825), attending to the points particularized (830, &c.)

226. Dry carbonic acid gas over muriate of lime (835) at the mercurial trough.

Tube Chemistry.

227. Test a mineral water (470, 851) or a solution, as that of experiment 76, in tubes (849), standing in corks (58) or glasses (343), or in a rack (849). Use the dropping bottle (372) and glass stirrers (850).

228. Dissolve a small silver coin in nitric acid in a tube (853); examine a part of the solution for copper in another tube (849); precipitate a part of the remaining solution in a third tube, by a piece of copper wire, and wash (852) and dry the silver precipitated. Then precipitate the remainder of the solution in a fourth tube, by a solution of common salt, and wash the precipitate well (850) in the tube itself.

229. Heat a little pulverized sulphuret of antimony in muriatic acid, using a bent tube of the form represented in Sect. xvi. for the purpose (857); examine the gas evolved at the mouth of the tube (885) by a taper flame, by acetate of lead on a strip of paper, by smell, &c. (884), it will be found to be sulphuretted hydrogen. Return the muriatic acid which will distil over (857), upon the sulphuret, once or twice in succession. At last pour the solution over the sulphuret forward into the angle (857), and ultimately pour a little of it into water, examine the effect, and observe whether a white precipitate be produced.

230. Distil some oil of turpentine from a tube retort (859) into a tube receiver or a phial (860), or use the open bent tube receiver, described (860), cooling the angular part by water (861) or ice (421).

231. Distil a piece of wax in the tube figured (862), cool the first receiving angle (861), and collect the liquid products there; at the same time immerse the open extremity of the tube in water in a basin (862), and collect the gas evolved in tubes (880). Examine it as to inflammability, &c.

232. Heat some copper or iron pyrites in a green glass tube (869), to redness. Receive the sulphur which sublimes into a plain or a bent tube (871). Heat a portion of the same pyrites in an open tube (872), and observe by the smell and appearance whether sulphur burns off or not.

233. Sublime a small quantity of crude naphthaline from a plain tube, into a bent tube receiver (871).

234. Put a minute quantity of metallic arsenic into a plain tube (869), closed at one end; sublime it to different parts of the tube by the heat of a spirit-lamp (176), and observe the metallic, crystalline, and other appearances of the film of sublimed metal.

235. Put a small piece of common paper, about half an inch square, into a tube (848), closed at one end; warm the part inclosing the paper (854), keeping the other part cold (869), and observe the dew which will appear on the cold part, and which proves the presence of moisture in the paper.

236. Repeat experiment 40, in open inclined tubes (872), for the purpose of observing the production of acid and alkali (591, 593) at the upper apertures.

237. Put some per-oxide of iron into a tube (848), examine it and remark that it is not magnetic (587); add a little naphthaline, and heat the oxide to redness in its (873) vapour; after a short time examine it again by the magnetic needle (588), when it will be found highly magnetic.

238. Evaporate a solution containing silver, or any other requiring the dissipation of excess of acid (564), in a bent tube evaporator (877), then add water, and apply a slight degree of heat to dissolve all that is soluble.

239. Make a little oxygen gas in a tube retort (859) from chlorate of potash, and receive it in tubes (848), immersed in a basin of water (880). Examine the gas by a splinter of wood, with a spark of fire at the extremity (723); ascertain how small a bubble of oxygen may be thus tried with readiness and certainty. Make a little hydrogen into tubes at the same trough (880), and try in a similar manner with how small a quantity its power of inflaming may be certainly ascertained. Then mix two volumes of the hydrogen with one volume of the oxygen (720), and remark with how minute a bubble the explosive power of the mixture may be observed in a tube.

240. Make a little muriatic acid gas (696) in a tube retort (859), and receive it into the mercurial receiver, de-

scribed (884); use it in small successive portions in the manner directed, for the purpose of ascertaining the general properties of the gas.

241. Make a little oxygen in the bottom of a tube (885), and try its powers in the tube itself. Prepare a little sulphurous acid gas in the same manner (885), and observe its powers of extinguishing flame, of reddening and then bleaching litmus paper (584), its odour, &c. at the mouth of the tube. Put a few pieces of zinc, and a little muriatic acid into such a tube, and examine the gas as it passes off. It will prove to be hydrogen.

242. Decompose oxalic acid by sulphuric acid in the bent tube, described (888). Test the combustibility and other properties of the gas evolved, upon successive portions at the mouth of the tube (884). The gas is a mixture of carbonic acid and carbonic oxide.

243. Generate muriatic acid gas in a phial, with a cork and tube (448), pass the gas over water in a tube Woulfe's apparatus (889), and examine the solution formed. It will be found to be powerfully acid (591), precipitating nitrate of silver (850), dissolving carbonate of lime (853), and indeed being a pure solution of muriatic acid.

244. Condense a gas into a liquid in the manner described p. 417. Experiment with sulphurous acid gas (898), or cyanogen (892), as being those substances which incur the least risk.

245. When upon any occasion a comparatively rare fluid product, as chloride of phosphorus for instance, has been obtained in a pure state, confine it in a retaining tube (863). Observe its action upon water or upon litmus paper, in the air (591), dispensing the small portions necessary from the beak of the tube, and sealing up the remainder (863). Seal up a specimen of the good chloride of phosphorus permanently (902, 1088) for preservation.

246. Decompose a certain weight (45) of chlorate of potash in a green glass tube (665, 848), by a heat (869) sufficient to drive off all that is readily volatile, and all the oxygen. Then again weigh the tube and its contents (52), and ascertain the loss of weight. This will be the weight

of the oxygen which existed in the salt that has thus been decomposed and analysed. The residue will be chloride of potassium.

247. Put tartrate of lead into a green glass tube (665, 848), contract the extremity, but do not close it (1085); heat the tartrate gradually, so as to decompose it in succession, beginning at the end nearest the aperture (869, 672). In this way dissipate all that is volatile. A black powder will remain, which will inflame the moment it is poured out into the air, and burn for some time. By sealing up the contracted aperture of the tube (1089), the powder may be preserved for any period of time without injury.

248. Heat a solution to 212° in a tube, by means of a water-bath formed by another tube (237), shorter and wider than the first.

249. Freeze a little water in a tube (848), by a piece of ice and some salt (241).

XVII. *Electricity.*

250. Excite a glass rod (940) by silk, with a little amalgam spread upon it (908). Observe its effect when brought near to the face, or its power over an electrometer (931). Excite a stick of wax or resin (940), by friction with flannel (933), and remark its influence upon the electrometer (941), and other light bodies.

251. Experiment with a Bennet's electrometer (931), first diverging the leaves by brushing the cap lightly with warm flannel, and then determining the kind of electricity produced (940). Diverge the leaves by the rapid evaporation of water, and ascertain the kind of electricity developed. Occasion divergence by contact of excited bodies (932, 939), and also by approximation (933, 939); and in each case determine the kind of electricity which has produced the effect (940). Insulate the substances whose electricity is to be examined, upon stick-lac or resin (989).

252 Excite an electrical machine (906), warming it carefully (907). Approach the knuckles of the hand to the cylinder or plate, and observe the brushes and sparks of

electricity which dart about them and the machine (909) when the latter is in good order. Put the prime conductor (910) into its place, and then take sparks from it to the hand, or a metallic ball. Warm a Leyden jar, charge it and discharge it (916). Remark for how long a period the charge can be retained by the jar (917).

253. Pass the charge of the Leyden jar through the eudiometer wires (915); pass it also through thin wires and through gunpowder, so as to ignite them. Detonate an explosive mixture of gases (921) in the eudiometer tube over water (919), and also over mercury. Insulate the jar when required on a plate of wax, glass, or mica (987).

254. Make a small electrophorus (927, 930), excite it (928), observe the sparks given by it to the knuckle, charge a warmed Leyden jar (916) by it (929), and use the jar to detonate a mixture of gases (921) in the eudiometer tube (923).

255. Charge a voltaic battery (944), and bring it into an efficient state (945); try the discharge between its poles by charcoal points (948), and observe the intensity of the light produced. Ignite some fine wires by discharging the electricity through them (986). Immerse the poles in water contained in a glass (953, 961), and remark the decomposition which takes place. Decompose saline solutions contained in tubes (961), using platina foil to extend the surface of contact (954). Collect the gases (964) evolved during the decomposition of water, and examine them (884) as to their qualities and nature; that at the positive pole will be oxygen, that at the negative pole hydrogen (965). Remark the double quantity of hydrogen produced in the experiment as compared to the oxygen evolved.

256. Observe the magnetic properties of a wire (956) connecting the poles of the battery just referred to (951). Place a magnetic needle under and over the wire, and remark the influence of the wire upon it (991). Dip a part of the connecting wire into iron filings, they will be attracted in rings, as it were, surrounding every part of the wire, and not in a particular part only, as is the case with a common magnet. Twist the wire which connects the poles into a

helix, then place a thick needle or a small bar of steel in this helix for a moment, break the voltaic communication, (956) remove the steel bar, and observe how suddenly it has been rendered a magnet.

257. Take a piece of zinc and a piece of silver, and observe their peculiar electric effect upon the tongue (980); their effect also upon frogs, fish, worms, or other small animals. Remark the power of the two metals, when, being in contact, they are immersed in a weak acid (976). Ascertain by the tongue the power of a fragment of metal, and another of glass or stone (980), with respect to the conduction of electricity.

258. Make a little voltaic battery of halfpence or discs of copper, with pieces of zinc (973), and flannel moistened in dilute acid (945). Discharge it through charcoal (948); try the conducting power of different specimens of charcoal; heat fine platina wire red hot (986), decompose water and saline solutions by it (991), and shew the magnetic influence which a wire connecting its extremities (956) has over a magnetic needle (991).

259. Precipitate a portion of copper from a solution of the sulphate in a platina crucible (979, 485), by Dr. Wollaston's method; wash the copper precipitated on the platina, and afterwards dissolve it from the vessel by a little pure nitric acid.

XVIII. *Lutes. Cements.*

260. Lute a glass retort (453, 996) with a coating of uniform thickness (998), attending carefully to the drying (999), and bringing it ultimately into a state fit for use.

261. Make a comparatively moist lute (1001), some straw, chaff, or other similar substance (1003) having been mixed with it (1004). Coat a phial with it uniformly (998), that when dry it may be ready for the preparation of pyrophorus.

262. Coat an earthenware (661) or a glass tube (665) with stiff lute (996), and surround it with a band of canvas (1005).

263. Fix one crucible firmly in another (614) by lute,

then fix the double crucible upon a third as a stand (637, 1012).

264. Cement a bent tube to the neck of a Florence flask (347, 448), by Parker's cement (1018), or plaster of Paris (1019). A flask of this kind is competent to the preparation of carbonic acid over a crucible furnace fire (143). A mass of the cement should in the first place be put round the tube and left to harden; this being cut into a conical form, and ground slightly, will, with very little management, close the mouth of a Florence flask accurately, and thus form a useful gas bottle (706).

265. Make a tight joint between a retort and a receiver (440) with bladder and string (1027), or with fat lute (1017, or with paste and paper (1028).

266. Connect apertures in tubular arrangements by means of caoutchouc connecters (416, 1032).

267. Examine the bottles containing solutions of muriatic acid and ammonia, to ascertain whether the stoppers are tight or leaky (1040). Examine the gas holder, exp. 220, as to the existence of leaks about the body (761) or the pipes connected with it (1040).

XIX. *Blowing and cutting of glass.*

268. Bend a piece of glass tube into a syphon (1062).

269. Make some tubes (1069) closed at one end (848); expand the open extremity of one or two into a flanch (1056); contract the apertures of others by scissors, so as to form a neck; bend some of them into tube retorts (859, 1078).

270. Close one of the open extremities of a short piece of tube (1077).

271. Soften the middle of a piece of tube (1044), and thicken it into a ring (1099), then draw it out into a contracted neck (1078).

272. Make a tube funnel (1083, 859) and a tube syringe (518, 1083).

273. Blow some glass into frost (1093). Blow a bulb at the end of a piece of tube (1093, 1095). Expand the angle of a tube retort (859, 1096) in the particular direction be-

fore explained (886), that it may answer the purpose of a temporary retort and receiver for gases. Make a separator (531, 1096). Make a few candle crackers (1098).

274. Join two pieces of tube together (1099). Seal a platina wire into a tube (1100) for the purposes of electrical decomposition (961). Make a small detonating eudiometer (919), and then graduate it (114).

275. Use quill tubes (848, 1105) with a common spirit-lamp (176) and the mouth blow-pipe (198). With these make some closed tubes (848, 1069); some small tube retorts (1078), expanding the bulb or body of a few (1093), so as to make them more capacious; some tube receivers (863) and other useful apparatus; performing the same operations in the small way, which have been directed upon a larger scale.

276. Seal up some water hermetically in a tube (1087, 1085), not leaving more than half an inch between the surface of the water and the extremity last closed. In the same manner seal up some ether in a tube hermetically (1088) leaving about $1\frac{1}{2}$ inches between the fluid and the extremity to be sealed, and make the glass thick and strong (1086). Practise the same operation by sealing up some fragments of sulphur in a tube (1085). The operation may be considered as well done when the end is made smooth and strong, without melting the included sulphur at the distance of $1\frac{1}{4}$ or $1\frac{1}{2}$ inches.

277. Seal up some water hermetically in a tube exhausted of air (1092).

278. Cut a piece of tube about twelve inches long into two (1060); make each of these into two tubes closed at one end, one about 4 and the other 2 inches long (1070). Take a piece of tube with a fractured and irregular termination, and cut it off straight and level (1060) within half an inch of the extremity, or else make the termination nearly straight by rasping off (1123) the irregularities.

279. Before dismissing broken apparatus to the waste glass box, collect them on a tray, and then cut up old retorts, flasks, or glasses, into dishes, by iron rings (1109) or a hot iron rod (1111); cut off the tops of fractured Florence

flasks (1109), and make the lower parts into basins, and convert old jars or bottles into shorter jars (1119) by the hot iron (1111).

280. Take every opportunity of becoming expert in loosening (1151) and removing glass stoppers which have become fixed in the bottles (701); in cutting pieces of crown glass into useful forms (1123, &c.) by means of a file (1121), and in crushing the edges of fragments (1123, &c.), so as to bring them into serviceable shape.

XX. *Cleanliness and Cleansing.*

281. The practice corresponding to this division of the volume, will be abundantly dictated by the wants which will occur the instant the student commences his progress in experimental chemistry. It will be well however that he should try to dry the insides of a retort, a flask, and a bottle, which have been washed clean, and observe how effectually and readily he may do it by the methods described (1147, 90). He should grease or wax a stopper (400, 701) with the precautions given, and minutely observe the degree of resistance and kind of feeling occasioned when it is properly lubricated (400).

282. A portion of foul mercury should be rendered pure and clean by Dr. Priestley's method (1174). Another portion by nitrate of mercury (1175), and some that is dusty and foul should be cleaned by sugar and agitation (1166, &c.)

XXII. *Uses of the scale of Equivalents, &c.*

283. Ascertain by the scale (1198) the quantity of nitric acid required to dissolve 473 grains of carbonate of lime (1210), and the quantity of crystallized carbonate of potassa (1211) required to precipitate the resulting nitrate.

284. Tell by the scale how much sulphuric acid is contained in the sulphate of baryta of exp. 104.

285. Ascertain how much muriatic acid and baryta (1209) are indicated in the chloride of silver and sulphate of baryta of exp. 105.

286. Observe by the scale how much metallic copper and oxide of copper (1212) may be expected in exp. 110.

287. Ascertain the composition of 250 grains of crystallized sulphate of magnesia as to its earth, acid and water (1214); and also as to the sulphur, oxygen, and hydrogen, in the acid and water of the salt (1212).

288. Ascertain by the scale (1212) the points expressed p. 558, relative to 300 grains of sulphate of copper.

289. What quantities of lime, baryta, strontia, magnesia, potassa, and soda will neutralize 320 grains of dry sulphuric acid (1206, 1209), and what quantities of their carbonates will produce the same effect?

290. Ascertain all these points by *calculation* from a table of equivalents (1217), and observe if the results agree with the conclusions arrived at by means of the scale (1209).

XXIII. *Miscellanea.*

291. Make some hydrogen from a few pieces of zinc and a little dilute sulphuric acid, in an oiled paper vessel (1222); conduct it through paper tubes (1223) into a trough made of a soup plate or a basin (693), and receive it in oiled paper tubes (1223, 1225), which will answer the purpose of jars (880). In these test its inflammability, and observe its other qualities, and remark with how simple an apparatus these and many other such experiments can be made. Attach the edges of oiled paper vessels, which are to be air and water tight for a time, by a little soft cement (1228, 1035).

292. Heat the interior of a steam-bath (248) by steam generated in a kettle (249), and conducted from its spout by oiled paper tubes (1224). Even the bath itself may be made of a few pieces of wire, or stick, and oiled or waxed paper.

293. Test a weak mixed solution of sulphate of copper and muriate of lime in paper vessels (1222), for all the proximate elements.

294. Pour a few drops of a weak solution of phosphate of potassa or soda upon one part of a sheet of white paper, and a few drops of a weak solution of arsenite of potassa upon

another part of the same paper (1222). Draw a piece of nitrate of silver through the two portions, pressing on the paper at the same time, and observe the differences in character between the two precipitates.

295. Boil half a pint of water in a paper vessel (1222).

296. Make (536) and crystallize a solution of alum (537) in oiled or waxed paper vessels (1222); separate the more perfect crystals, and preserve them in paper tubes (1227).

297. Heat a little white arsenic on platina foil (1239) by a small spirit-lamp flame (176, 182). Then heat a portion on the foil but with a large flame (182), and incline the foil that the hydrogen of the flame may mix with the vapours of arsenic; or heat the arsenic on a hot coal. Observe the difference in the odour occasioned in these two cases: the odour when developed is dependant upon the reduction of part of the white arsenic to the metallic state.

298. Draw out a small capillary tube (1079), examine its bore by a small quantity of mercury; graduate it (1255) and make it into an air guage (1254).

299. Retain a platina wire in a state of ignition in the vapour of ether, over a small portion of that fluid in a glass.

300. Sublime (869) a little cinnabar in a tube (848) not more than $1\frac{1}{2}$ inches in length (1221).

301. Sublime some naphthaline from one tube (871) into a long open tube fixed to the smaller by a perforated cork (1220, 432).

302. Put a fragment of camphor at the bottom of a tube two feet long, observe its odour by means of another tube (1250).

303. Try the phosphorescence of fluor spar, and different kinds of carbonate of lime (1266).

304. Mix equal volumes of hydrogen and chlorine over water; transfer portions of the mixture into glass tubes (848, 880), using paper funnels (1228), if there be occasion for such convenience: then expose these mixtures to sun light (4, 1272), and observe the explosion which immediately takes place.

305. Observe the effect of solar light and day light upon nitrate of silver and chloride of silver (4, 1273) spread upon

paper. Make Mr. Wedgwood's experiment, using magic lantern glasses for the purpose.

306. Make a magnet (1282). Make a magnetic needle (1282), suspending it in any convenient way (1281). Try a piece of Elba iron ore by this needle (1276), reiterating the approximations, or adopting Hauy's method (1278).

307. Write legibly on a glass tube with a scratching diamond (902), the tube being from one half to one quarter of an inch in diameter.

308. Cut a crucible, or stopper, with its cover and a support, out of a soft Windsor brick (1240), and make some box-wood charcoal in it (949).

309. Evaporate a mineral water to one-eighth its original bulk (566), and then test it on glass valves (1234). Crystallize a solution of nitre on a glass valve (538, 1234); also a solution of salt, and examine the forms of the crystals (552).

310. Freeze a little water in a cup of tin foil (1235), by a mixture of ice and salt.

311. Etch on glass by fluoric acid (1251), using a leaden dish (1252, 1236), for the mixture of acid and fluor spar.

312. Make a single electrical circuit (1238, 976); observe its effect in deflecting and otherwise influencing the magnetic needle.

313. Precipitate a solution of acetate of lead by zinc foil (1238); test the solution for lead in paper vessels (1222), that the completion of the precipitation may be ascertained.

314. Burn filaments of zinc foil (1238) in the flame of a lamp or candle.

315. Fuse a little piece of lead in platina foil (1239), and remark the instant liquefaction of the foil in consequence of the formation of an alloy (627). Even sulphuret of lead will, on trial, be found to have a similar action. Heat a little silver, or a little oxide of iron on the foil to whiteness; no harm will result (1239).

316. Distinguish wires of silver and platina by their power of conducting heat (1243).

317. Sublime a little calomel in a tube (869) enveloping

the tube about half way from the bottom (1237), so as to preserve the heat (678), and prevent condensation on that space; ultimately crack the end of the tube in mercury (1242).

318. Place a board within two or three inches of a hot furnace; protect one half of it by a plate of tin (1244), and observe the difference between that and the other half.

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THE END.

W. Phillips, Printer, George-yard, Lombard-street, London.

